FORCE TRANSDUCER

MODULE G25

THEORETICAL-CONSTRUCTIONAL HANDBOOK

SAFETY RULES

Carefully follow the instructions contained in this handbook as they supply important indications on the safety of the installation, use and maintenance.

Keep this handbook at hand for any further help.

UNPACKING
After the packaging has been removed, set all accessories in order so that they are not lost and check the equipment integrity. In particular, check that the equipment is integral and shows no visible damage.

Before connecting to power supply to the equipment, be sure wires are connect correctly with the power supply unit.

The power supply cables must be set so that they cannot be trodded upon or squeezed by objects.

On the equipment, there are some slots or opening for the ventilation; to ensure a reliable operation and to protect the equipment from overheating, they must not be blocked or covered. This equipment must be in such a position to enable a proper aeration.

Do never set the equipment on trolleys, supports, tripods, stirrups o unstable tables. The equipment could fall causing damages to the collided persons or it can damage itself. Any installation of the equipment must follow the instructions of the manufacturer and must be carried out using recommended accessories.

This equipment must be employed only for the use it has been conceived, i.e. as educational equipment, and must be used under the direct survey of expert personnel. Any other use is unproper and so dangerous. The manufacturer cannot be considered responsible for eventual damages due to unproper, wrong or unreasonable uses.

PRECAUTIONS!
In order to safeguard the user's safety and the equipment operation, when using electrical equipment some fundamental rules must be followed. In particular the following regulation for use must be followed:

Ambient temperature:	from 0 to 45°C.
Relative humidity:	from 20 to 80 %.

Avoid any quick shift of temperature and humidity.

In case of fault and/or bad operation, turn off the equipment and do not tamper it. In case of reparation, ask the center for technical assistance or ask exclusively original spare parts. If these conditions are not respected, the equipment can be compromised.

In case of penetration of objects or liquids inside the equipment, disconnect the power supply cable and make it checked by qualified personnel before using again.

CLEANING THE EQUIPMENT

Use a soft and dry cloth to clean the container and the silk screen panel. ` Do never use insecticide or chemical products or solvents for cleaning.

VIBRATIONS OR COLLISIONS

Be careful not to cause vibrations or collisions.

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INTRODUCTION

The development of automatic weighing and`systems of packaging and dosing has made the force sensor one of the most widely used transducers in the industrial sector.

As well as measuring forces, this type of transducer is also used for the measurement of torque (i.e. the moment of a force) and acceleration (which is linked to force through mass).

Also linked with the measurement of force is that of the dynamic viscosity which is to be found in a fluid in movement and which is expressed as follows: $N\ s\ m^{2}$ ($10^{-3}\ N\ s\ m^{-2} = cP$).

The force transducer supplies an analog output indicating the value of the force applied on input.

In order to utilize this analog output (in a system, an operator component etc.) it is very often necessary to insert electric interface systems for connection of the transducer. These interface systems are normally called "signal conditioners".

The purpose of this handbook is to introduce the reader to the operating principles, the selective criteria and the fundamental characteristics of the force transducer and the signal conditioner fitted to the panel.

The first part of this handbook describes the operating principles of the force transducers and signal conditioners most commonly used in industrial applications.

The second part examines the unit (transducer and signal conditioner) shown on the panel. This part of the handbook is concerned particularly with the characteristics of the components and with the way in which these affect the choice of a transducer which is required to work in certain conditions and to provide specific results.

The third part contains a number of suggested experiments which may be used to verify the characteristics of the transducer (and of the signal conditioner) and their influence in industral use.

1. FORCE TRANSDUCTION - OVERVIEW

Force - together with the magnitudes directly connected to force, such as torque and acceleration - may be measured electrically using an infinite variety of transducers. The term 'transducer' signifies a device which absorbs energy from one system and supplies this energy, generally in another form (such as electrical), to a second system.

According to the physical principle governing transducers, these may be classified in the following groups:

- based on the laws of statics
- based on the phenomenon of elastic reaction
- based on the phenomenon of piezoelectricity.

This section describes in detail these three types of transducers.

1.1 Transducers based on the laws of statics

If sample forces are available, it is always possible to measure an unknown force by applying the basic law of mechanics as expressed by the following equation:

$$\Sigma F - ma = 0$$

which indicates that the force system ΣF (including both active and feedback forces) exerts an acceleration 'a' on a mass 'm' to which the force is applied. The same may be said with regard to the angular acceleration $d\omega/dt$ of a body with an axial moment of inertia J around the relative axis of rotation, under the action of a torque system ΣM exerted along the same axis:

$$\Sigma M - J \frac{dw}{dt} = 0$$

In industrial measurement systems, the transducers which use the laws expressed in these equations are used with constant loads, in which the only accelerations present are those consequent to the transient application of the unknown magnitude. For the purposes of this handbook, this transient is considered as being depleted, and reference is made to the following expressions:

$$\Sigma F = 0$$

$$\Sigma M = 0$$

An example of this application is the automatic counterweight balance, whose operating principle is shown in fig. 1.1.

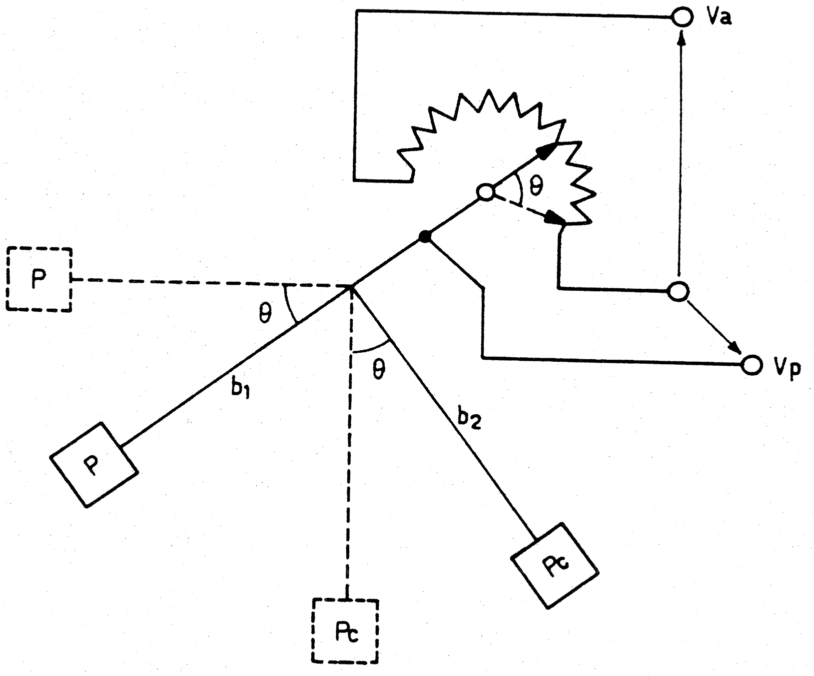


Fig. 1.1

If the weight of the two arms relative to the sample weight Pc and the unknown weight P is not taken into consideration, the following expression is found:

$$P = Pc \; \frac{b_2}{b_1} \; \text{tang}\, \vartheta$$

As a voltage proportional to angle ϑ may be read using the potentiometer, the counterweight balance becomes an angular rotation weight sensor with non-linear characteristics.

In practice, the characteristic is linearized by mechanical function generators (cams, levers etc.).

The so-called dynamometric balance, which is used to measure the torque reaction generated between the stator and the rotor of an electric motor, functions on the same principle. The product of these magnitudes, together with the speed of rotation, provides measurement of the mechanical power of the motor.

The diagram representing this principle is shown in fig. 1.2, which differs from fig. 1.1 only in the fact that the unknown magnitude is the torque 'c' transmitted by the rotor to the stator of the electric motor.

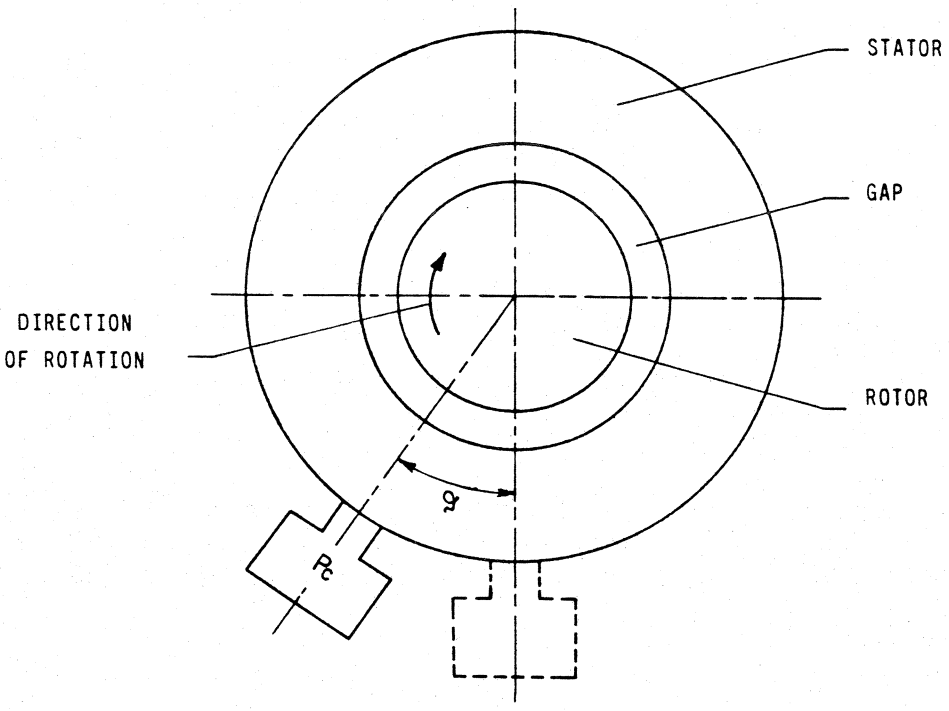


Fig. 1.2

1.2 Transducers based on elastic reaction

Let us consider a homogeneous and isotropic prism-shaped body, one of whose sides (with an area 'A') rests on an infinitely rigid support, while a force 'F' is applied to the other side in a normal direction.

The body is deformed, reacting with a force 'Fr' in accordance with Hooke's law, until a purely elastic behaviour is reached.

In a state of equilibrium, i.e. when F = Fr, the height of the prism will vary by the following percentage:

$$\varepsilon_1 = \frac{\delta L}{L} = \frac{F}{EA} = K F$$

where E is the modulus of longitudinal elasticity (Young's modulus) of the material.

Any body, therefore, according to Hooke's law, may constitute a linear sensor between the applied force and the longitudinal deformation.

The material and its section are, however, carefully selected, taking into account the maximum value of F, in order to stay within the straight line of the transduction curve:

$$\frac{\delta L}{L} = f\left(\frac{F}{A}\right)$$

It should also be remembered that the longitudinal deformation ε_l is accompanied by a corresponding transversal deformation ε_t, of opposite sign and linked to it by the Poisson ratio ν; therefore, within the sphere of application of Hooke's law, there also exists a linear connection between the force applied and the transversal deformation:

$$\varepsilon_t = -\nu \ \varepsilon_1 = -\frac{\nu}{EA} F = -K'F$$

This gives a linear force/deformation transduction; the problem therefore remains of measuring this deformation and transforming it into a proportional electrical signal. This is done in a variety of ways and is explained in the following paragraphs.

For force/deformation transduction, annular section prisms are normally inserted between the unknown weight and the support. Typical examples of this application are the weighing of substances in tanks, in rotating ovens and on conveyor belts. Typical full-scale values vary from 10^2 to 10^6 Newton.

In these applications it is possible to utilise both the longitudinal and transversal deformations to form bridge measuring systems which are self-compensating as regards temperature.

Note also that, in practical applications, the transmission of the load to the body of the transducer is through a spherical element as shown in fig. 1.3.

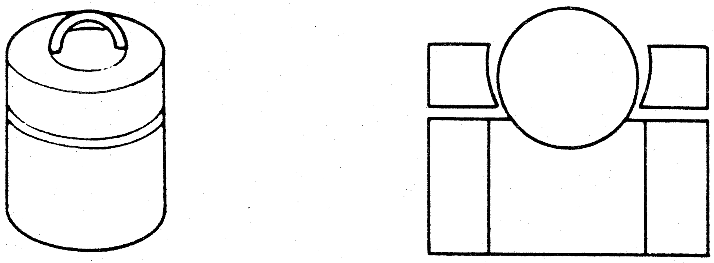


Fig. 1.3

The load being equal, it is also possible to amplify the degree of deformation by applying a bending load to a thin fixed prismatic bar, as shown in fig. 1.4.

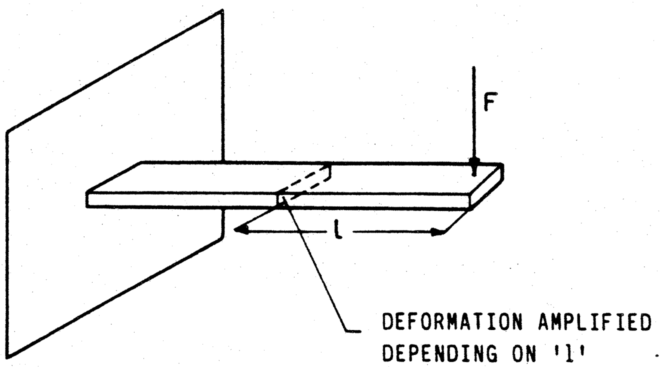


Fig. 1.4

A typical example of the use of fixed bar sensors may be seen in seismic mass accelerometers. In some applications it is preferable to use an elastic body having a section whose area varies linearly with the distance from the point of fixing (fig. 1.5).

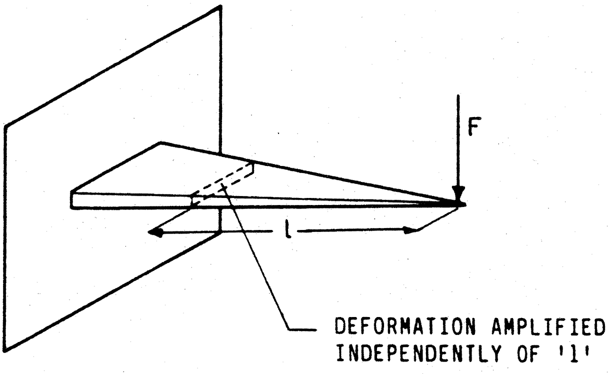
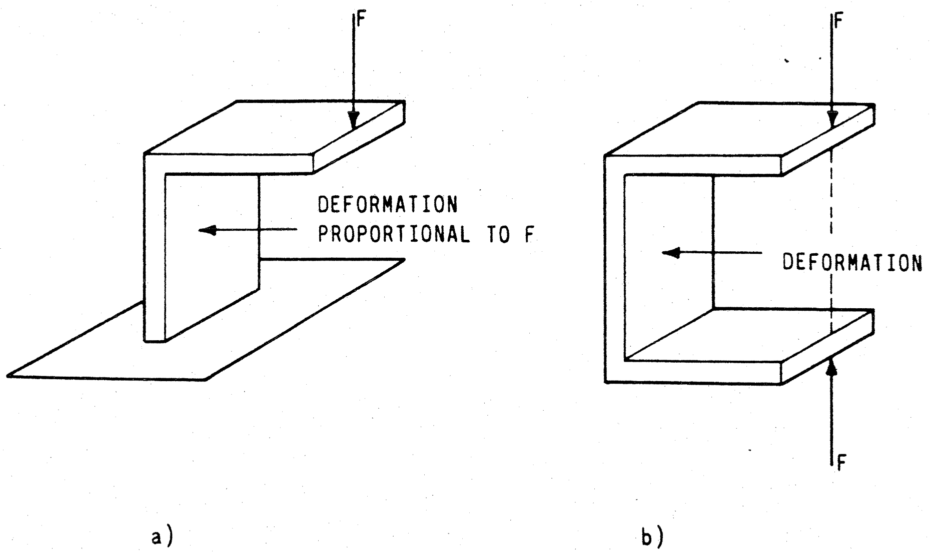


Fig. 1.5

An alternative is to apply the force to an overhang as shown in fig. 1.6 a). The movement is constant on the part of the structure which is parallel to the direction of the force; on the lateral surfaces, therefore, ε_f also is constant. An interesting variation is that in which the force measured must also be transmitted. This is achieved by using a double structure as shown in fig. 1.6. b).

Fig. 1.6



In order to simplify the application of the force, a ring-type structure such as that shown in fig. 1.7 may be used.

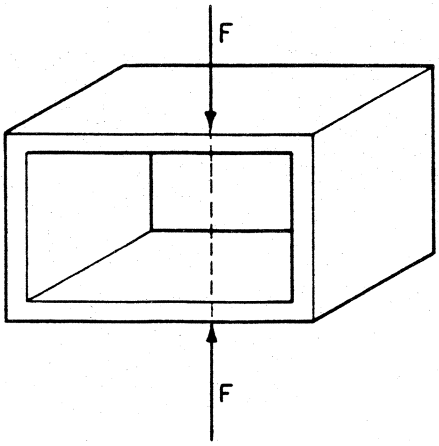


Fig. 1.7

In practical applications, the angular structural characteristics of this form make such a structure of limited strength in the case of variable forces.
This problem is solved by using a cylindrical structure such as that shown in fig. 1.8 and generally referred to as a proving ring.

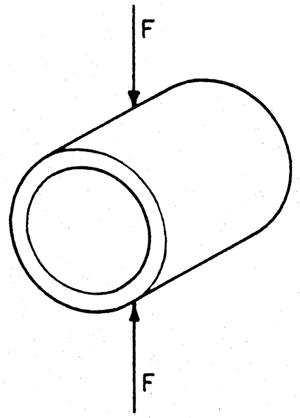


Fig. 1.8

Let us now examine the measurement of the deformations caused in these elements by a force. The sensors studied are those which feature:

- resistive strain gages
- semiconductor strain gages.

These are devices whose deformation is related to a variation in their resistance.

1.2.1 Sensors based on resistive strain gages

These sensors are extremely widely used, and link a percentage longitudinal expansion to the consequent variation in resistance. Sensors based on this principle are referred to as extensometers, but the term 'strain gage' is also widely used.

It may be stated that

$$\frac{\delta_R}{R} = K \frac{\delta_L}{L}$$

The coefficient of proportionality 'K' is called the 'calibration factor', and may have any value between -11 and +4.5 according to the materials used (Nickel, Manganin, Constantan, Platinum, Tungsten).

The simplest way of applying this principle is to measure the variation in the resistance of a metal wire whose ends are fixed at the two points between which the variation in distance δ_L is to be measured. It is clear that, in order to obtain values of δ_R that may be easily measured, the section of the wire 'S' must be so small as to be practically unusable. To overcome this problem, the length of the wire is multiplied as shown in fig. 1.9.

In most cases, however, the extensometer is used to

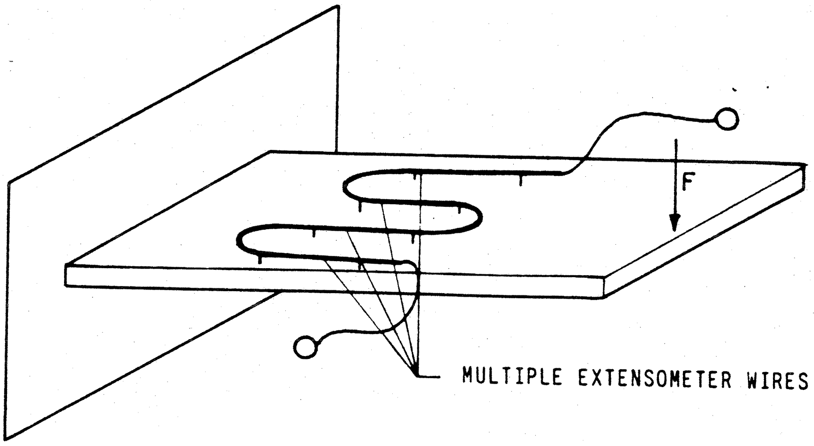


Fig. 1.9

measure the deformation of a surface along a given direction. In this case, two points at a distance of 'L' cannot be easily used, and the wire itself would be difficult or impossible to fit, especially in view of its serpentine dislocation. This problem is overcome by using specially shaped wire which is contained in a flexible support as shown schematically in fig. 1.10.

In this way, the distance 'L', to which the measured deformation δ_L refers, is defined by the extensometer itself.

The section of the curved parts is much more than that of the straight parts, and their resistance is there-

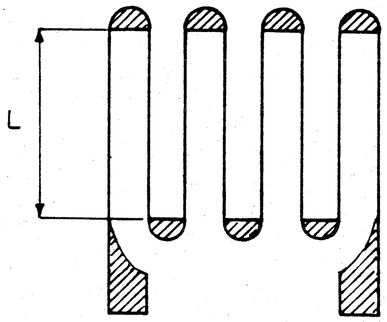


Fig. 1.10

fore negligible.

The section of the wire is rectangular and particularly flat, and the extremities are specially widened in order to facilitate soldering. The dimensions of 'L' may vary from 2 to 20 millimeters approximately.

In force transducers, these extensometers are supplied already glued to the element which is deformed when the magnitude to be measured is applied.

One of the disadvantages of these extensometers is their dependance on temperature. A temperature variation implies a corresponding variation in resistance and a volumetric variation of the deformable material which may taken for a non-existent deformation. In order to avoid this, two extensometers are used, only one of which is deformed. The difference in their resistance is measured. Heat-compensated strain gages may also be used; these use materials whose temperature coefficients are equal and opposite to the coefficent of thermal expansion (same effects) of the deformable material.

1.2.2 Sensors based on semiconductor strain gages

Piezoresistivity - that is, the variation of electrical resistance with volume - is a major factor in semiconductors. The value of K, therefore, which in resistance extensometers was extremely low, is very much higher in semiconductor extensometers (40 to 200).

The undoubted advantage represented by a significant increase in sensitivity is, however, diminished by a marked dependance on the temperature; this is sufficient to limit the use of force transducers with semiconductor extensometers to applications in which sensitivity is essential and temperature variations are almost non-existent.

1.3 Load cells

The load cell is the form of extensometer-based force transducer most widely used in industrial applications. It converts an applied force (weight) into a variation in the output voltage of an extensometer bridge.

In a load cell, several extensometers are generally used, and these are connected in bridge configurations fitted to the deformable mechanical element.

Load cells which use resistive strain gages have an impedance of approximately 350 ohm and a full-scale sensitivity of about 2 mV/V. This means that, if a voltage of 10V is applied to the extensometer bridge, the output variation will be 20 mV when the full-scale load is applied.

Load cells which use semiconductor strain gages offer increased sensitivity.

Load cells with full-scale loads from kg to thousands of tons are used in industrial applications.

1.4 Transducers based on piezoelectricity

This type of transducer is used when the fòrces to be measured are dynamic (i.e. alter constantly with frequencies to the order of KHz), and is based on the effect discovered in 1880 by Pierre and Jacques Curie, i.e. that physical stress applied to certain materials produces variations in their charge. Piezoelectric devices are used in instruments (e.g. accelerometers) for vibration analysis. The materials used in the construction of these transducers are ceramics (synthetic materials) such as barium or lead titanate. The most commonly used crystals are tourmaline, quartz and Rochelle salt (sodium potassium tartrate).
For a series of technological reasons, quartz is always used in industrial applications.

1.5 Signal conditioners used with force transducers

The interface system for force transducers which feature resistive extensometers (load cells) must be able to excite the strain gage (single or bridged) at constant voltage.

In view of the low ohmic resistance of the extensometer or the bridge, 'sense' terminals are often fitted to check that the voltage applied is constant (see fig. 1.11).

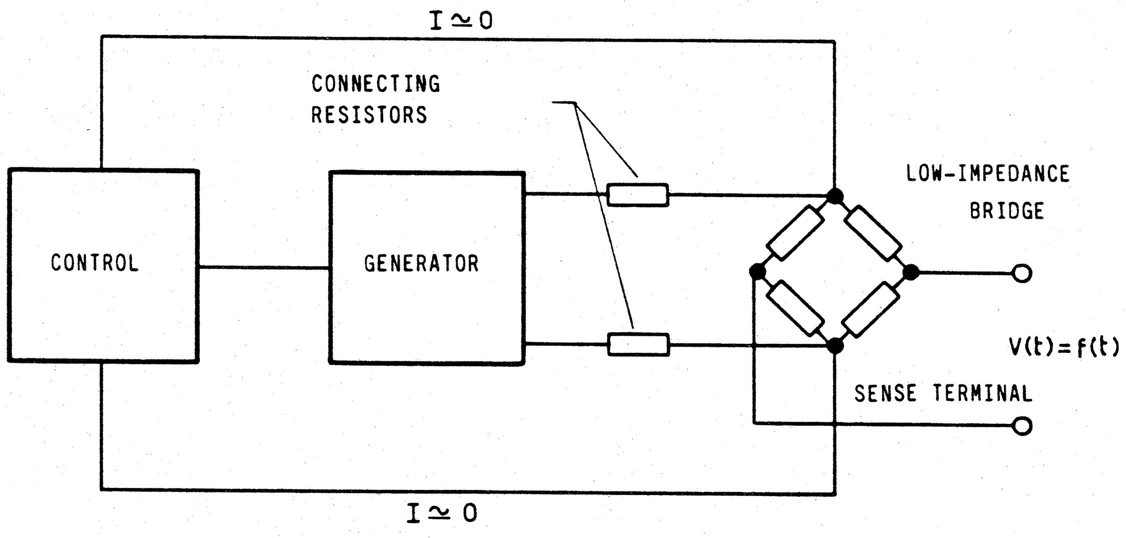


Fig. 1.11

The output voltage of the bridge is normally measured by a differential amplifier for high-gain components (see fig. 1.12).

As these sensors are normally used in devices in which the force does not vary rapidly, a second-order low-pass filter (with a five second delay) is fitted in order to reduce noise.

The choice of differential amplifier must take into

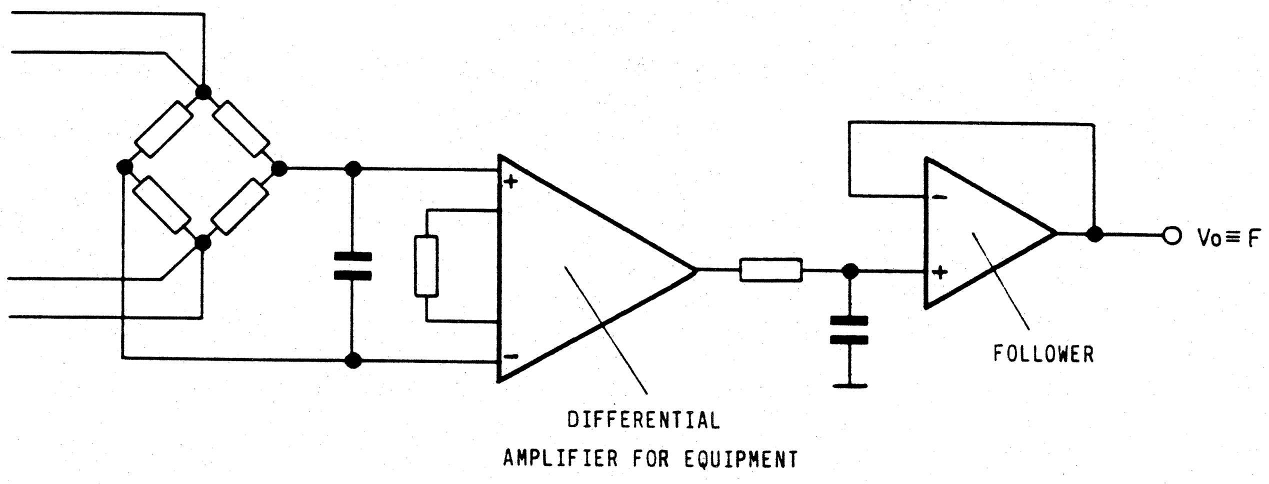


Fig. 1.12

account the fact that the the voltage drift with temperature must be as low as possible (e.g. less than 5 µV/°C).

Very often, a trimmer is used for offest nulling (zero calibration), and a calibration potentiometer is used to calibrate the output to its exact full-scale value (amplification calibration). Some load cells also feature a check terminal which is used to unbalance the bridge so that the output becomes, for example, 50% of the full-scale value.

Load cells (more precisely, force transducers based on resistive extensometers) are generally factory calibrated, and are often fitted with a heat compensation circuit.

Force transducers with semiconductor extensometers output high electric signals, and therefore require extremely simple interface systems for offset and scales.

The high degree of sensitivity of the bridge resistors to temperature variations make calibration somewhat complex when a certain precision in measurement is required.

With regard to piezoelectric force transducers, the interface system consists of a charge amplifier whose basic circuit is shown in fig. 1.13.

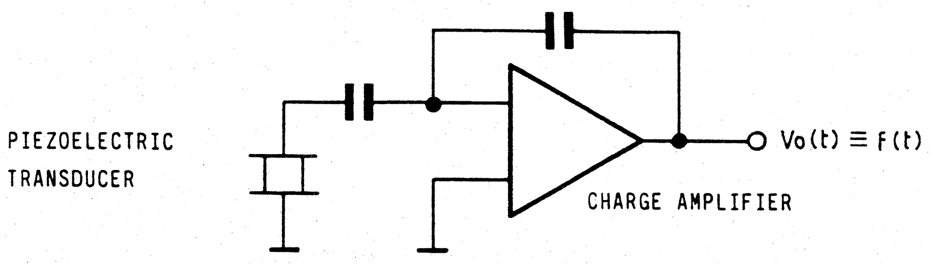


Fig. 1.13

1.6 Specifications of force transducers

Apart from the deformable mechanical element, the following are fundamental characteristics which dictate the fields of application and the quality of a force transducer:

- range of measurement, expressed in Kg, N or tons. This is the range of forces that the sensor is able to transduce while maintaining the accuracy of its measurement specifications. The measurement range may be unipolar (compression) or bipolar (compression and tension).
- allowable static overload, expressed in Kg, N or tons. This is the maximum force that the transducer can withstand without sustaining damage.
- operating temperature range, expressed in °C.
- storage temperature range, expressed in °C.
- temperature error, expressed in °C. This is the temperature range within which the measurement specifications have a given precision.

With regard to the quality of the measurement, specifications for the temperature error are given:

- linearity, expressed as a percentage of the full-scale value. This is the deviation of the transducer indication from the best fit straight line.

- sensitivity (or 'resolution'): this is the smallest input variation which can produce a measurable output variation. Expressed as a value of the output signal per unit of input.
- repeatability, expressed as a percentage of the full-scale value. This parameter indicates the ability of the transducer to reproduce an output signal when the same magnitude is presented on input at different times.
- stability, expressed as a percentage of the full-scale value. This parameter indicates the ability of the transducer to maintain the output signal when the force to be transduced is maintained constant on input.
- hysteresis, which is defined as the maximum displacement between two readings supplied by the transducer for the same force when reached from opposite directions.
- null shift and sensitivity shift with temperature, i.e. the variation of these parameters caused by temperature variations (always in the primary range).

Important factors in the interface system are:

- excitation voltage: the voltage used to feed the transducer.

- output voltage: the full-scale force per unit of feed voltage. This value is expressed in mV/V, and indicates the value of the transducer output (in mV) when the full-scale force is applied and excitation is unitary (in volts).
- F.S.O. (Full-Scale Output). This is the difference between the output voltages of the transducer, corresponding to the limits of the force range.
- ohmic resistance of the strain-gage (or the bridge).

* Characteristics of force transducers based on elastic reaction

- type $\left\{\begin{array}{l}\text{with resistive extensometer}\\ \text{with semiconductor extensometer}\\ \text{(load cells)}\end{array}\right.$

- measurement range
- temperature error
- allowable static overload
- operating temperature range
- storage temperature range
- vibration, shock etc.
- linearity
- sensitivity
- stability
- repeatability
- hysteresis
- excitation voltage
- F.S.O. (Full Scale Output)
- sensitivity per unit of force
- Full Scale Output per unit of excitation

2. DESCRIPTION OF THE APPARATUS

The force transduction teacher unit consists of two main sections: the panel which houses the signal conditioner and the force transducer.

This section describes the structure and operation of each part of the unit (see fig. 2.1).

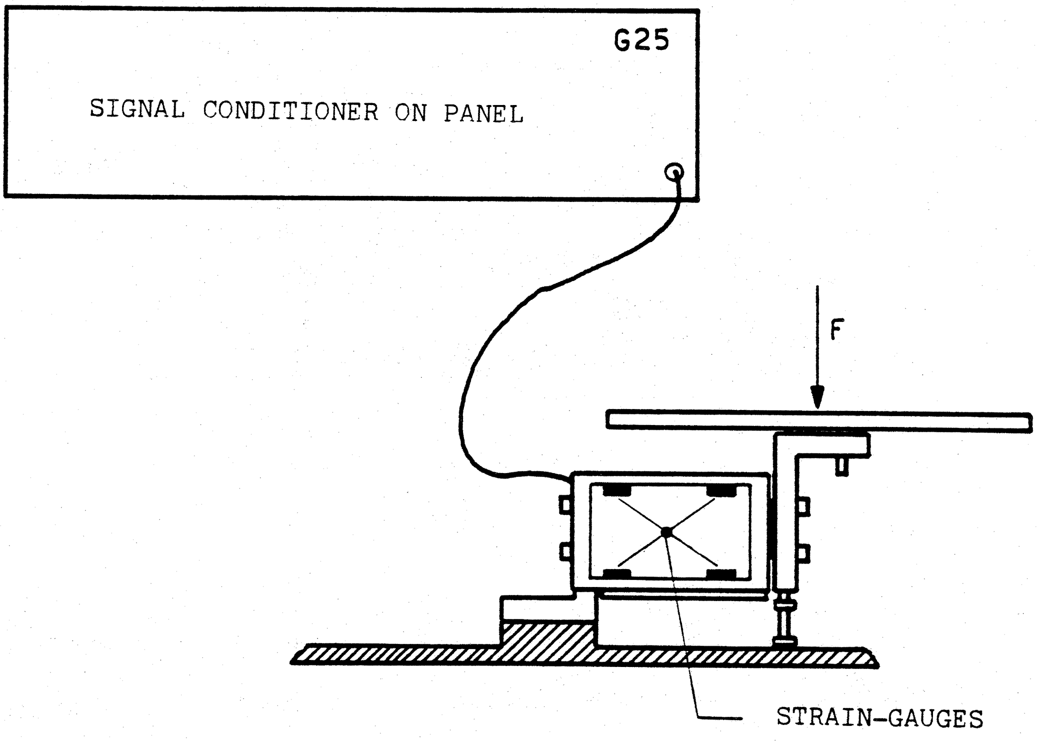


Fig. 2.1

2.1 Force transducer

The sensor fitted to the teacher unit is a load cell featuring resistive extensometers. The force applied causes the deformation of a metallic structure such as that shown in fig. 2.2.

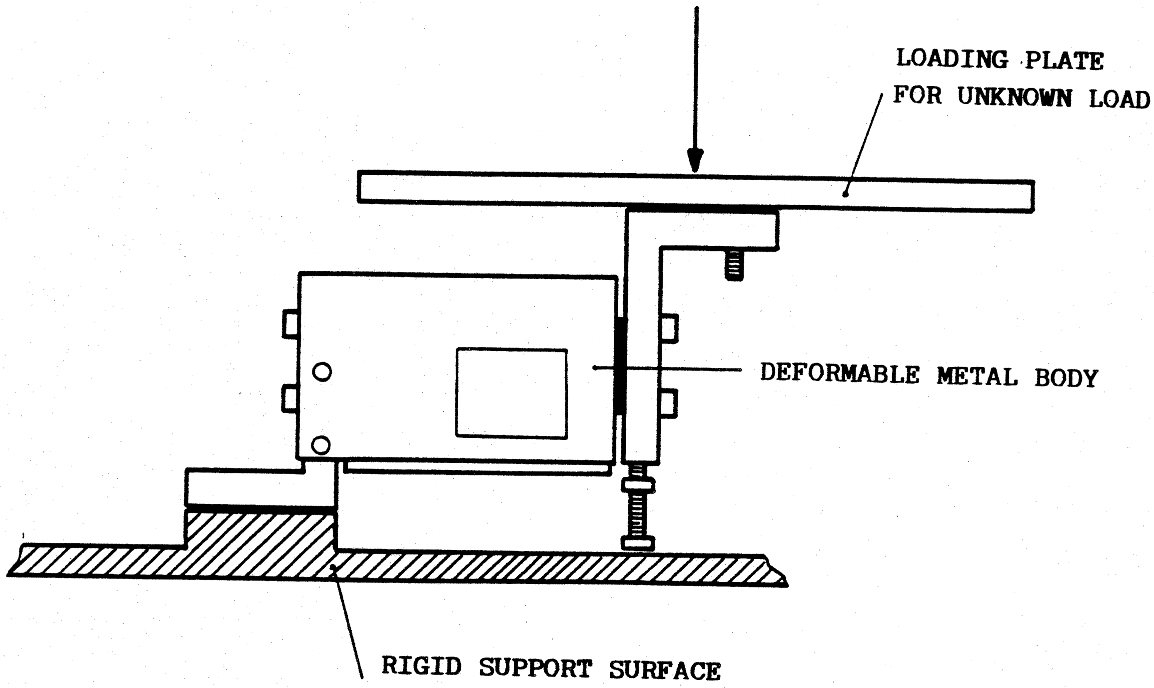


Fig. 2.2

The quality of transduction, and thus of the force measurement, depends largely on the quality of the connections between the load cell and the support surfaces.

These must be rigid and perfectly flat, and must offer the greatest possible area of contact which must remain

invariable when the position and the value of the load alter. The two fixing screws are positioned in line and guarantee uniform interconnection in all directions, including that transversal to the axis of the cell, which is the most sensitive to the position of the load.
This excellent level of rigidity allows the area of the transducer load plate to be increased, i.e. reduces the incidence of measurement errors caused by non-centered loads (see fig. 2.3) to the values shown overleaf.

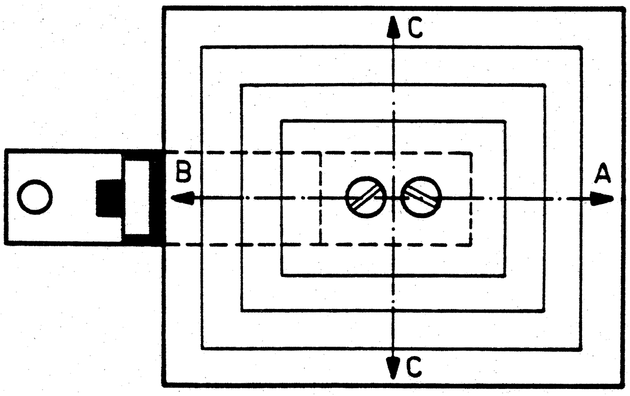


Fig. 2.3

A = 0.006% fs/cm

B = 0.005% fs/cm

C = 0.0002% fs/cm

where % fs/cm is the percentage of the full scale value for each centimeter of distance between the point of application of a punctiform load and the axis of measurement of the cell.

These values show that this force sensor is perfectly suited to non-centered loads, i.e. can be used with weighing platforms of up to 15 x 20 cm.

Overloading these cells may cause damage even if the power supply is switched off; it is therefore necessary to take care in assembling cells with low full-scale values (0.5 - 20 kg). For these cells, it is absolutely essential to avoid any torsional stress and loads in excess of the full-scale value.

In the case of vibration, shock or knocks, the force applied is always the product of the mass multiplied by the acceleration (F = m a), and the cell may be subjected to stress in excess of its allowable limits.

For rapid-cycle weighing or in cases where the load falls onto the component, the full-scale value of the cell should be higher than normal.

The four resistive extensometers which measure the deformation occurring in the mechanical structure when subjected to a load are connected by a bridge complete with four active elements. The position of the extensometers is shown in fig. 2.4. Automatic machines are used for assembly in order to maximise the compensation for spurious forces.

The cell also provides automatic temperature compensation and elimination of the rigidity effect of the interconnection wires.

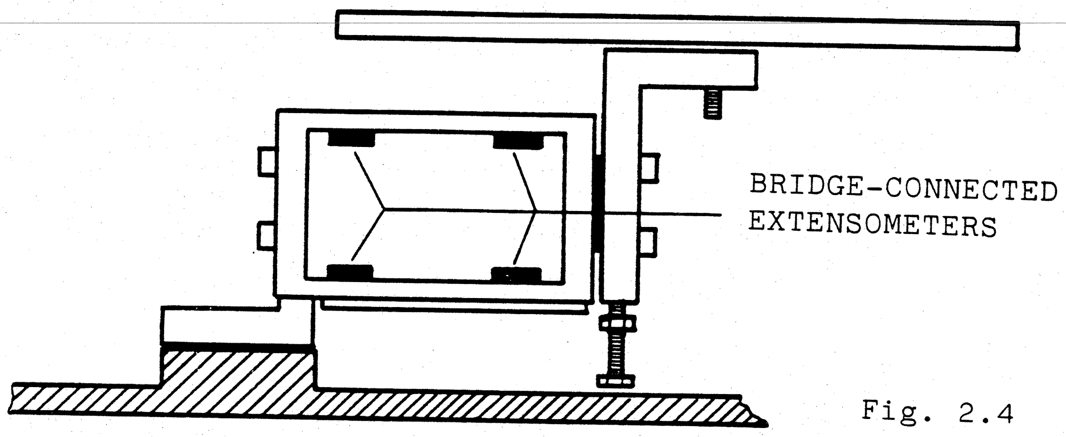


Fig. 2.4

Fig. 2.4

In order to ensure the constancy of the electrical parameters and stability of measurement, the extensometers are protected against humidity.

The terminals of the transducer follow the standards shown below:

Connector n°	Color of wire	Functions
1	red	+ power supply to extensometer bridge
4	black	- power supply to extensometer bridge
2	green	+ signal output
3	grey	- signal output

The bias of the output signal is negative in compression and positive in tension.

The cell is tested with compression.

In order to calibrate the trasduction system, it is clearly necessary to adjust the signal conditioner.

The characteristics of the load cell are shown in the sheets which follow. These "data sheets" or "product sheets" are supplied by the manufacturer together with the testing certificate, and contain the methods of use and the specifications of the measurements that may be carried out with the transducer.

The first sheet lists the general characteristics of the cell and the error factors for non-centered loads.

The second sheet describes the main characteristics of the model cell (QUADRILATERAL SERIES).

The first column lists the measurement ranges; in our case, 0 - 20 kg. The second column lists the sensitivity, i.e. the value of the output signal with full-scale load for each volt of power supplied by the bridge; this value is ± 2mV/V.

The next column contains the maximum voltage allowable for feeding the extensometer bridge (18V AC or DC).

The fourth column shows the operating temperature range, which is -40 to +120°C. Note that the compensation temperature range is -10 to +70°C (primary range in which the measurement specifications apply).

The next columns give the linearity, hysteresis and repeatability, as well as the null shift and sensitivity shift with temperature.

These three columns are repeated for three different types of cell (3-star, 2-star and industrial). The transducer used in the teacher unit is an industrial version, therefore the linearity, hysteresis and non-repeatability are 0.3% of the full scale value. Null and sensitivity shift with temperature are ± 0.03% of the full-scale value for a temperature variation of 1°C.

This sheet also shows data relative to other characteristics such as the allowable static overload (150% full scale) and the maximum testing overload (200% full scale), the recommended bridge power rating (5 - 10V AC or DC), and the null offset (± 1% full scale), as well as other relevant information.

The third sheet reproduces a testing certificate showing the characteristics of a specific load cell:

- measurement range
- sensitivity
- non-linearity and hysteresis (at certain points)
- resistance of the bridge (input and output)
- maximum operating temperature
- simulated load used for calibration.

The data shown on the data sheets may be used to determine the limits of transduction of the sensor. For example: the linearity error + hysteresis + non-repeatability totals ± 60 grams; the variation of the full-scale value for a 50°C variation is 0.3 kg.

Rated capacity (R.C.)	30 kg
Rated output (R.O)	2mV/V
Creep	0.03% R.O./30 min.
Non-linearity	0.02% R.O.
Hysteresis	0.02% R.O.
Repeatability	0.02% R.O.
Zero balance	±5% R.O.
Temp. range compensated	-10 ~ 70° C
Temp. range sate	-10 ~ 50° C
Temp. effect on rated output	±0.012% LOAD/10° C
Temp. effect on zero balance	±0.04% R.O./10° C
Terminal resistance input output	 430Ω±5Ω 350Ω±5Ω

Electrical connection	ø3mmx4C x40cm
Insulation resistance (Min) bridge to ground shield to ground	 2000MΩ 1000MΩ
Excitation. recommended	12V
Excitation. Max.	20V
Safe overload	150% R.C.

2.2 Signal conditioner

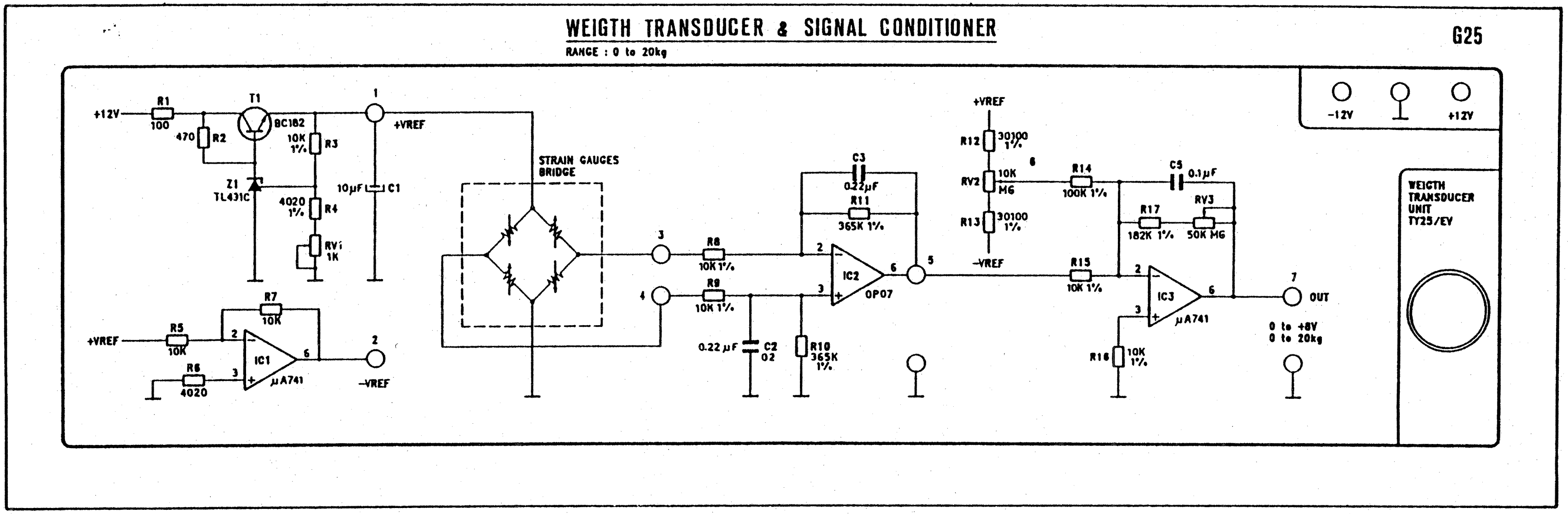
The signal conditioner for a force transducer with resistive extensometer load cell is quite complex, as the output signal of the sensor, which is proportional to the force, is very low.

The conditioner must provide a high level of amplification to output a signal (proportional to the force) which may be easily manipulated. It must also provide adequate offset (nulling) and be able to adapt the scales (amplification variations) to obtain a numerical relationship between force and voltage. The interface circuit (fig. 2.5) is shown in its entirety on the trainer panel.

The excitation signal +VREF (8V)is provided by voltage regulator Z1 (TL431); the integrated circuit IC1 generates -VREF (-8V).

The reference voltage shift with temperature is extremely low (maximum 0.015%/°C); this signifies that a temperature variation of 50°C (alteration of the ambient temperature from 20°C to 70°C which limits the effective measurement range) causes a variation in the excitation of 0.075V. This is equivalent to a variation of 7 per thousand, which is negligible with respect to the variation measured by the transducer.

FIG. N. 2.5


WEIGTH TRANSDUCER & SIGNAL CONDITIONER
RANGE : 0 to 20kg
G25
+12V
R1
100
470
R2
T1
BC182
10K
1%
R3
Z1
TL431C
4020
1%
R4
RVi
1K
10μF
C1
1
+VREF
R7
10K
+VREF
R5
10K
R6
4020
IC1
μA741
2
-VREF
STRAIN GAUGES
BRIDGE
3
4
R8
10K 1%
R9
10K 1%
0.22 μF
C2
02
R10
365K
1%
C3
0.22μF
R11
365K 1%
IC2
OP07
5
+VREF
R12
30100
1%
RV2
10K
MG
R13
30100
1%
-VREF
R14
100K 1%
R15
10K 1%
C5
0.1μF
R17
182K 1%
RV3
50K MG
IC3
μA741
R16
10K
1%
7
OUT
0 to +8V
0 to 20kg
-12V
+12V
WEIGTH
TRANSDUCER
UNIT
TY25/EV

The excitation voltage is regulated by trimmer RV1.
The reading stage consists of a differential amplifier (operational amplifier IC2 connected differentially). The operational used (OP07DP) has a low input offset voltage drift with temperature. The data sheet gives a value of 3 μV/°C, which signifies that a temperature variation of 50°C will alter the input offset voltage by 150 μV.
As 2 mV is equivalent to 1 kg, it may be deduced that the error is 75 grams, which corresponds approximately to the transducer non-linearity error, and is significantly lower than the measurement drift caused by variations in the temperature of the transducer.
The differential amplifier has a gain of 36.5.

The output signal from the differential enters the amplification stage IC3 (μA741), whose function is to adapt the scales and to annul the offset of the transducer. For this purpose, the amplification may be regulated by trimmer RV3 (amplification 5÷9) and the offset may be varied from -810 mV to +1.2 V by trimmer RV . This gives an output voltage which is proportional to the force in the ratio of 400 mV = 1 kg.

Note that the conditioner amplifiers also perform a filtering function (low-pass filter) in order to eliminate high-frequency noise.

The presence of the filter does not affect the quality of the system, as the variations in the force applied to the transducer are always extremely slow.

The filter cutoff frequencies are set to approximately 5 Hz.

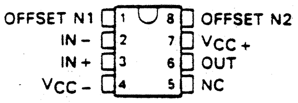
LINEAR
INTEGRATED
CIRCUITS

TYPES OP-07C, OP-07D, OP-07E ULTRA-LOW-OFFSET-VOLTAGE OPERATIONAL AMPLIFIERS

D2757, OCTOBER 1983

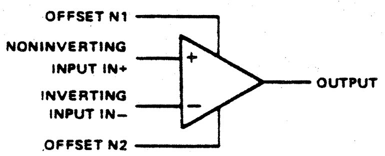
- **Ultra-Low Offset Voltage . . . 30 μV Typ (OP-07E)**
- **Ultra-Low Offset Voltage Temperature Coefficient . . . 0.3 μV/°C Typ (OP-07E)**
- **Ultra-Low Noise**
- **No External Components Required**
- **Replaces Chopper Amplifiers at a Lower Cost**
- **Single-Chip Monolithic Fabrication**
- **Wide Input Voltage Range**
  0 to ±14 V Typ
- **Wide Supply Voltage Range**
  ±3 V to ±18 V
- **Essentially Equivalent to Fairchild μA714 Operational Amplifiers**
- **Direct Replacement for PMI OP-07C, OP-07D, OP-07E**

D, JG OR P DUAL-IN-LINE PACKAGE
(TOP VIEW)



NC – No internal connection

symbol

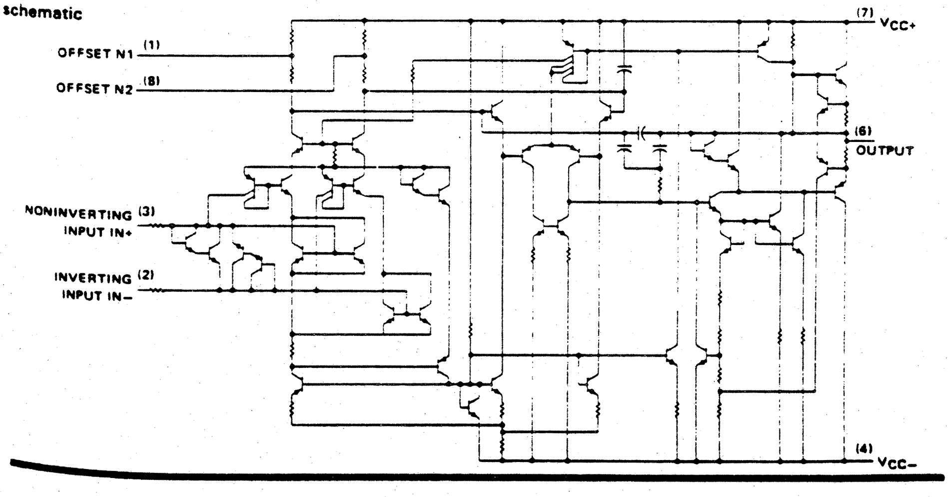


description

These devices represent a breakthrough in operational amplifier performance. Low offset and long-term stability are achieved by means of a low-noise, chopperless, bipolar-input-transistor amplifier circuit. For most applications, no external components are required for offset nulling and frequency compensation. The true differential input, with a wide input voltage range and outstanding common-mode rejection, provides maximum flexibility and performance in high-noise environments and in noninverting applications. Low bias currents and extremely high input impedances are maintained over the entire temperature range. The OP-07 is unsurpassed for low-noise, high-accuracy amplification of very-low-level signals.

These devices are characterized for operation from 0°C to 70°C.

schematic



TYPES OP-07C, OP-07D, OP-07E
ULTRA-LOW-OFFSET VOLTAGE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage V_{CC+} (see Note 1)	22 V
Supply voltage V_{CC-}	−22 V
Differential input voltage (see Note 2)	±30 V
Input voltage (either input, see Note 3)	±22 V
Duration of output short circuit (see Note 4)	unlimited
Continuous total dissipation at (or below) 25 °C free-air temperature (see Note 5)	500 mW
Operating free-air temperature range	0 °C to 70 °C
Storage temperature range	−65 °C to 150 °C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300 °C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: P package	260 °C

NOTES:
1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-}.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply.
5. For operation above 25 °C free-air temperature, refer to Dissipation Derating Curves in Section 2. In the JG package, these chips are glass-mounted.

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

PARAMETER		TEST CONDITIONS†		OP-7C			OP-7D			OP-7E			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_O = 0$, $R_S = 50\ \Omega$	25°C		60	150		60	150		30	75	μV
			0°C to 70°C		85	250		85	250		45	130	
α_{VIO}*	Temperature coefficient of input offset voltage	$V_O = 0$, $R_S = 50\ \Omega$	0°C to 70°C		0.5	1.8		0.7	2.5		0.3	1.3	μV/°C
	Long term drift of input offset voltage	See Note 6			0.4			0.5			0.3		μV/mo
	Offset adjustment range	$R_S = 20$ kΩ, See Figure 1	25°C		±4			±4			±4		mV
I_{IO}	Input offset current		25°C		0.8	6		0.8	6		0.5	3.8	nA
			0°C to 70°C		1.6	8		1.6	8		0.9	5.3	
α_{IIO}	Temperature coefficient of input offset current		0°C to 70°C		12	50		12	50		8	35	pA/°C
I_{IB}	Input bias current		25°C		±1.8	±7		±2	±12		±1.2	±4	nA
			0°C to 70°C		±2.2	±9		±3	±14		±1.5	±5.5	
α_{IIB}*	Temperature coefficient of input bias current		0°C to 70°C		18	50		18	50		13	35	pA/°C
V_{ICR}	Common-mode input voltage range		25°C	±13	±14		±13	±14		±13	±14		V
			0°C to 70°C	±13	±13.5		±13	±13.5		±13	±13.5		
V_{OM}	Peak output voltage	$R_L \geq 10$ kΩ	25°C	±12	±13		±12	±13		±12.5	±13		V
		$R_L \geq 2$ kΩ		±11.5	±12.8		±11.5	±12.8		±12	±12.8		
		$R_L \geq 1$ kΩ			±12			±12		±10.5	±12		
		$R_L \geq 2$ kΩ	0°C to 70°C	±11	±12.6		±11	±12.6		±12	±12.6		
A_{VD}	Large-signal differential voltage amplification	$V_{CC\pm} = \pm 3$ V, $V_O = \pm 0.5$ V, $R_L \geq 500$ kΩ	25°C	100	400			400		150	400		V/mV
		$V_O = \pm 10$ V, $R_L = 2$ kΩ	25°C	120	400		120	400		200	500		
			0°C to 70°C	100	400		100	400		180	450		
B_1*	Unity gain bandwidth		25°C	0.4	0.6		0.4	0.6		0.4	0.6		MHz
r_i*	Input resistance		25°C	8	33		7	31		15	50		MΩ
CMRR	Common-mode rejection ratio	$V_{IC} = \pm 13$ V, $R_S = 50\ \Omega$	25°C	100	120		94	110		106	123		dB
			0°C to 70°C	97	120		94	106		103	123		
k_{SVS}	Supply voltage sensitivity ($\Delta V_{IO}/\Delta V_{CC}$)	$V_{CC\pm} = \pm 3$ V to ± 18 V, $R_S = 50\ \Omega$	25°C		7	32		7	32		5	20	μV/V
			0°C to 70°C		10	51		10	51		7	32	
P_D	Power dissipation	$V_O = 0$, No load	25°C		80	150		80	150		75	120	mW
		$V_{CC\pm} = \pm 3$ V, $V_O = 0$, No load			4	8		4	8		4	6	

†All characteristics are measured under open loop conditions with zero common-mode input voltage unless otherwise noted.

NOTE 6: Since long term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the averaged trend line of drift versus time over extended periods after the first thirty days of operation.

*These parameters are guaranteed but not tested.

operating characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

PARAMETER		TEST CONDITIONS†		OP-7C			OP-7D			OP-7E			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_n	Equivalent input noise voltage	T_A = 25°C	f = 10 Hz		10.5	20		10.5	20		10.3	18	nV/√Hz
			f = 100 Hz		10.2	13.5		10.3	13.5		10.0	13	
			f = 1 kHz		9.8	11.5		9.8	11.5		9.6	11	
V_{NPP}	Peak-to-peak equivalent input noise voltage	f = 0.1 Hz to 10 Hz, T_A = 25°C			0.38	0.65		0.38	0.65		0.35	0.6	μV
I_n	Equivalent input noise current	T_A = 25°C	f = 10 Hz		0.35	0.9		0.35	0.9		0.32	0.8	pA/√Hz
			f = 100 Hz		0.15	0.27		0.15	0.27		0.14	0.23	
			f = 1 kHz		0.13	0.18		0.13	0.18		0.12	0.17	
I_{NPP}	Peak-to-peak equivalent input noise current	f = 0.1 Hz to 10 Hz, T_A = 25°C			15	35		15	35		14	30	pA
SR	Slew rate	$R_L \geq 2$ kΩ, T_A = 25°C		0.1	0.3		0.1	0.3		0.1	0.3		V/μs

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

TYPICAL APPLICATION DATA

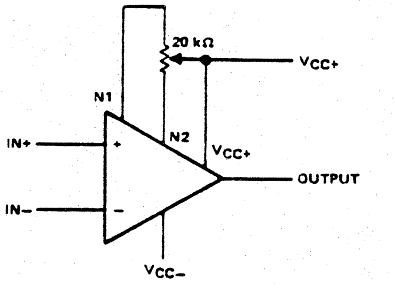


FIGURE 1—INPUT OFFSET VOLTAGE NULL CIRCUIT

LINEAR INTEGRATED CIRCUITS

TYPES uA741M, uA741C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

BULLETIN NO. DL-S 11363, NOVEMBER 1970–REVISED OCTOBER 1979

- Short-Circuit Protection
- Offset-Voltage Null Capability
- Large Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-up

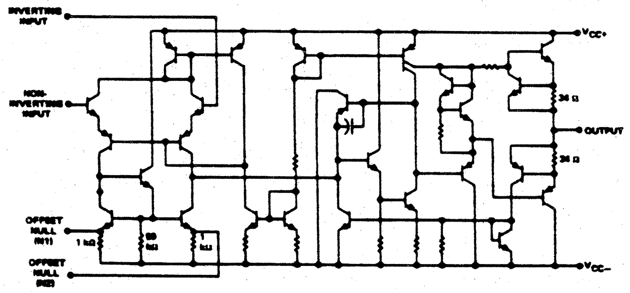
description

The uA741 is a general-purpose operational amplifier featuring offset-voltage null capability.

The high common-mode input voltage range and the absence of latch-up make the amplifier ideal for voltage-follower applications. The device is short-circuit protected and the internal frequency compensation ensures stability without external components. A low-value potentiometer may be connected between the offset null inputs to null out the offset voltage as shown in Figure 2.

The uA741M is characterized for operation over the full military temperature range of −55°C to 125°C; the uA741C is characterized for operation from 0°C to 70°C.

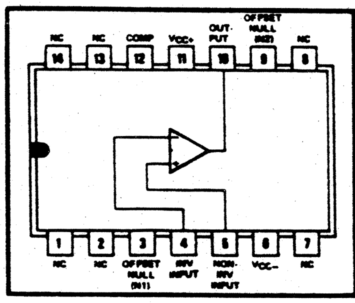
schematic



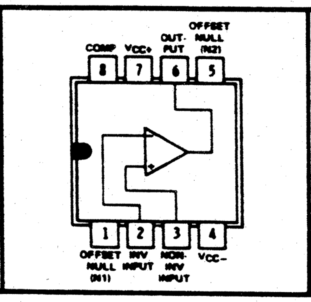
Resistor values shown are nominal

terminal assignments

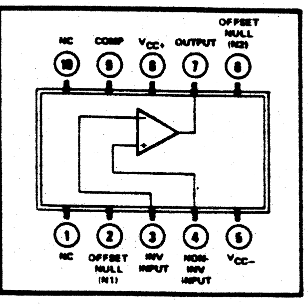
J OR N DUAL-IN-LINE OR W FLAT PACKAGE (TOP VIEW)



JG OR P DUAL-IN-LINE PACKAGE (TOP VIEW)



U FLAT PACKAGE (TOP VIEW)



NC—No internal connection

TYPES uA741M, uA741C
GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

		uA741M	uA741C	UNIT
Supply voltage V_{CC+} (see Note 1)		22	18	V
Supply voltage V_{CC-} (see Note 1)		−22	−18	V
Differential input voltage (see Note 2)		±30	±30	V
Input voltage (either input, see Notes 1 and 3)		±15	±15	V
Voltage between either offset null terminal (N1/N2) and V_{CC-}		±0.5	±0.5	V
Duration of output short-circuit (see Note 4)		unlimited	unlimited	
Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 5)		500	500	mW
Operating free-air temperature range		−55 to 125	0 to 70.	°C
Storage temperature range		−65 to 150	−65 to 150	°C
Lead temperature 1/16 inch (1,6 mm) from case for 60 seconds	J, JG, U, or W package	300	300	°C
Lead temperature 1/16 inch (1,6 mm) from case for 10 seconds	N or P package		260	°C

NOTES:
1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-}.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or either power supply. For the uA741M only, the unlimited duration of the short-circuit applies at (or below) 125°C case temperature or 75°C free-air temperature.
5. For operation above 25°C free-air temperature, refer to Dissipation Derating Curves, Section 2. In the J and JG packages, uA741M chips are alloy-mounted; uA741C chips are glass-mounted.

electrical characteristics at specified free-air temperature, $V_{CC+} = 15$ V, $V_{CC-} = -15$ V

PARAMETER		TEST CONDITIONS†		uA741M			uA741C			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$R_S < 10$ kΩ	25°C		1	5		1	6	mV
			Full range			6			7.5	
$\Delta V_{IO(adj)}$	Offset voltage adjust range		25°C		±15			±15		mV
I_{IO}	Input offset current		25°C		20	200		20	200	nA
			Full range			500			300	
I_{IB}	Input bias current		25°C		80	500		80	500	nA
			Full range			1500			800	
V_{ICR}	Common-mode input voltage range		25°C	±12	±13		±12	±13		V
			Full range	±12			±12			
V_{OPP}	Maximum peak-to-peak output voltage swing	$R_L = 10$ kΩ	25°C	24	28		24	28		V
		$R_L \geq 10$ kΩ	Full range	24			24			
		$R_L = 2$ kΩ	25°C	20	26		20	26		
		$R_L \geq 2$ kΩ	Full range	20			20			
A_{VD}	Large-signal differential voltage amplification	$R_L \geq 2$ kΩ, $V_O = \pm 10$ V	25°C	50	200		20	200		V/mV
			Full range	25			15			
r_i	Input resistance		25°C	0.3	2		0.3	2		MΩ
r_o	Output resistance	$V_O = 0$ V, See Note 6	25°C		75			75		Ω
C_i	Input capacitance		25°C		1.4			1.4		pF
CMRR	Common-mode rejection ratio	$R_S < 10$ kΩ	25°C	70	90		70	90		dB
			Full range	70			70			
k_{SVS}	Supply voltage sensitivity ($\Delta V_{IO}/\Delta V_{CC}$)	$R_S < 10$ kΩ	25°C		30	150		30	150	µV/V
			Full range			150			150	
I_{OS}	Short-circuit output current		25°C		±25	±40		±25	±40	mA
I_{CC}	Supply current	No load, No signal	25°C		1.7	2.8		1.7	2.8	mA
			Full range			3.3			3.3	
P_D	Total power dissipation	No load, No signal	25°C		50	85		50	85	mW
			Full range			100			100	

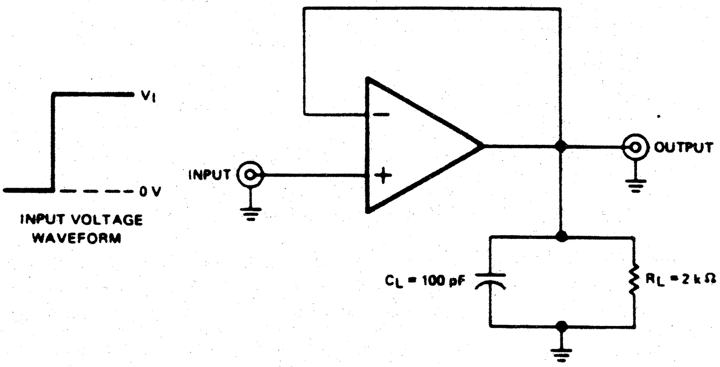
†All characteristics are specified under open-loop operation. Full range for uA741M is −55°C to 125°C and for uA741C is 0°C to 70°C.

NOTE 6: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

operating characteristics, $V_{CC+} = 15$ V, $V_{CC-} = -15$ V, $T_A = 25°C$

PARAMETER		TEST CONDITIONS	uA741M			uA741C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
t_r	Rise time	V_I = 20 mV, R_L = 2 kΩ, C_L = 100 pF, See Figure 1		0.3			0.3		µs
	Overshoot factor			5%			5%		
SR	Slew rate at unity gain	V_I = 10 V, R_L = 2 kΩ, C_L = 100 pF, See Figure 1		0.5			0.5		V/µs

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT
FIGURE 1–RISE TIME, OVERSHOOT, AND SLEW RATE

TYPICAL APPLICATION DATA

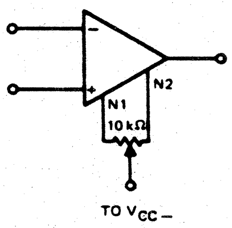


FIGURE 2–INPUT OFFSET VOLTAGE NULL CIRCUIT

TYPES uA741M, uA741C
GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

TYPICAL CHARACTERISTICS

INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

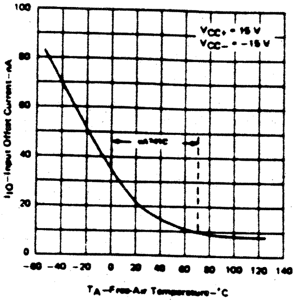
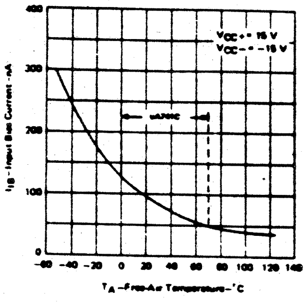


FIGURE 3

INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE



FIGUER 4

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
LOAD RESISTANCE

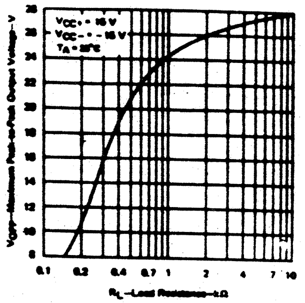


FIGURE 5

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
FREQUENCY

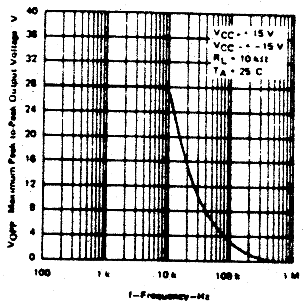


FIGURE 6

OPEN-LOOP LARGE-SIGNAL
DIFFERENTIAL
VOLTAGE AMPLIFICATION
vs
SUPPLY VOLTAGE

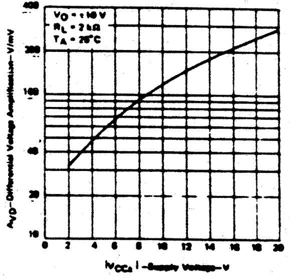


FIGURE 7

OPEN-LOOP LARGE-SIGNAL
DIFFERENTIAL
VOLTAGE AMPLIFICATION
vs
FREQUENCY

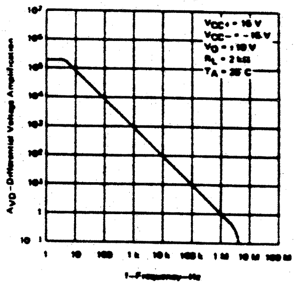


FIGURE 8

COMMON-MODE REJECTION RATIO
vs
FREQUENCY

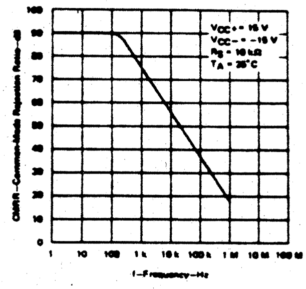


FIGURE 9

OUTPUT VOLTAGE
vs
ELAPSED TIME

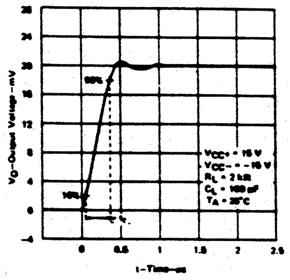


FIGURE 10

VOLTAGE-FOLLOWER
LARGE-SIGNAL PULSE RESPONSE

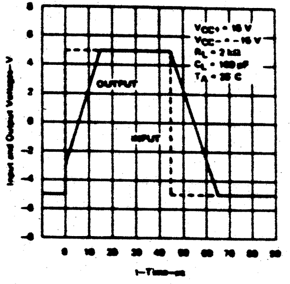


FIGURE 11

2.3 Sample force

The load cell is calibrated for a unit of measurement force equivalent to 1 kg of force = 0.9806 daN, where 0.9806 is the acceleration of gravity (Milan).

The transducer should be considered as a spring which is subjected to a force F (=ma) caused by a mass m (sample weights plus own mass) subjected to the acceleration of gravity (=a). The latter quantity varies according to the latitude and the altitude of the location where the measurements are carried out.

The table below lists the gravity values for a number of European localities.

VIENNA	980.960 m/sec^2	PARIS	980.943 m/sec^2
BRUSSELS	981.112 m/sec^2	GREENWICH	981.188 m/sec^2
COPENHAGEN	981.559 m/sec^2	MUNICH	980.733 m/sec^2
MILAN	980.569 m/sec^2	OSLO	981.927 m/sec^2
LENINGRAD	981.929 m/sec^2	BARCELONA	980.240 m/sec^2
POLE	983.217 m/sec^2	EQUATOR	978.039 m/sec^2

3. SUGGESTED EXERCISES

The exercises which follow are designed to help the student to understand the operation and the characteristics of the load cell and the signal conditioner. Note that the sample force is obtained using weights directly calibrated in kilograms weight. The following instruments and apparatus are required for the exercises:

- 3½ digit digital voltmeter (such as our model MD-79)
- stabilized power supply, output ± 12V DC
- sample weights

3.1 Calibration of the signal conditioner

Purpose of the exercise

The purpose of this exercise is to set up the signal conditioner, i.e. to calibrate it so that if no force is applied, the output voltage is 0V, while a force of 20 kg corresponds to an output signal of 8 V.

Instruments used

- digital voltmeter

Procedure

- Connect the ± 12V, 0 V jacks of the panel to a stabilized power module (switched off).
- Connect the load module to the panel via the appropriate connector.
- Connect the digital voltmeter between jack 1 and ground.
- Switch on the stabilized power supply.
- Calibrate trimmer RV1 until 8.0 V is shown on the digital voltmeter (calibration of the excitation voltage).

- Connect the digital voltmeter to the OUT output.
- Calibrate trimmer RV2 until the digital voltmeter reads 0 V (calibration of the offset of the load cell).
- Apply a sample load of 20 kg. to the cell.
- Calibrate trimmer RV3 until the digital voltmeter reads 8 V (calibration of the conditioner scale).

3.2 Measuring the output voltage/force curve

Purpose of the exercise

The purpose of this exercise is to plot the curve which represents the relationship between the force applied on input to the transducer and the voltage present at its output.

Instruments used

3 ½ digit digital voltmeter

Procedure

- Calibrate the conditioner as described in paragraph 3.1.
- Connect the digital voltmeter to the OUT output.
- Apply known weights to the cell (in increasing order and at intervals of 1 kg); measure the output voltage.

The data should be noted in table 3.1.

A curve similar to that shown in fig. 3.1 may be traced by plotting the force on the x-axis and the output voltage of the conditioner on the y-axis. This graph represents the characteristic curve of the transducer conditioner.

N	F [Kg]	Vout [V]

TABLE 3.1

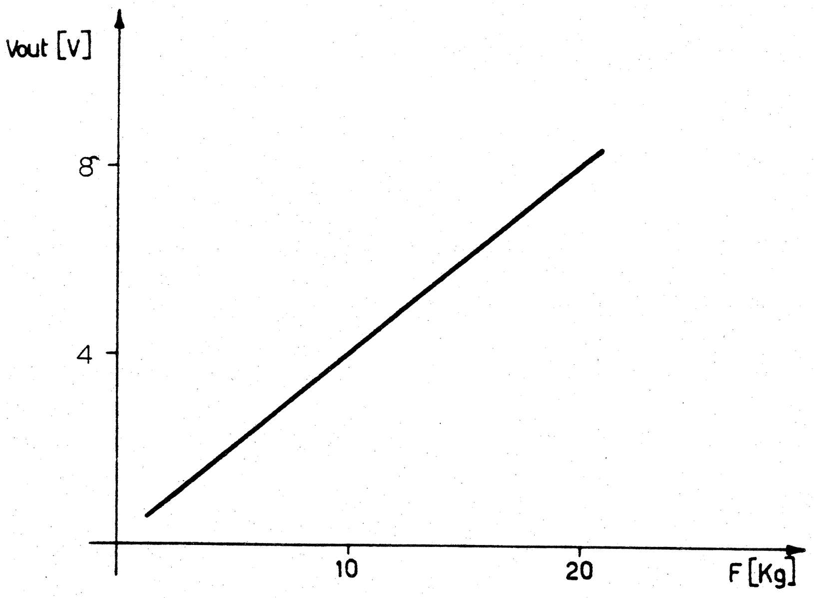


Fig. 3.1

3.3 Tracing the best fit straight line of the transducer

Purpose of the exercise

The purpose of this exercise is to plot the best fit straight line of the transducer, i.e. the line which perfectly represents the relationship between the force applied to the transducer and the output voltage of the conditioner.

Instruments used

3½ digit digital voltmeter

Procedure

- Calibrate the conditioner as shown in exercise 3.1.
- Connect the digital voltmeter to the OUT output.
- Apply known weights to the cell (in increasing order and at intervals of 1 kg); measure the output voltage.

The data should be noted in table 3.2.

A dot graph similar to that shown in fig. 3.2 may be produced by plotting the force on the x-axis and the output voltage of the conditioner on the y-axis.

N	F [Kg]	Vout [V]

Table 3.2

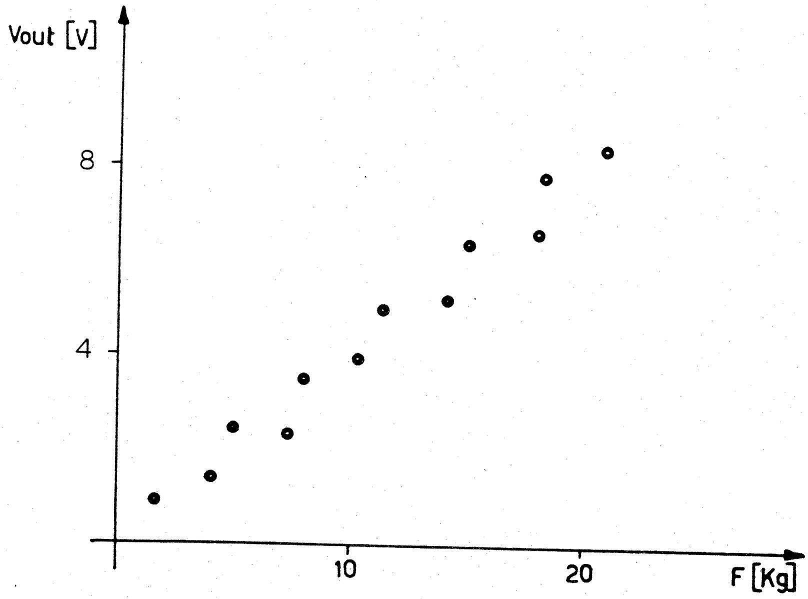


Fig. 3.2

The best fit straight line is obtained by plotting a straight line through the points on the graph (fig. 3.3).

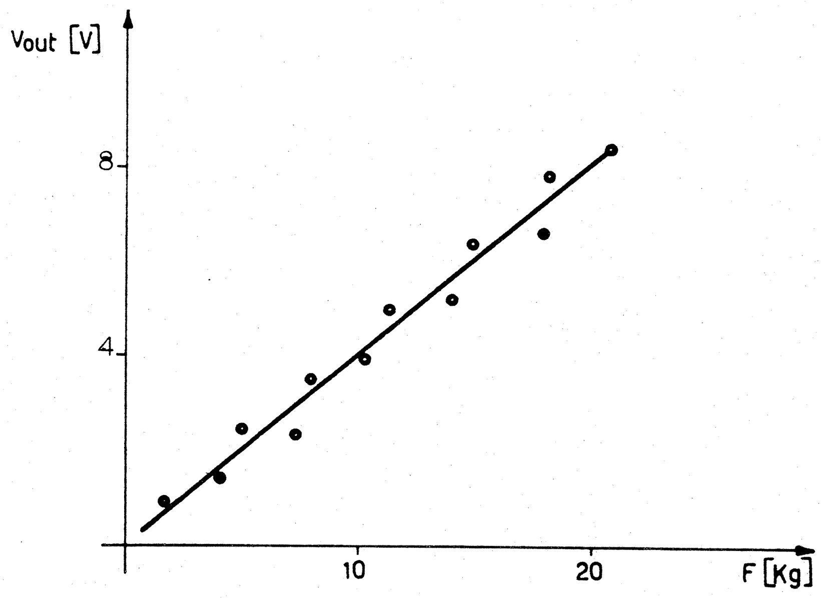


Fig. 3.3

3.4 Calculating the linearity of the transducer/conditioner

Purpose of the exercise

The purpose of this exercise is to determine the linearity of the transducer/conditioner system.

Instruments used

3½ digit digital voltmeter

Procedure

- Calibrate the conditioner as shown in exercise 3.1.
- Plot the best fit straight line as described in exercise 3.3.

A graph similar to that shown in fig. 3.4 is obtained.

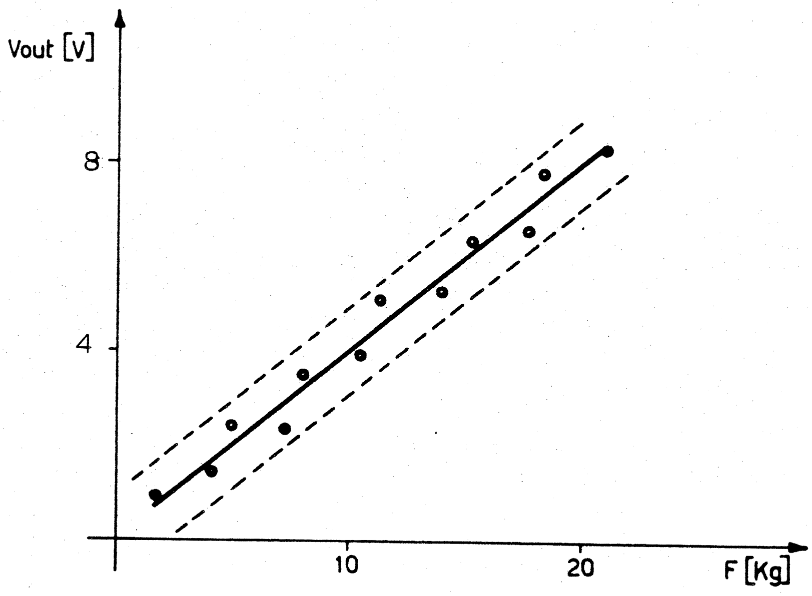


Fig. 3.4

Trace two lines, parallel to and equidistant from the best fit straight line, which enclose all the points plotted on the graph.

By adding a straight line parallel to the y-axis and reading off the voltage values corresponding to the intersections of the two lines plotted previously to enclose all the measurement points (fig. 3.5) the linearity for full scale is:

$$\pm \frac{1}{8} \frac{|V_2 - V_1|}{\text{F.S.O.}} = \text{linearity}$$

This value is generally expressed as a percentage.

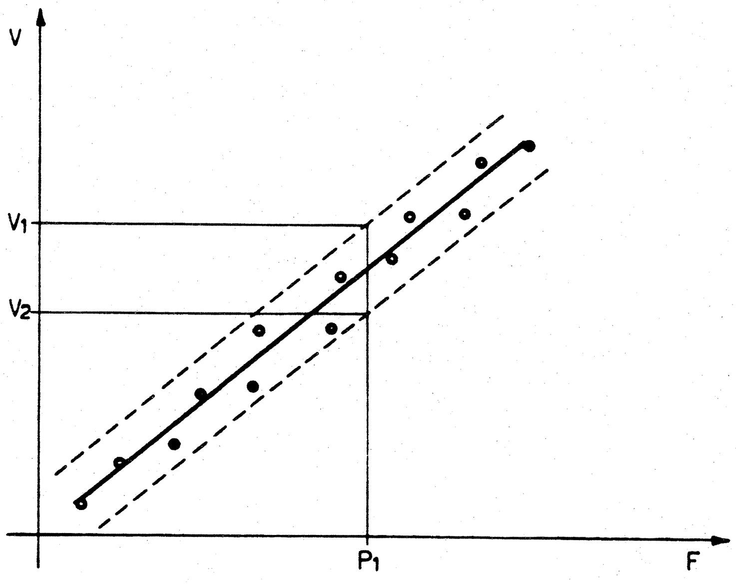


Fig. 3.5

F.S.O. stands for "full scale output", i.e. the voltage drift to which the output is subjected when the force varies by a quantity equivalent to its entire range.

In our case, F.S.O. = 8 V.

In fact, for F = 0, V_{out} = 0, and for F = 20 kg, V_{out} = 8 V.

3.5 Determination of the variation in measurement on variation of the temperature of the load cell

Purpose of the exercise: to determine the variation in the measurements as the temperature of the transducer varies.

Instruments used: 3½ digit digital voltmeter.

Procedure

- Calibrate the conditioner as shown in exercise 3.1.
- Determine the best fit straight line of the transducer as described in exercise 3.3.
- Heat the load cell using an incandescent lamp and under these conditions (transducer at high temperature) determine the best fit straight line as described in exercise 3.3.

The data should be plotted on a graph similar to that shown in fig. 3.6. Calculate the voltage variation relative to the full scale value:

$$\frac{V_1 - V_2}{F.S.O.} \quad \text{(percentage)}$$

where F.S.O. = 8 V.

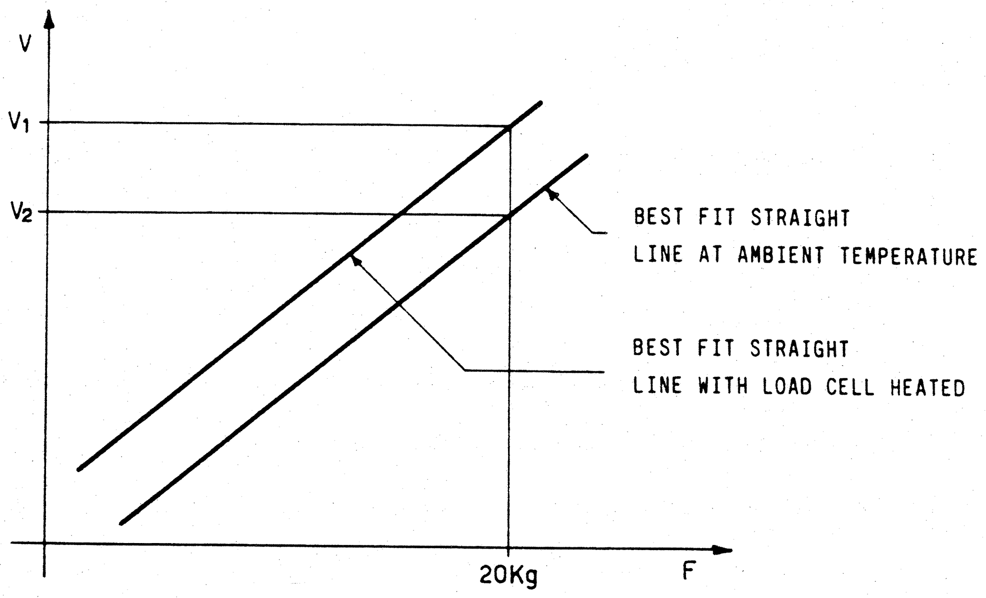

V
V1
V2
BEST FIT STRAIGHT
LINE AT AMBIENT TEMPERATURE
BEST FIT STRAIGHT
LINE WITH LOAD CELL HEATED
20Kg
F

Fig. 3.6

3.6 Determining the variation in measurement on variation of the temperature of the signal conditioner

Purpose of the exercise: to determine the variation in measurement as the temperature of the signal conditioner varies.

Instruments used: 3½ digit digital voltmeter

Procedure

- Calibrate the conditioner as shown in exercise 3.1.
- Plot the best fit straight line of the transducer as described in exercise 3.3.
- Heat the signal conditioner using an incandescent lamp. Under these conditions (conditioner at high temperature) plot the best fit straight line as described in exercise 3.3, without re-calibrating the conditioner.

The data should be plotted on a graph similar to that shown in fig. 3.7. Calculate the voltage variation relative to the full scale value:

$$\frac{V_1 - V_2}{F.S.O.} \quad \text{(percentage)}$$

where F.S.O. = 8 V.

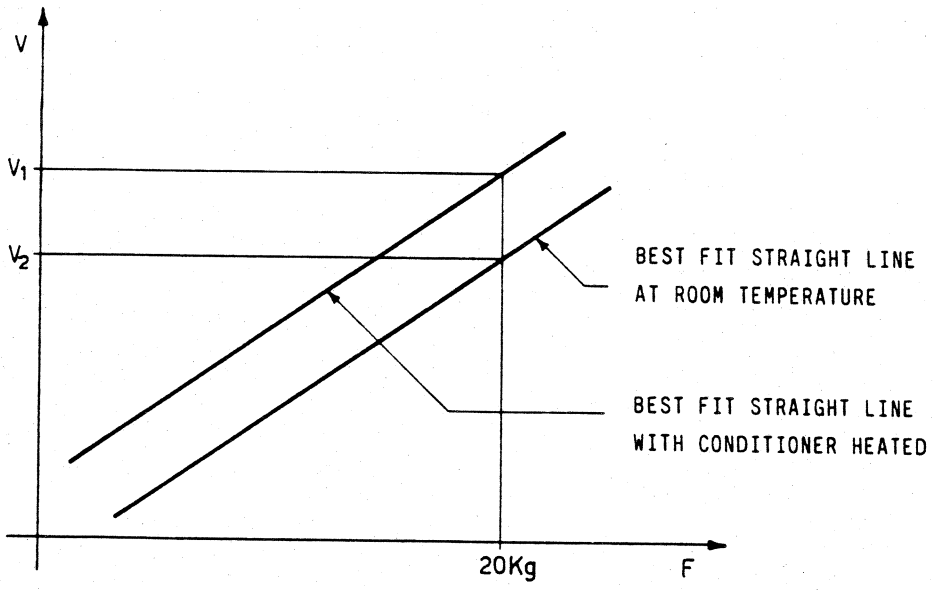

V
V_1
V_2
BEST FIT STRAIGHT LINE
AT ROOM TEMPERATURE
BEST FIT STRAIGHT LINE
WITH CONDITIONER HEATED
20Kg
F

Fig. 3.7

APPENDIX A

A.1 CONNECTION TO THE PERSONAL COMPUTER

In order to be connected to a personal computer, the force transducer module must be connected to an Analog/Digital converter. The analog output from Module G25 is presented as input to the Analog/Digital Converter F03A which transforms this signal into a corresponding digital signal to be sent to the personal computer for further processing.
The connection of the Analog/Digital converter to the computer is carried out with Input/Output parallel ports.

Port C is used with the module under test.

Hereafter follows the detailed description of the connection of the Analog/Digital converter module to the input/output ports of the computer and the connections between the weight transducer and the converter.

A.2 STRUCTURE OF THE CONNECTION

The parallel port C must be used for connecting module F03A to the Personal Computer.
The connection is well represented in figure 1:

- the data acquisition from the A/D converter is carried out by port C

- port C must be set to take an INPUT configuration
  The external control of port C depends on line 5 which must be set to logic level "1".
  In this way, this port takes the INPUT configuration independently from its inner configuration.

The complete table, with the port specifications, address and the meaning of the signals is shown in fig. 2.

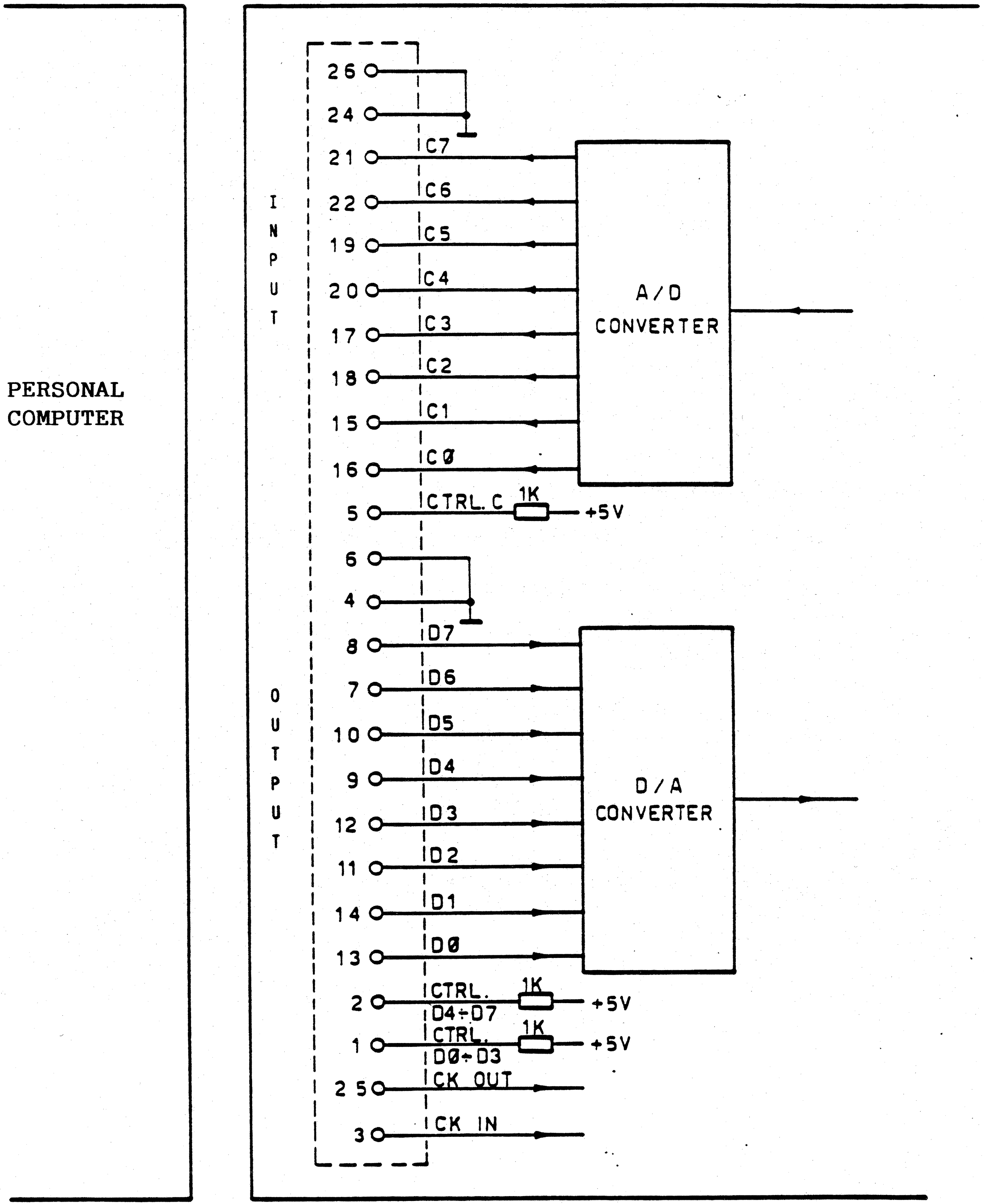

PERSONAL COMPUTER
INPUT
OUTPUT
26
24
21
22
19
20
17
18
15
16
5
6
4
8
7
10
9
12
11
14
13
2
1
25
3
C7
C6
C5
C4
C3
C2
C1
C0
CTRL. C
1K
+5V
D7
D6
D5
D4
D3
D2
D1
D0
CTRL. D4÷D7
CTRL. D0÷D3
CK OUT
CK IN
A/D CONVERTER
D/A CONVERTER

Fig. 1

PORT	SIGNAL BITS		DIRECTION	ADDRESSES
C	**C7**	**bit 7**	**INPUT**	**&H302**
	C6	**bit 6**		
	C5	**bit 5**		
	C4	**bit 4**		
	C3	**bit 3**		
	C2	**bit 2**		
	C1	**bit 1**		
	C0	**bit 0**		
	CTRL.C	Control of port C direction		
D	**D7**	**bit 7**	**OUTPUT**	**&H303**
	D6	**bit 6**		
	D5	**bit 5**		
	D4	**bit 4**		
	D3	**bit 3**		
	D2	**bit 2**		
	D1	**bit 1**		
	D0	**bit 0**		
	CTRL. D4+D7	Control of port D direction **bit 4 + 7**		
	CTRL. D0+D3	Control of port D direction **bit 0 + 3**		
	CK-INPUT	Clock signal input	**INPUT**	
	CK-OUTPUT	Output if processed clock signal	**OUTPUT**	

Fig.2

The electrical connections between module G25 and F03A are the following:
The output of the conditioner circuit (OUT on module G25) is connected to the input of module F03A (INPUT A/D CONVERTER) once the range 0 to 8V has been selected with the proper slide switch.
Module F03A is connected to the Personal Computer with the FLAT CABLE on the connector (EXTERNAL COMPUTER module F03A) and the C/D port of the card ITF01 which must be inserted in the Personal computer.

A.3 CONTROL PROGRAM

The control program enables the following:

1. ACQUISITION OF WEIGHT MEASUREMENTS

2. DETECTION OF THE CHARACTERISTIC
   WEIGHT - VOLTAGE

1. ACQUISITION OF WEIGHT MEASUREMENTS

The analog output of the weight transducer is a voltage ranging from 0.00 to 8.00 V.
The Analog/Digital converter module F03A automatically operates within this measurement range.

The datum obtained is processed to calculate the index position on the proper scale produced by the video of the Personal Computer.

2. DETECTION OF THE CHARACTERISTIC WEIGHT - VOLTAGE

The known weights are loaded on the load cell. The max. number can be 80 and the max. weight can be 20 kg.

A cartesian graph displays the points which abscissas report the introduced known weights and which coordinates reports the corresponding voltage values acquired by the computer via the analog/digital converter.
These points define a line which relates the force applied to the input of the transducer to the voltage present across its output.

APPENDIX B: BIBLIOGRAPHY

1) Transducer interfacing handbook
Analog devices Inc. - Norwood, Massachusetts

2) Strumentazione Industriale - trasduttori e regolatori
Peternella Vitelli - UTET Torino

3) The Linear Control Circuits data-book for Design Engineers - Second Europe Edition
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4) Data-acquisition databook 1984 - Vol. I - Integrated Circuits
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