PROXIMITY SENSORS

MODULE G29

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.

CONTENTS

INTRODUCTION

Modern equipment must preserve their high reliability even when operating in rather difficult conditions, that is, in presence of lubricants, oils, vibrations, etc... This problem has been resolved designing a new type of position transducer (limit switch) constructed without mechanical contact between actuator and sensor. These devices are called "proximity sensors (or transducers)": they can transduce a position (linear type) and there are also sensors of ON-OFF type, that is, their switching indicates a particular position.

This electrical analog information given by the proximity sensor can profitably be used by a programmable controller, a warning light, a computer, etc..., only if the sensor is connected through electrical interface systems.

These interface systems are normally called "signal conditioners".

This handbook can help to understand the operation, the choice criteria and the main characteristics of the proximity sensors and signal conditioners included in the module G29.

The first chapter illustrates the operation principles of the proximity sensors mainly used in the industry.

The second chapter describes and examines the equipment (proximity sensor + conditioners) of the auxiliary unit and of the module.

In detail, the characteristics of the sensor will exhaustively be analysed, so it will be clear how these parameters can condition the choice of the sensor which must operate in certain conditions giving particular performances.

At last, the third chapter describes some exercises through which it is possible to check the characteristics of the proximity sensors (and of the signal conditioners) and their influence in the industrial use.

1. HINTS ON THE PROXIMITY SENSORS

As already explained in the introduction, these proximity sensors are the position transducers in which there is no mechanical contact between sensor and actuator.
There are two main types of proximity sensors, that is:

- **inductive proximity sensors;**
- **capacitive proximity sensors.**

The difference consists in the operation principle of the sensor.
But the inductive proximity sensors can be subdivided into:

- inductive proximity sensors with linear output (displacement sensors);
- non-amplified inductive proximity sensors with two-level output;
- inductive proximity sensors with amplified output (self-amplified sensors).

The capacitive sensors can be subdivided into two subclasses:

- direct-current capacitive proximity sensors;

- alternating-current capacitive proximity sensors.

There are also the magnetic proximity sensors which operate thanks to a reed relay.

1.1 Inductive proximity sensors

The operation principle of the inductive proximity sensors is based on the damping of an electromagnetic field due to the eddy currents induced within conducting materials placed near the sensors.

An oscillating circuit generates a high-frequency electromagnetic field which induces eddy currrents within the near metallic actuators.

These currents cause an energy loss in the oscillator, damping the signal amplitude. This damping is detected and transmitted to the output. The intervention distance depends on the type of metal of the actuator (fig. 1.1).

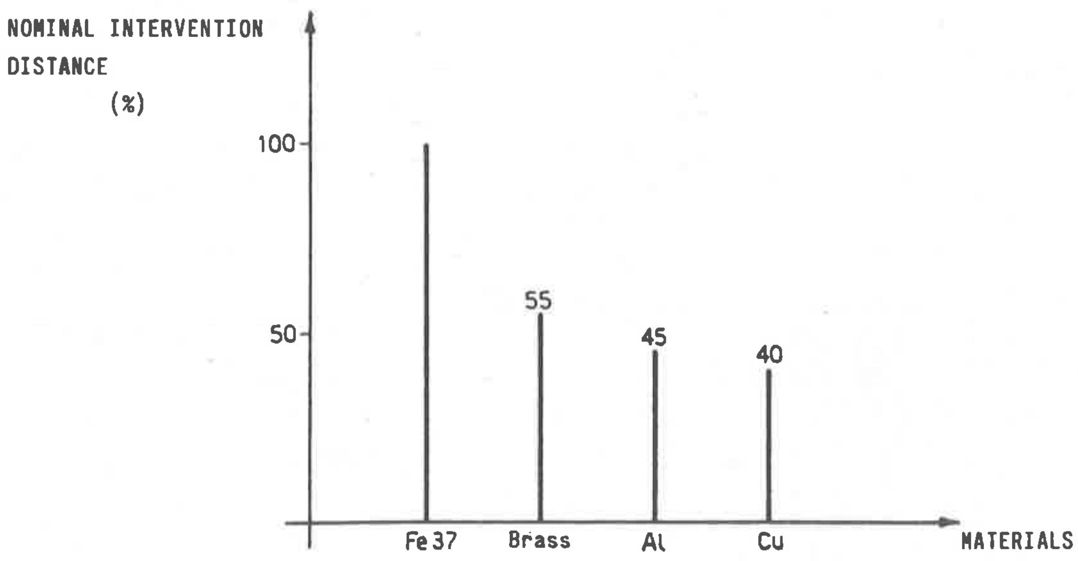


FIG. 1.1

The inductive proximity sensors can be divided into two classes:

- **non-amplified sensors:** they consist of the only oscillator and are used to obtain low-level signals for controlling a separate amplifier. Their use is compulsory in installations requiring a very high safety level (ambients with danger of fire, explosions, etc...). These sensors are subdivided (with respect to the type of output) into sensors with two-level output and sensors with linear output;
- **self-amplified sensors:** there are two types: the direct-current sensors and the alternating-current sensors.

Fig. 1.2 shows the block diagram of an inductive proximity sensor.

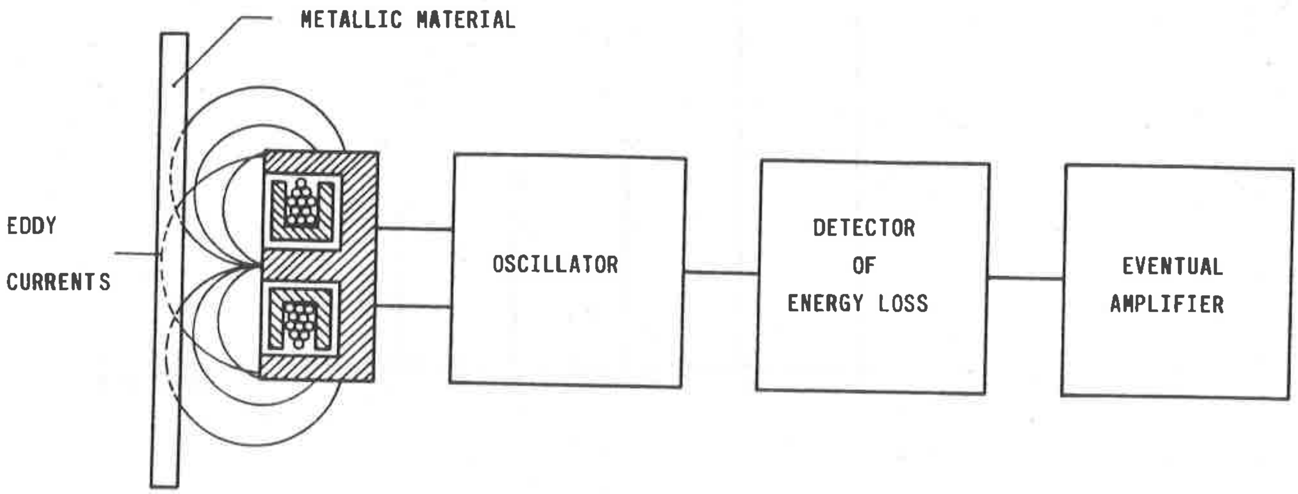


FIG. 1.2

1.1.1 Non-amplified inductive proximity sensors with two-level output.

These sensors deliver two different output current values, according to the position of the metallic actuator. Actually, they can be considered current regulators with two possible output values depending on the distance of the metallic actuator.

These sensors are particularly used to drive a separate amplifier (in conformity with the standards DIN 19234 in force at present).

They operate at very low electric levels. Thanks to this characteristic, they are necessarily used in installations and systems which operate in ambients with danger of explosion (standards NAMUR).

Fig. 1.3 shows the diagram of a proximity sensor of this type connected to the amplifier (signal conditioner); generally the amplifier is physically placed far from the sensor.

In the symbol of the sensor there are the marks of sine wave which indicate the oscillating circuit generating the magnetic field, and the mark of the step which indicates the two-level output.

The amplifier mainly consists of a voltage generator connected in series to a resistor. Varying the current, also the voltage drop across the resistor varies, so that an ON-OFF (voltage) signal is generated at the output. This signal indicates whether the distance of the actuator is shorter or longer than the switching distance.

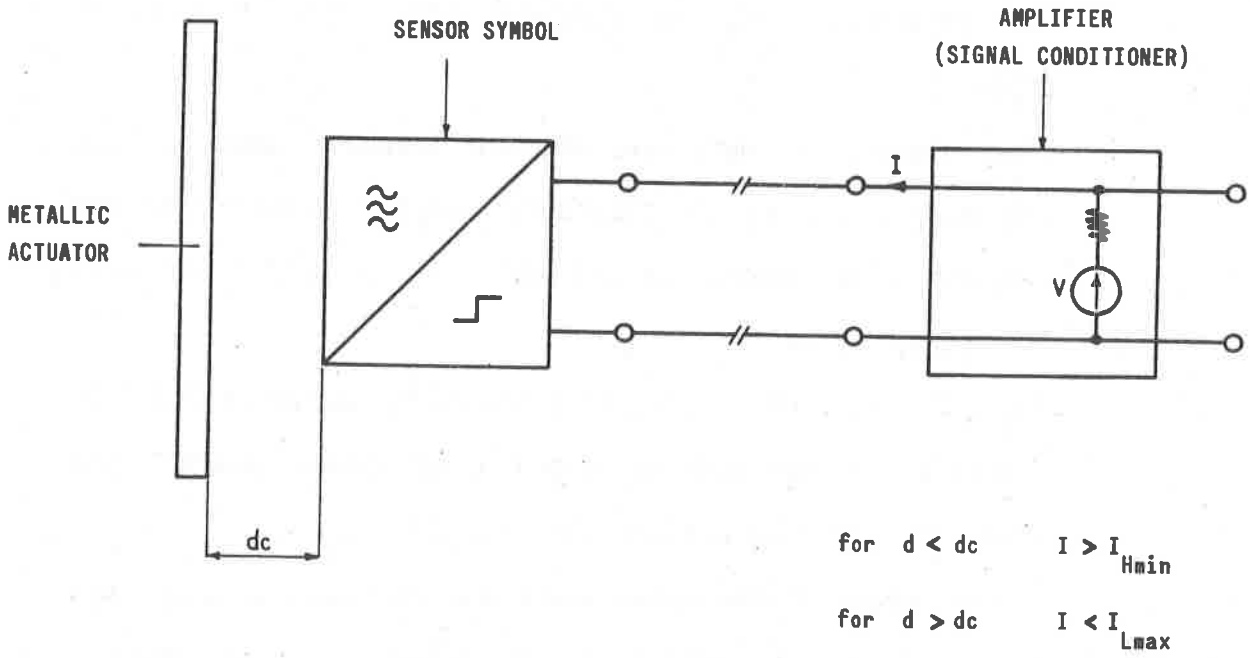


FIG. 1.3

1.1.2 Inductive proximity sensors with linear output

The inductive proximity sensors with linear output can generate a variable output voltage; this voltage variation is directly proportional (linear) to the distance actuator/sensor, within certain limits. This characteristic can be useful when carrying out very accurate positionings for detecting thicknesses, flexures, vibrations: more generally, it is used to convert distance into voltage, in electroconducting materials.

Fig. 1.4 shows the characteristic curve of this type of sensor.

The voltage-vs-distance relation is linear only between the two values d_m (minimum distance) and d_M (maximum distance).

The minimum distance d_m does not coincide with the null position.

The output voltage signal of the sensor is normally amplified and shifted so that the signal conditioner can generate a voltage proportional to the distance between actuator and sensor.

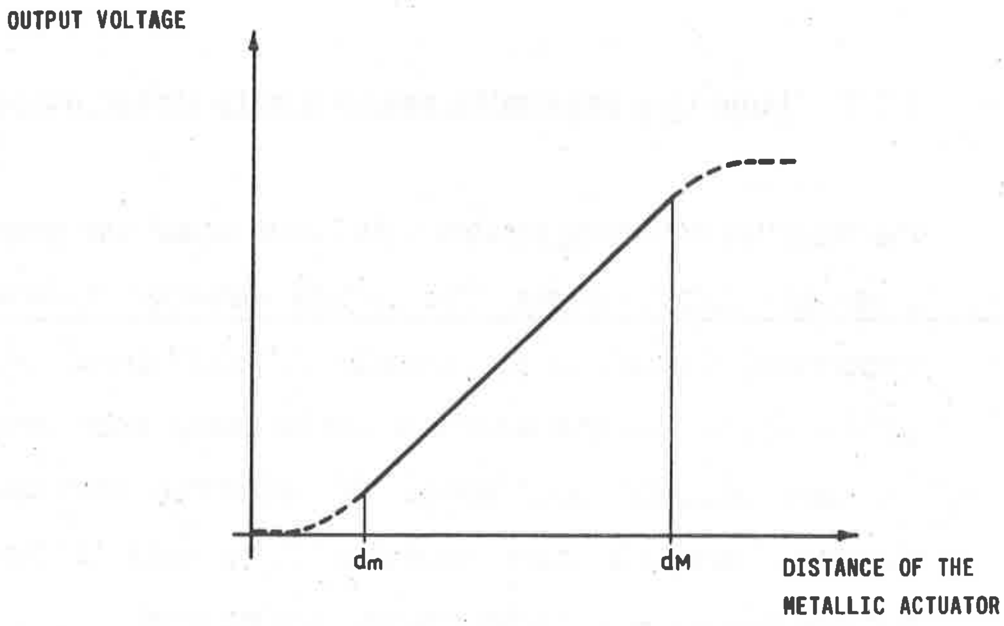

OUTPUT VOLTAGE
dm
dM
DISTANCE OF THE
METALLIC ACTUATOR

FIG. 1.4

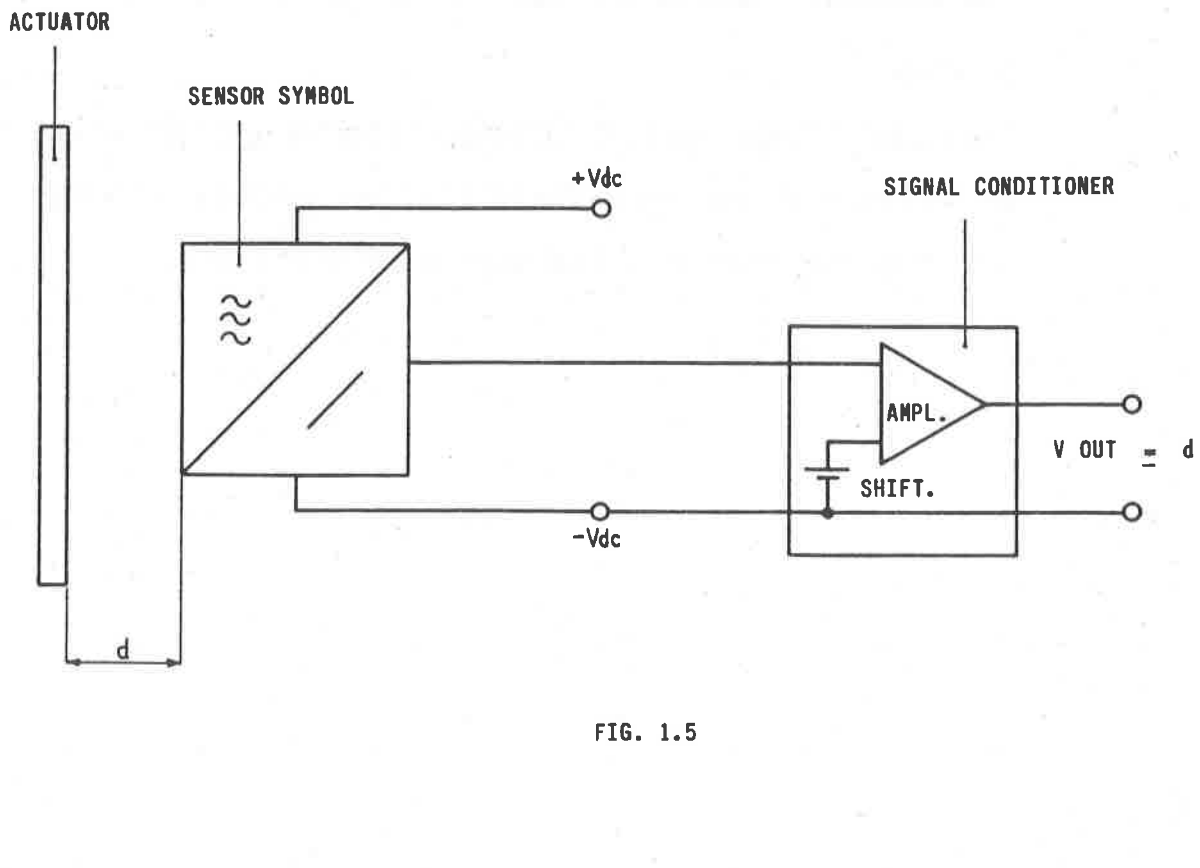

ACTUATOR
SENSOR SYMBOL
+Vdc
SIGNAL CONDITIONER
AMPL.
SHIFT.
V OUT = d
-Vdc
d

FIG. 1.5

1.1.3 Self-amplified inductive proximity sensors

The self-amplified inductive proximity sensors are different from those explained in the last paragraph only for the final built-in amplifier.

Fig. 1.6 shows the block diagram of a self-amplified inductive proximity sensor.

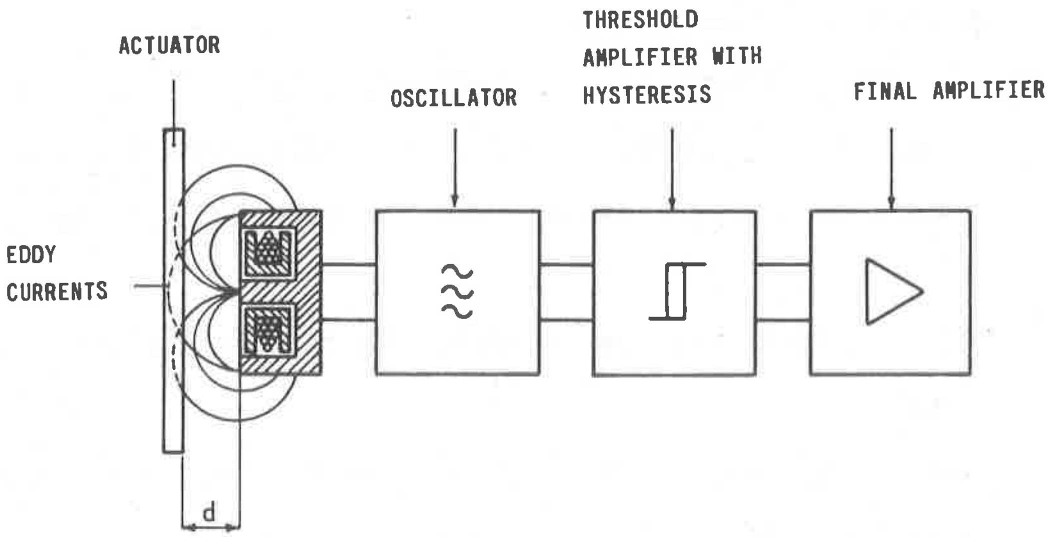


FIG. 1.6

Even in these sensors, the eddy currents induced within the metallic actuator provoke an energy loss in the oscillator, damping the signal amplitude. This damping of the oscillator amplitude is detected by a threshold amplifier with hysteresis which guarantees a net trigger; this amplifier controls a final amplifier for driving an external load. These sensors can be classified into direct-current inductive sensors and alternating-current inductive sensors, according to the type of final amplifier they include.

The former (d.c.) sensors can be supplied in partially shielded and totally shielded versions.

The totally shielded sensors guarantee higher stability. These models can be embedded into metal up to the support edge; when assembling in battery, respect the distances indicated in the fig. 1.7.

Fig. 1.8 shows how the partially shielded sensors must be mounted.

When some applications require a side-by-side installation, respect the indications shown in the fig. 1.9.

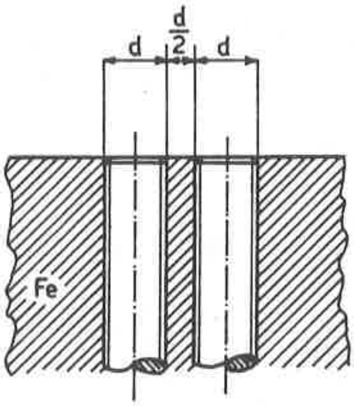


FIG. 1.7
TOTALLY SHIELDED SENSORS

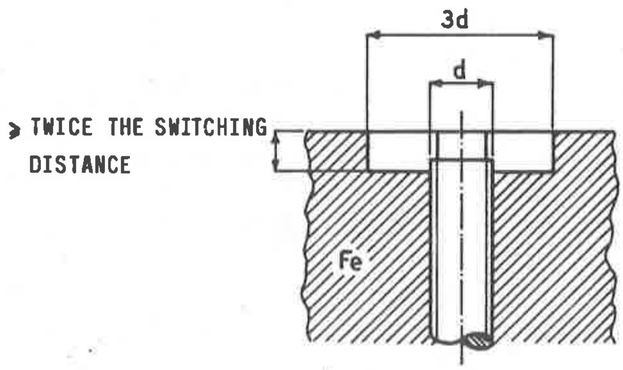


FIG. 1.8
PARTIALLY SHIELDED SENSOR

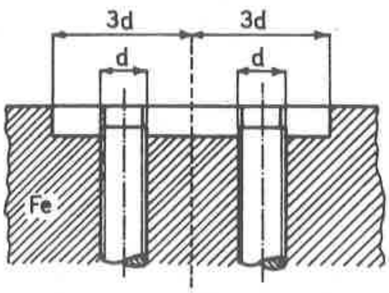


FIG. 1.9

PARTIALLY SHIELDED SENSORS

Generally, the final amplifier gives the following outputs:

- polarity: NPN - PNP
- output functions: normally closed, normally open, ambivalent or exchange.

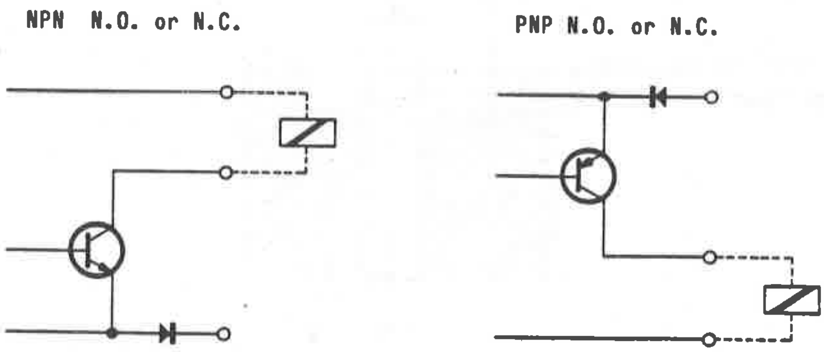


FIG. 1.10

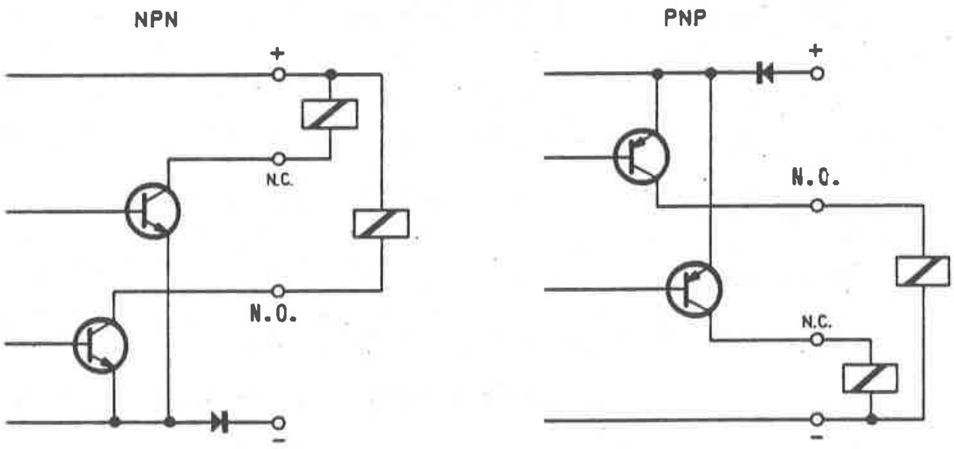


FIG. 1.11

The self-amplied a.c. inductive sensors use the same operation principle of the d.c. ones; consequently, the part concerning oscillator and trigger is the same.
When driving an a.c. load, the output actuator must be a SCR with its own driving circuit.

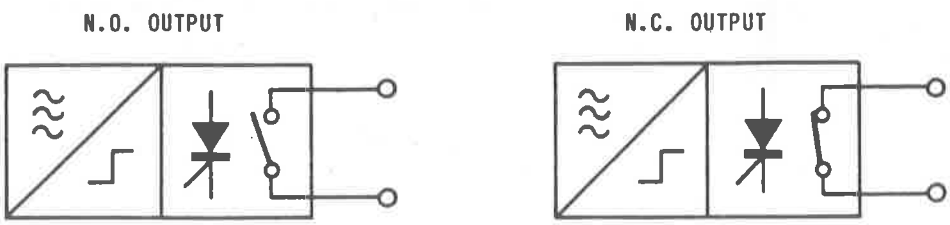


FIG. 1.12

1.2 Capacitive proximity sensors

The operation principle of the capacitive proximity sensors is based on the variation of stray capacitance generated between the sensor and the object to be detected. At a certain distance of this object from the sensitive surface of the sensor, a circuit starts oscillating: the beginning or stopping of this oscillation is perceived by a threshold detector which controls an amplifier for driving an external load.

Fig. 1.13 shows the block diagram of this device.

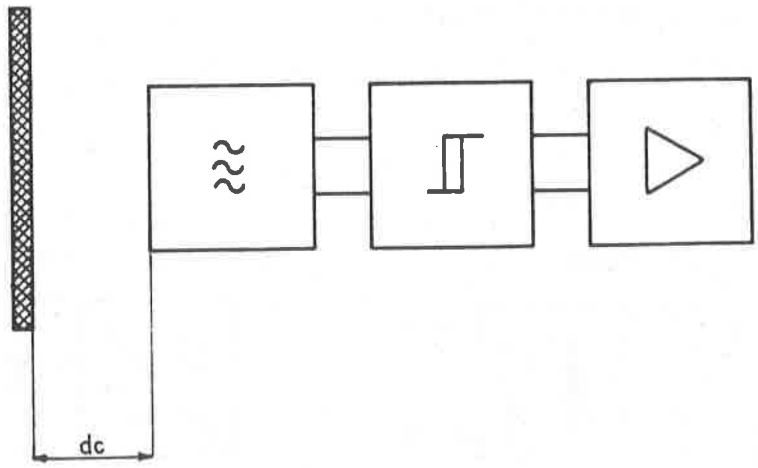


FIG. 1.13

Then it is clear that a capacitive proximity sensor can be used to detect metallic and non-metallic objects, as wood, liquids, plastic materials.

For instance, these sensors are typically used in the piece-counters, in the level checks of vessels, etc...

Even, these sensors can be classified into:

- direct-current capacitive proximity sensors;
- alternating-current capacitive proximity sensors,

according to the type of final amplifier they include.

The former (d.c.) sensors give the following types of outputs:

- polarity: NPN and PNP
- output function: normally closed, normally open, ambivalent or exchange.

In the a.c. sensors, the output actuator is a SCR with the relevant driving circuit.

The output can be N.C. (normally closed) or N.O. (normally open).

1.3 Magnetic proximity sensors

A typical magnetic (or reed) proximity sensor consists of contacts mounted on low-reluctance magnetic reeds (of ferronickel) enclosed in a glass bulb full of inert gas: these reeds are sensitive to the influence of magnetic fields.
These fields can be generated by permanent magnets or by coils crossed by current; the reeds have opposite polarities, due to the magnetic induction.
When the force of attraction overcomes the elastic strength of the reeds, these are bent to each other and make the electric contact (fig. 1.14).

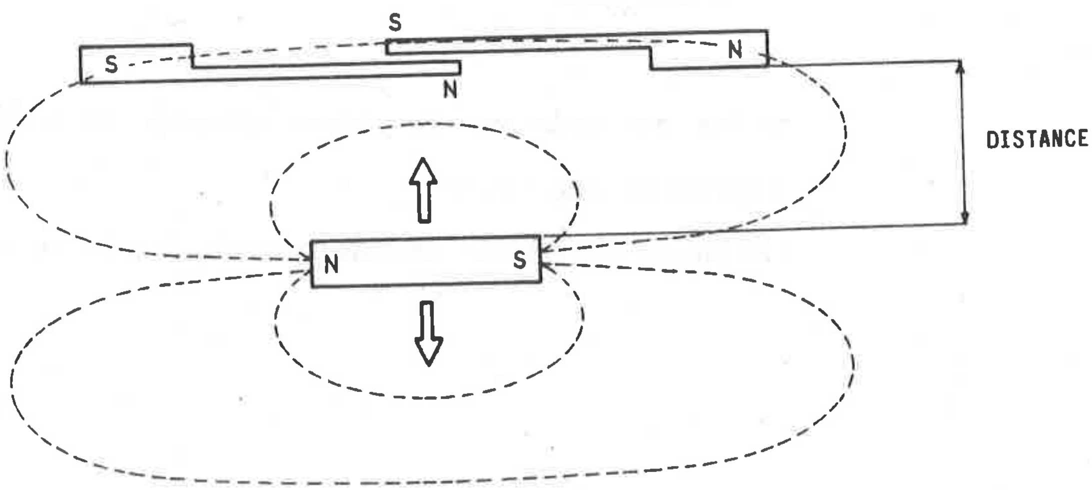


FIG. 1.14

The make of the contacts depends on the sensitivity of the reeds and on the magnet strength in the pull-in phase; whereas, removing the magnet, the contacts are opened again (drop-out). Generally, the contacting surfaces of the reeds are coated with precious metals (gold, rhodium, tungsten) which enable them to control circuits with low currents or high inductive loads. They offer several advantages, with respect to the traditional mechanically operated contacts, that is:

- the airtight enclosure in noble gas protects the contacts from dust, oxidation and corrosion;
- the operation of the contacts does not require complex and encumbering devices, because it depends on the influence of a magnetic field;
- high operating rates, up to 300 Hz for some types;
- absence of maintenance and very small overall dimensions.

Actually, the functions of the contacts are:

- **"normally open" function** (N.O.): the make contact is normally open when it is so far from the magnet that its influence is null; the contact closes when it is biased by the approaching magnet;

- **"normally closed" function** (N.C.): the back contact has been already closed through a magnet in contact with the glass bulb of the reeds; when the driving magnet (with opposite polarities) approaches, it nullifies this first magnetic field provoking the opening;
- **"exchange" function**: the N.O. and N.C. functions are carried out in a single glass bulb.

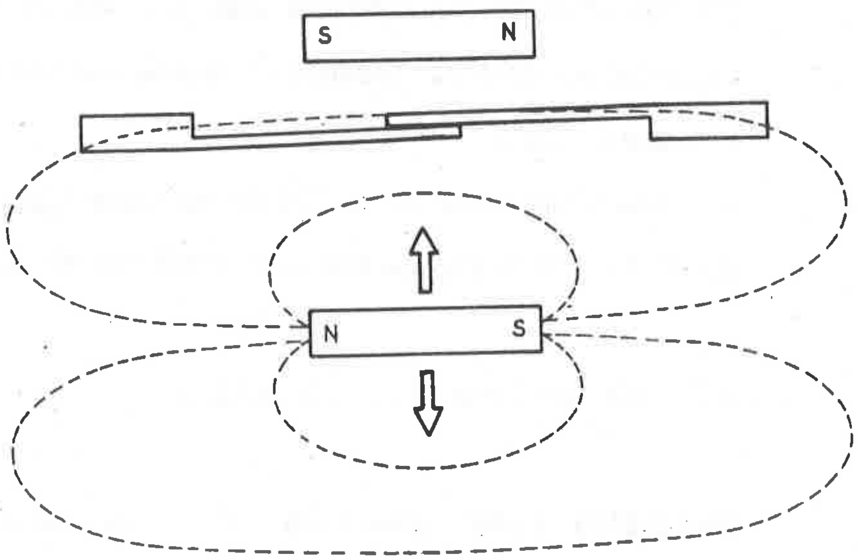


FIG. 1.15

1.4 Characteristics of the proximity sensors

The main characteristics of a proximity sensor are:

- **Nominal intervention distance**: it is the geometrical distance of the actuator from the detector, at the moment when the quick switching of the logic state occurs.
- **Differential stroke**: it is the distance between the driving point, as the actuator approaches, and the disconnection point, as the actuator goes away. Its value is calculated in % of the intervention distance.
- **Repeatability**: it is the difference of two any values of the intervention distance measured for 8 hours, at a temperature included between 15°C and 30°C and with a supply voltage within ±5% of the rated value.
- **Operating frequency**: this parameter is measured with the dynamical method shown in the fig. 1.16 (according to the standard CENELEC EN 50010), with the sensor in the position (a) or (b); S is the nominal intervention distance. The frequency is calculated through the formula:

$$f = \frac{1}{t_1 + t_2}$$

(refer to the fig. 1.17) when t_1 or t_2 reach 50 µs.

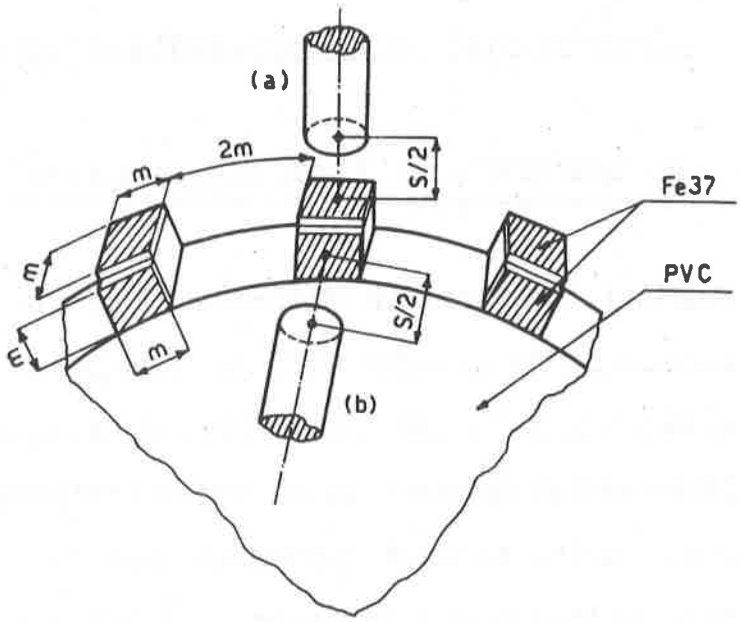


FIG. 1.16

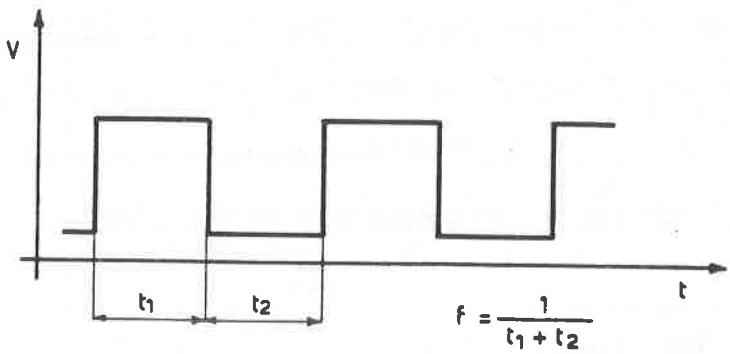


FIG. 1.17

- **Residual ripple**: it is the percent ratio between the residual a.c. (peak-to-peak) component (superimposed on the d.c. supply voltage) and the supply voltage.
- **Voltage drop**: it is the voltage drop measured across the sensor, with enabled output.
- **Residual current**: it is the load current, with non-enabled output.
- **Permanent current capacity**: it is the maximum current which the sensor can deliver in continuous operation.

1.5 Signal conditioners for proximity sensors

The self-amplified inductive sensors and the capacitive sensors are supplied with built-in signal conditioner. Relays or loads can directly be connected to these sensors. Take care in choosing the proper output configuration for the final amplifier.

In the non-amplified inductive sensors with two-level output, the signal conditioner consists of a very stable voltage generator connected in series to a resistance of known value.

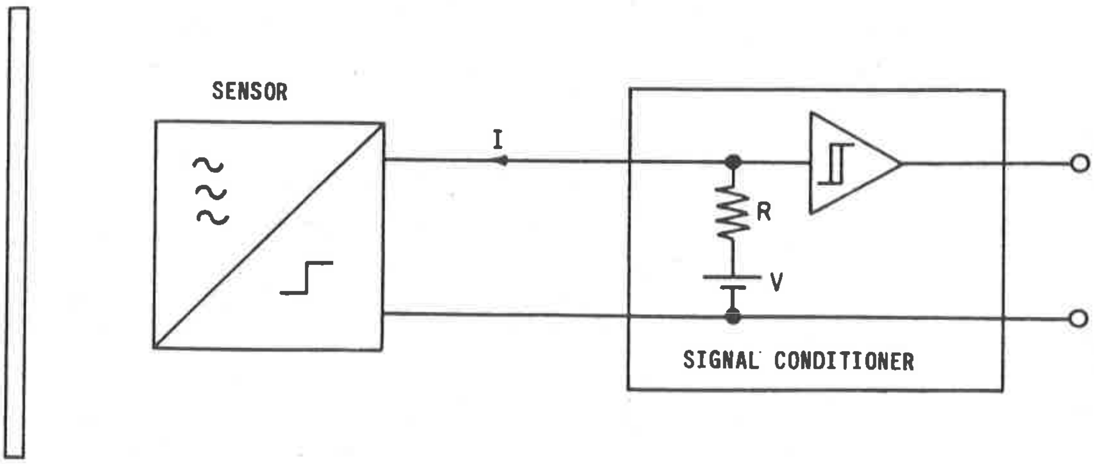


FIG. 1.18

When designing the conditioner, it is important to choose a proper value for **V** and **R**, so that the voltage across the sensor is included within the allowable range. This does not depend on the value of the current **I** crossing the sensor, but this current depends on the distance of the metallic actuator.
The voltage across **R** is sent to a comparator so that an ON-OFF voltage signal is generated at its output.
In the inductive proximity sensors with linear output, the voltage signal must be amplified and shifted to obtain an output (voltage) signal proportional to the distance between sensor and actuator.

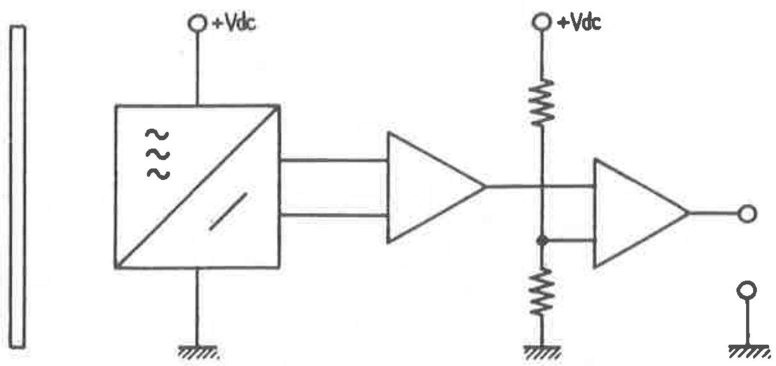
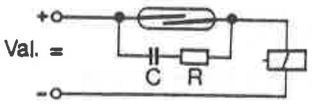


FIG. 1.19

The connection of the magnetic proximity sensors including reed relays requires some protections.

Fig. 1.20 illustrates the protections normally adopted in the industrial circuits.

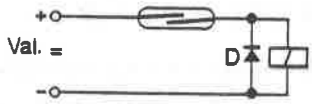
a) d.c. R-C PROTECTION



C = 0.47 to 1 µF 250 VL, versus the power absorbed by the load

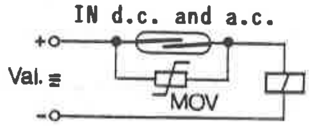
R = 68 Ohm 0.5 W, for Val = 24 V d.c.
R = 220 Ohm 0.5 W, for Val = 110 V d.c.

b) PROTECTION WITH DIODE IN d.c.



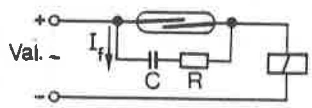
D = 1N 4006

c) PROTECTION WITH VARISTOR IN d.c. and a.c.



MOV: it must be chosen according to the supply voltage and to the power absorbed by the load

d) a.c. R.C. PROTECTION



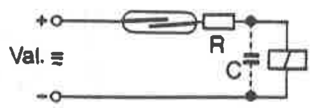
C (µF) ≃ 1 to 4 x holding current (A)

R (Ohm) ≃ R x Val; 0.5 W

Leakage current ≃ 0.1 to 0.15 x holding current

Cond. operat. V = 2 to 3 x Val

e) d.c. and a.c. R PROTECTION



C = cable capacitance

R = (Ohm) ≃ 2 x Val

FIG. 1.20

2. DESCRIPTION OF THE EQUIPMENT

This equipment is an educational system of proximity sensors: it consists of two main parts, that is, the panel including the signal conditioners and the device generating the linear displacement (TY 29), on which 3 proximity sensors of different type are mounted.

The following paragraphs examine the single components of the equipment.

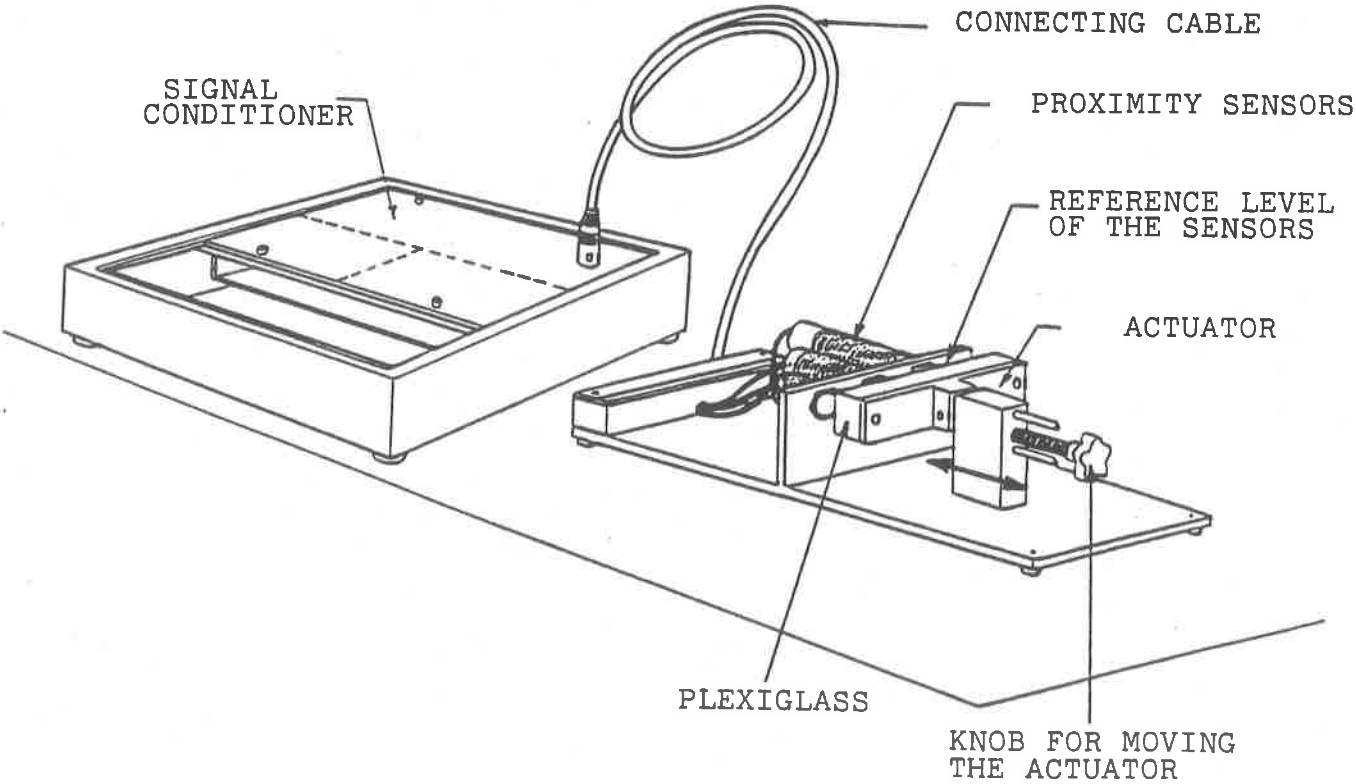


FIG. 2.1

2.1 Proximity sensors

In this equipment there are three types of proximity sensors, that is:

- inductive sensor with linear output
- inductive sensor with two-level output
- capacitive sensor with d.c. output.

2.1.1 Inductive sensor with linear output

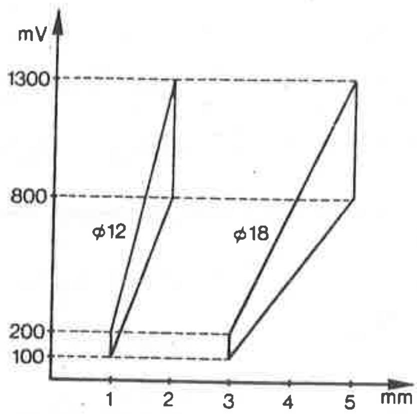
The (non amplified) inductive proximity sensor with linear output included in this equipment is manufactured by the company SAIET under the model code R-A2TM/XP: its characteristics are indicated in the "data sheets" supplied by the manufacturer.

These specifications include the general characteristics, the operating characteristics (supply voltage, output voltage, repeatability, etc...), the displacement-vs-output voltage curve, the connections and the mechanical dimensions.

The table (1) summarizes all these data.

General characteristics

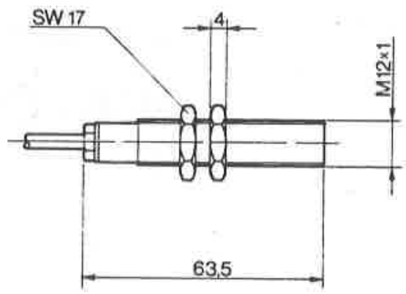
- threaded cylindrical shape
- metallic case
- impact strength according to the standard IEC 68.2.27
- vibration strength according to the standard IEC 68.2.26
- protection: IP 67
- temperature range: from -10°C to +60°C
- protection against reversions of polarity
- total shielding

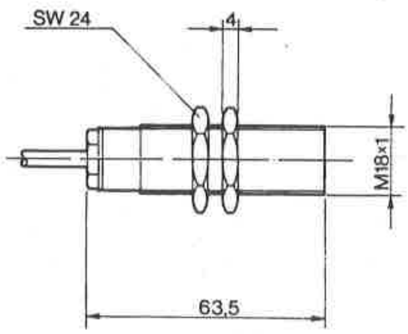


Operating characteristics

- supply voltage range (V): 10 to 30
- typical supply voltage (V): 24
- maximum residual ripple: 5%
- typical load resistance (kΩ): 10
- minimum load resistance (kΩ): 1
- no-load absorption (mA): ≤10
- output voltage at S_{min} (1) (mV): **900 to 1000**
- output voltage at S_{max} (1) (mV): **8000 to 9000**
- repeatability (2) (mm): ± 0.01
- average variation of the operating distance range with linear output

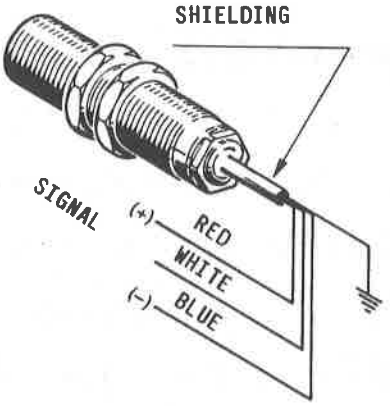
$$\frac{\Delta (S_{max} - S_{min})}{S_{max} - S_{min}} \cdot 100 \qquad \pm 10\%$$





(1) S_{min} and S_{max} represent the minimum and maximum values of the actuator-sensor distance within which the output is linear (frontal driving)

(2) At constant temperature.



INDUCTIVE SENSORS WITH LINEAR OUTPUT

MODEL CODE	MAXIMUM SIZE AND DIAMETER	DISTANCE RANGE WITH LINEAR OUTPUT (mm)	TYPICAL RAMP OF THE OUTPUT VOLTAGE	SHIELDING	OUTPUT VOLTAGE (mV)		DRIVING TORQUE MAX (Kg m)
					S_{min}	S_{max}	
R-A1TM/XP	M12x1	1 to 2	0.7	Total	100 to 200	800 to 1300	1.0
R-A2TM/XP ①	M18x1	1 to 4	7	Total	900 to 1000	8000 to 9000	3.0

2.1.2 Inductive sensor with two-level output.

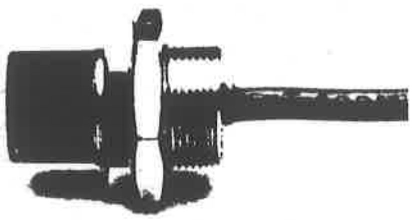
The (non amplified) inductive proximity sensor with two-level output included in this equipment is manufactured by the company SAIET with the model code T-A2TM: its characteristics are illustrated in the following data sheets.

These data include the general characteristics (supply voltage, electric response in the worst conditions, repeatability accuracy, maximum switching frequency, etc...), the connections and the types of shieldings.

The table (2) includes all these data.

General characteristics

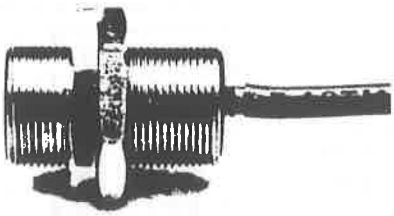
- case: metallic, of cylindrical threaded shape, or plastic, of parallelepiped shape
- partially or totally shielded versions (limited only to the cylindrical sensors)
- unlimited number of operations
- impact strength according to the standard IEC 68.2.27
- vibration strength according to the standard IEC 68.2.6
- protection: IP67 (cylindrical); IP65 (parallelepiped)
- temperature range: -25°C to +70°C



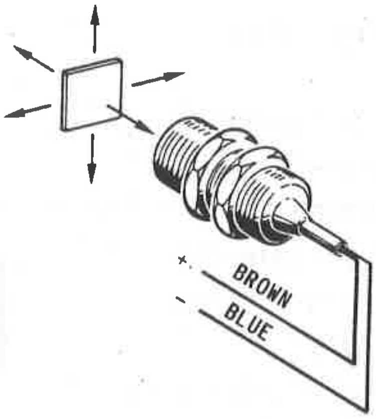
PARTIALLY SHIELDED SENSOR

Operating characteristics

- tolerance on the frontal intervention distance (S) ±10%
- differential stroke in % of S: ≤10%
- repeatibility accuracy (mm): ≤0.02
- supply voltage (V)
  - cylindrical 6 to 12
  - parallelepiped 6.5 to 9.5
- electric response in the worst conditions provided by the standards (mA)
  - current with actuator ≤1.1
  - current without actuator ≤2.2
- max. switching frequency (Hz) (it depends on the chosen model): 100 to 3000



TOTALLY SHIELDED SENSOR



NON-AMPLIFIED INDUCTIVE SENSORS WITH TWO-LEVEL OUTPUT

Sensors in threaded metallic cylindrical case

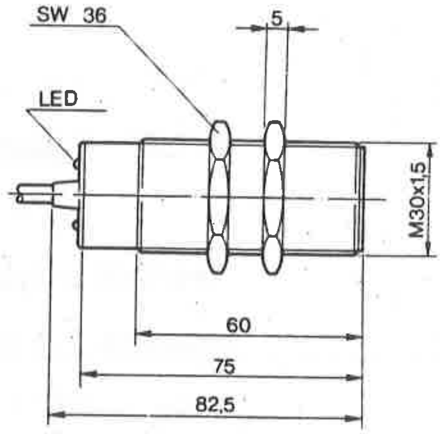
MODEL CODE	MAXIMUM SIZE AND DIAMETER				INTERVENTION DISTANCE (mm)							MAX. SWITCHING FREQUENCY (Hz)						SHIELDING		REPEATABILITY ACCURACY (mm)		DRIVING TORQUE MAX (Kg m)
	M8x1	M12x1	M18x1	M30x1.5	1	2	4	5	8	10	15	3000	2000	1000	600	300	150	Partial	Total	≤ 0.02	≤ 0.05	
T-A0TM	●				●							●							●	●		0.8
T-A0PM	●					●							●					●		●		0.8
T-A1TM		●				●							●						●	●		1.0
T-A1PM		●					●							●				●		●		1.0
② T-A2TM			●					●							●				●	●		3.0
T-A2PM			●						●							●		●		●		3.0
T-A3TM				●						●						●			●		●	4.0
T-A3PM				●							●						●	●			●	4.0

2.1.3 Capacitive sensor

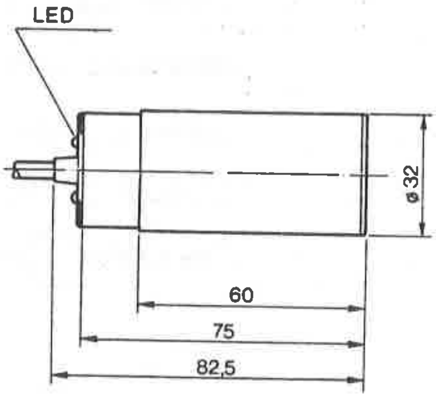
The (self-amplified) d.c. capacitive proximity sensor used in this equipment is manufactured by the Company SAIET with the model code C-A2TMU/3 AN: its characteristics are indicated in the following data sheets.

These specifications include the general characteristics, the operating characteristics (supply voltage, maximum output current, repeatability, differential stroke, maximum switching frequency), the type of output and the relevant connections.

The table (3) includes all these data.



THREADED DIAMETER: 30 mm
(OVERALL DIMENSIONS)



SMOOTH DIAMETER: 32 mm
(OVERALL DIMENSIONS)

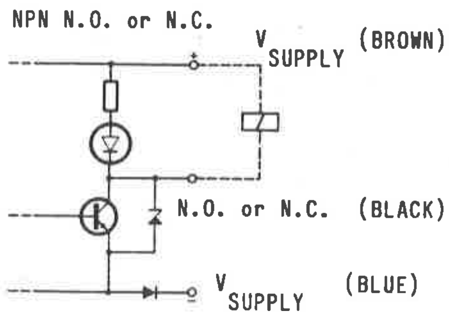
General characteristics

- threaded and non-threaded smooth cylindrical (for the type with the diameter of 32 mm) shapes.
- metallic case
- adjustable driving distance
- unlimited number of operations
- impact strength according to the standard IEC 68.2.27
- vibration strength according to the standard IEC 68.2.6
- protection: IP 65
- operating temperature range: from -20°C to +60°C
- protection against polarity reversions
- protection against the electrical noises due to induction
- protection against the load short circuit
- display of the output logic state
- output connecting cable, 2 m long; inner leads with section of 0.15 sq.mm

(*) In this case, the nominal intervention distance is the maximum intervention distance at which all the operating characteristics of the sensor are guaranteed.

Operating characteristics

- tolerance on the frontal intervention distance (Sn) ±15%
- differential stroke in % of Sn: ≤15
- max. output current (mA) 150
- repeatability in % of Sn (at a temp. of 15°C to 30°C): ≤10
- supply voltage (V) 10 to 30 V
- max. residual ripple 10%
- voltage drop at the max. delivered current (V) ≤3
- max. no-load absorption: 15 mA
- max. switching frequency: 100 Hz



MODEL CODE	MAXIMUM SIZE AND DIAMETER			NOMINAL INTERV. DISTANCE (mm)			OUTPUT FUNCTION			OUTPUT POLARITY		MAX. SWITCHING FREQ. (Hz)		DRIVING TORQUE (Kgm)	
	M18x1	M30x1.5	Smooth diam. 32	8	15	20	Open (N.O.)	Closed (N.C.)	Exchange (S)	NPN	PNP	100	200	3	4
③ C-A2TMU/3AN	●			●			●			●			●	●	
C-A2TMU/3CN	●			●				●		●			●	●	
C-A2TMU/3AP	●			●			●				●		●	●	
C-A2TMU/3CP	●			●				●			●		●	●	
C-A3TMU/3SN		●			●				●	●		●			●
C-A3TMU/3SP		●			●				●		●	●			●
C-B3TMU/3SN			●			●			●	●		●			●
C-B3TMU/3SP			●			●			●		●	●			●

2.2 Signal conditioners

The configuration of the signal conditioners of the proximity sensors depends on the used sensor. Fig. 2.2 shows the interface circuits of the three sensors of the module G29: these diagrams are also printed on the equipment.

Fig. 2.3 shows the electric diagrams. The equipment can operate when power-supplied with regulated voltages of ±12 V, 5 V.

The unit TY 29 is connected to the panel through a cable (terminal TY29).

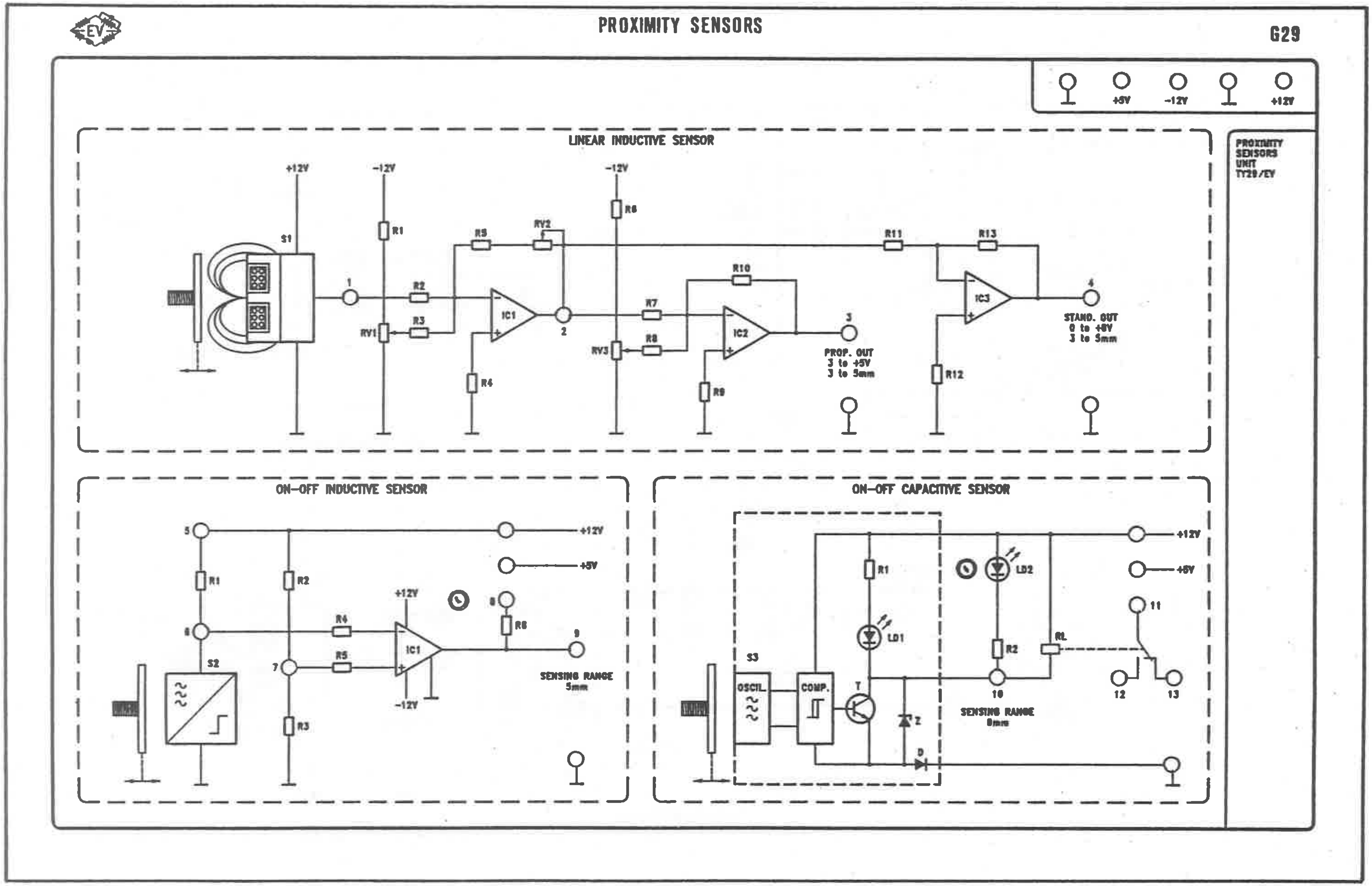

PROXIMITY SENSORS
G29
+5V
-12V
+12V
PROXIMITY SENSORS UNIT TY29/EV
LINEAR INDUCTIVE SENSOR
S1
R1
R2
R3
RV1
R4
R5
RV2
IC1
R6
R7
R8
RV3
R9
R10
IC2
R11
R12
R13
IC3
PROP. OUT
3 to +5V
3 to 5mm
STAND. OUT
0 to +8V
3 to 5mm
ON-OFF INDUCTIVE SENSOR
S2
SENSING RANGE
5mm
ON-OFF CAPACITIVE SENSOR
S3
OSCIL.
COMP.
LD1
LD2
RL
SENSING RANGE
8mm

FIG. 2.2

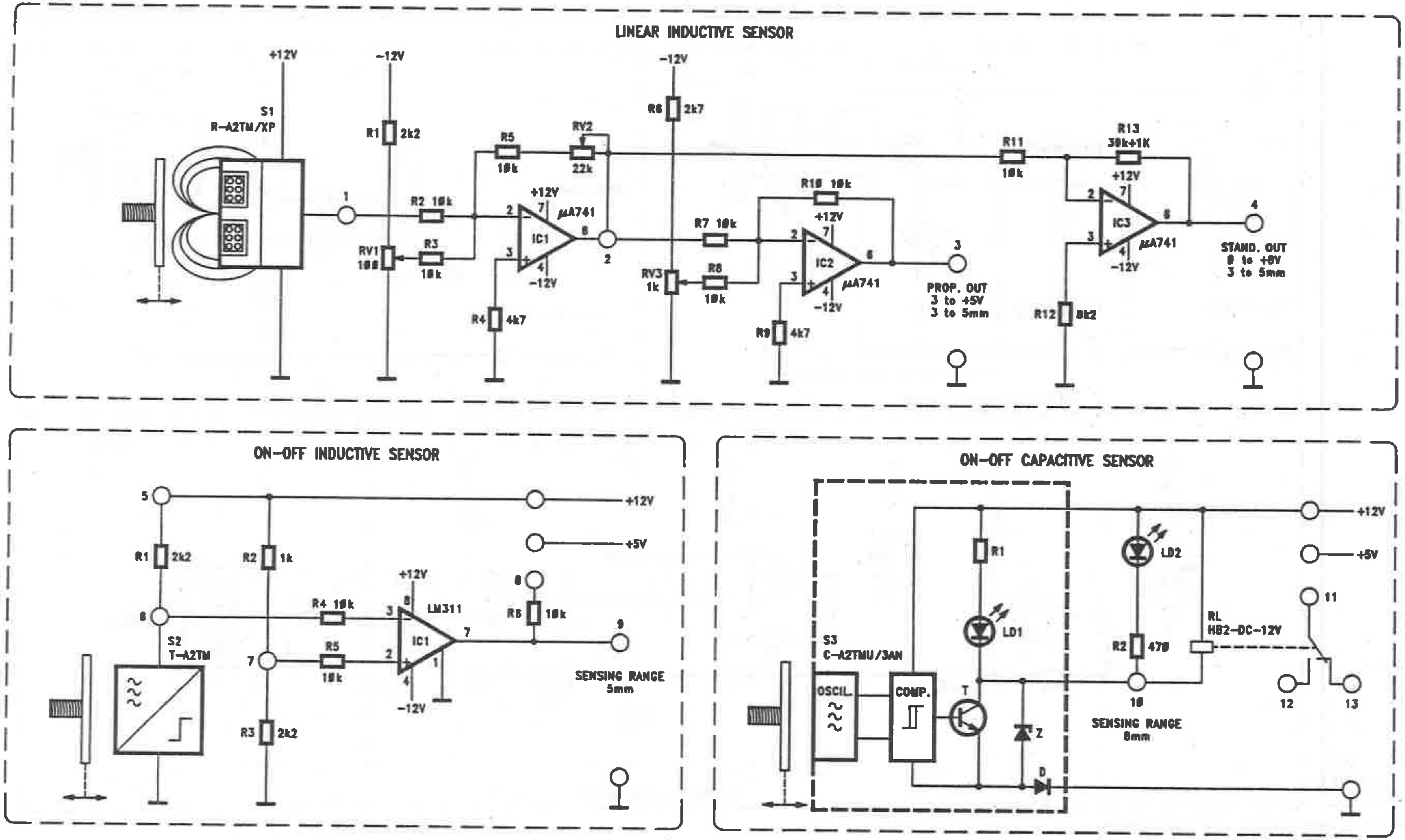

LINEAR INDUCTIVE SENSOR
+12V
-12V
S1
R-A2TM/XP
R1 2k2
RV1 100
R2 10k
R3 10k
R4 4k7
R5 10k
RV2 22k
IC1
µA741
R6 2k7
RV3 1k
R7 10k
R8 10k
R9 4k7
R10 10k
IC2
µA741
PROP. OUT
3 to +5V
3 to 5mm
R11 10k
R12 8k2
R13 39k+1K
IC3
µA741
STAND. OUT
0 to +5V
3 to 5mm
ON-OFF INDUCTIVE SENSOR
R1 2k2
R2 1k
R3 2k2
R4 10k
R5 10k
R6 10k
S2
T-A2TM
IC1
LM311
+12V
+5V
-12V
SENSING RANGE
5mm
ON-OFF CAPACITIVE SENSOR
S3
C-A2TMU/3AN
OSCIL.
COMP.
R1
LD1
T
Z
D
LD2
R2 470
RL
HB2-DC-12V
+12V
+5V
SENSING RANGE
8mm

FIG. 2.3

2.2.1 Conditioner for linear inductive sensor

This circuit, indicated as INDUCTIVE PROXIMITY SENSOR - LINEAR OUTPUT on the panel, includes three operational amplifiers.
The first one (IC_1) shifts the signal coming out from the sensor, to zero, then it amplifies the shifted signal.
The second amplifier (IC_2) carries out a voltage shift of the amplified signal so that the proportional output voltage can correspond to the actual distance transduced by the sensor.
The operational amplifier IC_3 standardizes the voltage output (0 to 8V) in correspondance with the linear transducing range of the sensor (1 to 4 mm).

2.2.2 Conditioner for inductive sensor with two-level output.

The circuit, indicated as INDUCTIVE PROXIMITY SENSOR - TWO LEVEL OUTPUT on the educational panel, consists of a comparator (LM 311).

When the voltage on the terminal 6 is lower than that on the terminal 7, the output (terminal 9) is equal to 1.

It is possible to connect the (TTL-compatible) +5 V or the (CMOS-compatible) +12 V output.

Examining this circuit, remember that the current crossing the sensor with the actuator, is very weak. In this case, there is the maximum voltage on the terminal 6 and the output is equal to zero.

2.2.3 Connection to the self-amplified capacitive sensor

The capacitive sensor included in the equipment is self-amplified. Therefore, when using it, no interface system is necessary.

The circuit is indicated as CAPACITIVE PROXIMITY SENSOR - TWO LEVEL OUTPUT in the educational panel and explains how to connect a relay to the output of the self-amplified sensor. The output stage of the amplifier is indicated in the diagram.

Note that the LED LD1 is mounted on the same sensor: it turns off with the actuator out of range, it turns on with the actuator within the range.

A screw on the rear of the sensor allows an adjustment (of some mm) of the intervention distance.

The common contact of the relay (terminal 9) can be connected to +12 V or to +5 V so that a CMOS or TTL compatible signal can be available at the terminals 12, 13.

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

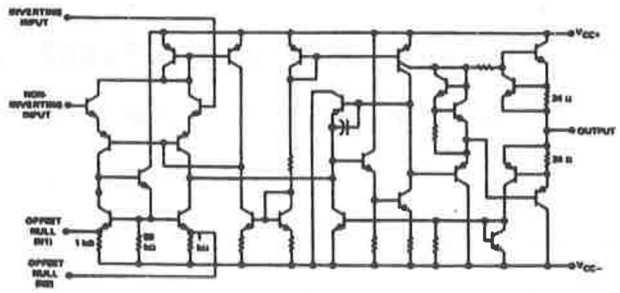
description

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



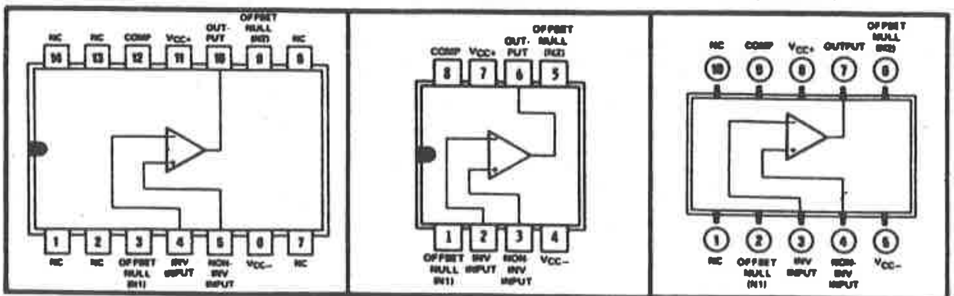
Resistor values shown are nominal

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

LINEAR INTEGRATED CIRCUITS

TYPES uA741M, uA741C GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

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

- Short-Circuit Protection
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description

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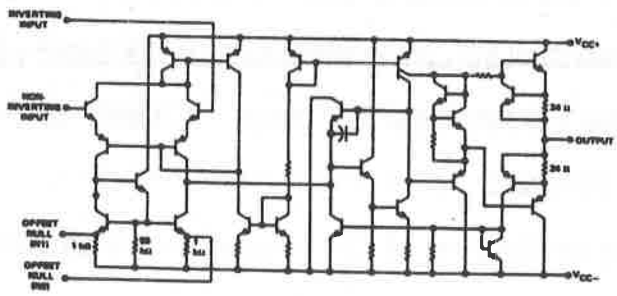
The uA741M is characterized for operation over the full military temperature range of $-55°C$ to $125°C$; the uA741C is characterized for operation from $0°C$ to $70°C$.

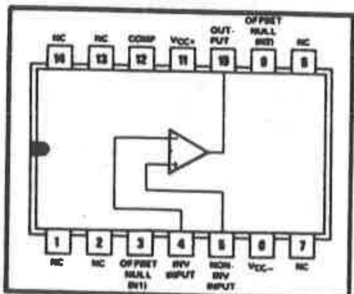
schematic



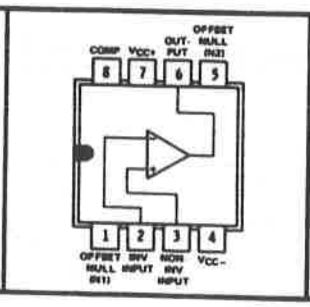
Resistor values shown are nominal

terminal assignments

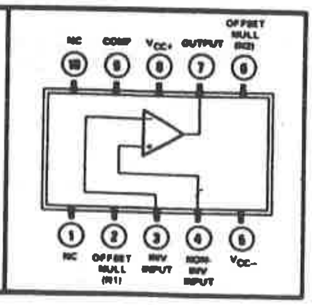
J OR N DUAL-IN-LINE OR W FLAT PACKAGE (TOP VIEW)



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 MIN	uA741M TYP	uA741M MAX	uA741C MIN	uA741C TYP	uA741C MAX	UNIT
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 ≥ 10 kΩ	Full range	24			24			
		R_L = 2 kΩ	25°C	20	26		20	26		
		R_L ≥ 2 kΩ	Full range	20			20			
A_{VD}	Large-signal differential voltage amplification	R_L ≥ 2 kΩ, V_O = ±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	

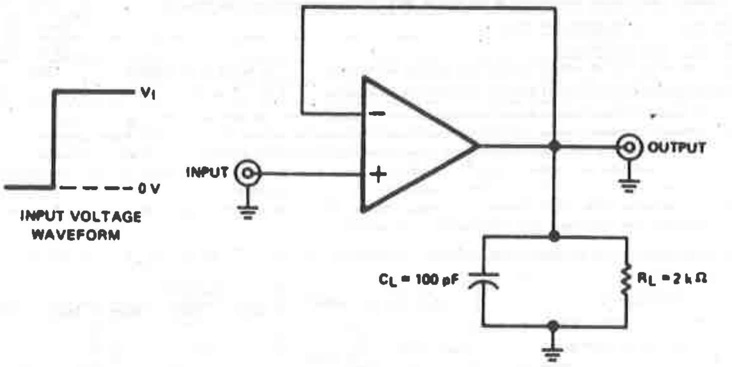
† All characteristics are specified under open-loop operation. Full range for uA741M is −55°C to 125°C and for uA741C is 0°C to 70°C.

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,		0.3			0.3		μs
	Overshoot factor	C_L = 100 pF, See Figure 1		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

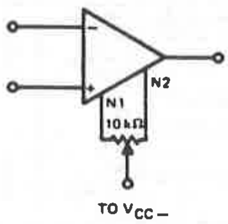


FIGURE 2–INPUT OFFSET VOLTAGE NULL CIRCUIT

TYPES uA741M, uA741C
GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

TYPICAL CHARACTERISTICS

INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

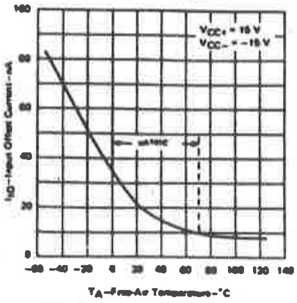
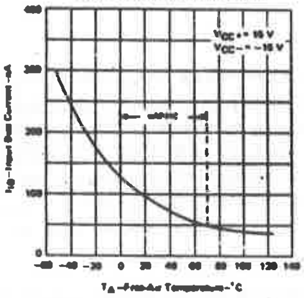


FIGURE 3

INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE



FIGUER 4

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
LOAD RESISTANCE

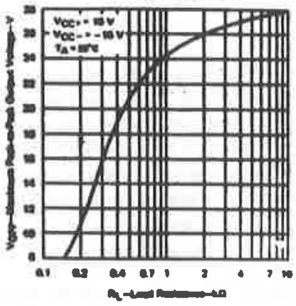


FIGURE 5

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
FREQUENCY

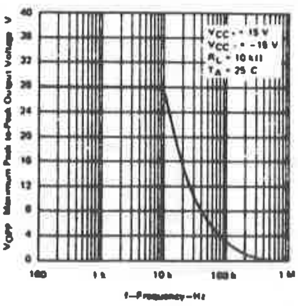


FIGURE 6

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

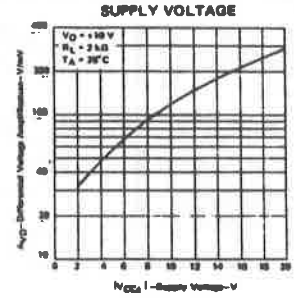


FIGURE 7

OPEN-LOOP LARGE-SIGNAL
DIFFERENTIAL
VOLTAGE AMPLIFICATION
vs
FREQUENCY

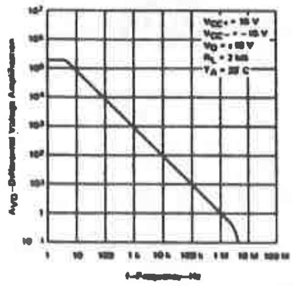


FIGURE 8

COMMON-MODE REJECTION RATIO
vs
FREQUENCY

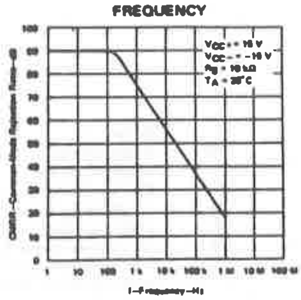


FIGURE 9

OUTPUT VOLTAGE
vs
ELAPSED TIME

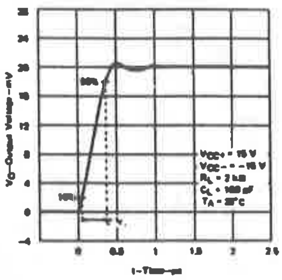


FIGURE 10

VOLTAGE-FOLLOWER
LARGE-SIGNAL PULSE RESPONSE

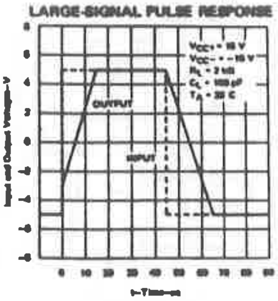


FIGURE 11

LINEAR INTEGRATED CIRCUITS

TYPES LM111, LM311 DIFFERENTIAL COMPARATORS WITH STROBE

BULLETIN NO. DL-S 7611797, SEPTEMBER 1973–REVISED JULY 1976

FORMERLY SN52111, SN72311

- Fast Response Times
- Strobe Capability
- Designed to be Interchangeable with National Semiconductor LM111 and LM311
- Maximum Input Bias Current . . . 300 nA
- Maximum Input Offset Current . . . 70 nA
- Can Operate From Single 5-V Supply

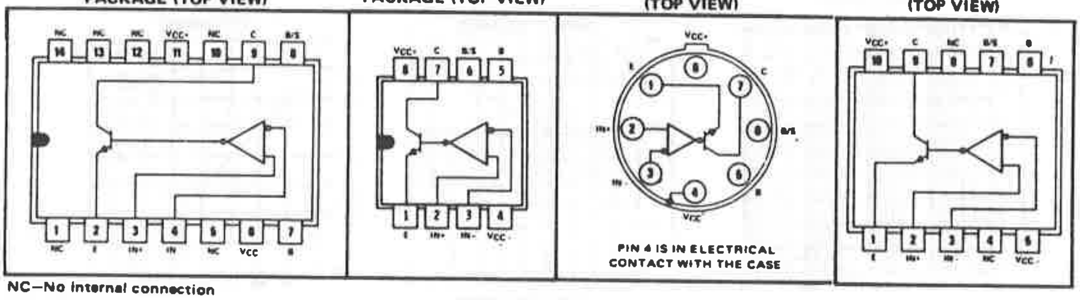
description

The LM111 and LM311 are single high-speed voltage comparators. These devices are designed to operate from a wide range of power supply voltage, including ±15-volt supplies for operational amplifiers and 5-volt supplies for logic systems. The output levels are compatible with most DTL, TTL, and MOS circuits. These comparators are capable of driving lamps or relays and switching voltages up to 50 volts at 50 milliamperes. All inputs and outputs can be isolated from system ground. The outputs can drive loads referenced to ground, V_{CC+}, or V_{CC-}. Offset balancing and strobe capability are available and the outputs can be wire-OR connected. If the probe input is low, the output will be in the off state regardless of the differential input. Although slower than the TL506 and TL514, these devices are not as sensitive to spurious oscillations.

The LM111 is characterized for operation over the full military temperature range of −55°C to 125°C; the LM311 is characterized for operation from 0°C to 70°C.

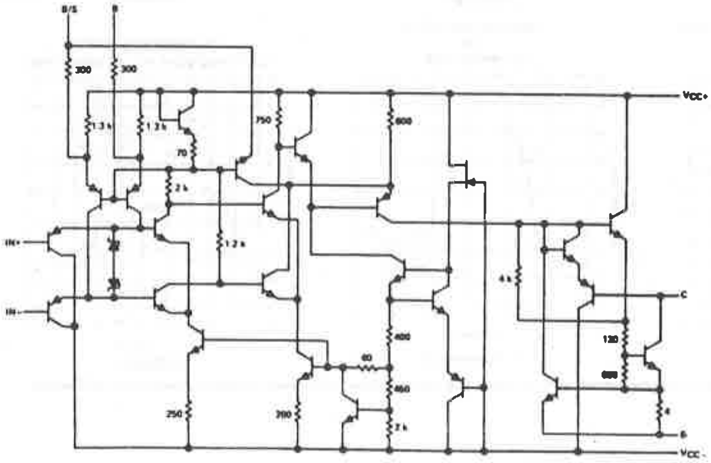
terminal assignments

J OR N DUAL-IN-LINE PACKAGE (TOP VIEW) — JG OR P DUAL-IN-LINE PACKAGE (TOP VIEW) — L PLUG-IN PACKAGE (TOP VIEW) — U FLAT PACKAGE (TOP VIEW)



NC—No internal connection

schematic



B	Balance
B/S	Balance/Strobe
C	Collector Output
E	Emitter Output
IN+	Noninverting Input
IN−	Inverting Input
NC	No Internal Connection
V_{CC+}	Positive Supply Voltage
V_{CC-}	Negative Supply Voltage

Resistor values shown are nominal and in ohms.

TYPES LM111 LM311
DIFFERENTIAL COMPARATORS WITH STROBE

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

		LM111	LM311	UNIT
Supply voltage, V_{CC+} (see Note 1)		18	18	V
Supply voltage, V_{CC-} (see Note 1)		−18	−18	V
Differential input voltage (see Note 2)		±30	±30	V
Input voltage (either input, see Notes 1 and 3)		±15	±15	V
Voltage from emitter output to V_{CC-}		30	30	V
Voltage from collector output to V_{CC-}		50	40	V
Duration of output short-circuit (see Note 4)		10	10	s
Continuous total 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 from case for 10 seconds	J, JG, L, or U package	300	300	°C
Lead temperature 1/16 inch from case for 60 seconds	N or P package	260	260	°C

NOTES: 1. All voltage values, unless otherwise noted, are with respect to the zero-reference level (ground) of the supply voltages where the zero-reference level is at the midpoint between V_{CC+} and V_{CC-}. If the zero-reference level of the system is not the midpoint of the supply voltages, all voltage values must be adjusted accordingly.
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 V, 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, Section 2.

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

PARAMETER		TEST CONDITIONS†			LM111 MIN	LM111 TYP‡	LM111 MAX	LM311 MIN	LM311 TYP‡	LM311 MAX	UNIT
V_{IO}	Input offset voltage	$R_S \le 50$ kΩ,	See Note 6	25°C		0.7	3		2	7.5	mV
				Full range			4			10	
I_{IO}	Input offset current	See Note 6		25°C		4	10		6	50	nA
				Full range			20			70	
I_{IB}	Input bias current	$V_O = 1$ V to 14 V		25°C		75	100		100	250	nA
				Full range			150			300	
$I_{IL(S)}$	Low-level strobe current	$V_{(strobe)} = 0.3$ V,	$V_{ID} \le -10$ mV	25°C		−3			−3		mA
V_{ICR}	Common-mode input voltage range			Full range		±14			±14		V
A_{VD}	Large-signal differential voltage amplification	$V_O = 5$ V to 35 V,	$R_L = 1$ kΩ	25°C		200			200		V/mV
I_{OH}	High-level (collector) output current	$V_{ID} = 5$ mV,	$V_{OH} = 35$ V	25°C		0.2	10				nA
				Full range			0.5				µA
		$V_{ID} = 10$ mV	$V_{OH} = 35$ V	25°C					0.2	50	nA
V_{OL}	Low-level (collector-to-emitter) output voltage	$I_{OL} = 50$ mA	$V_{ID} = -5$ mV	25°C		0.75	1.5				V
			$V_{ID} = -10$ mV	25°C					0.75	1.5	
		$V_{CC+} = 4.5$ V, $V_{CC-} = 0$ V, $I_{OL} = 8$ mA	$V_{ID} = -6$ mV	Full range		0.23	0.4				
			$V_{ID} = -10$ mV	Full range					0.23	0.4	
I_{CC+}	Supply current from V_{CC+}, output low	$V_{ID} = -10$ mV,	No load	25°C		5.1	6		5.1	7.5	mA
I_{CC-}	Supply current from V_{CC-}, output high	$V_{ID} = 10$ mV,	No load	25°C		−4.1	−5		−4.1	−5	mA

†Unless otherwise noted, all characteristics are measured with the balance and balance/strobe terminals open and the emitter output grounded. Full range for LM111 is −55°C to 125°C and for LM311 is 0°C to 70°C.
‡All typical values are at $T_A = 25$°C.
NOTE 6: The offset voltages and offset currents given are the maximum values required to drive the collector output up to 14 V or down to 1 V with a pull-up resistor of 7.5 kΩ to V_{CC+}. Thus these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.

switching characteristics, V_{CC+} = 15 V, V_{CC-} = −15 V, T_A = 25°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time, low-to-high-level output	R_C = 500 Ω to 5 V, C_L = 5 pF, See Note 7		115		ns
Response time, high-to-low-level output			165		ns

NOTE 7: The response time specified is for a 100-mV input step with 5-mV overdrive. The typical values are specified for a nominal threshold voltage of 1.4 V.

TYPICAL CHARACTERISTICS

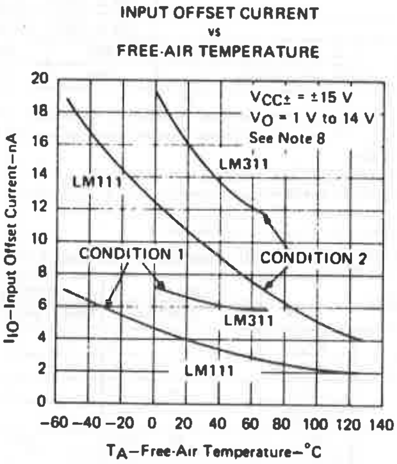


FIGURE 1

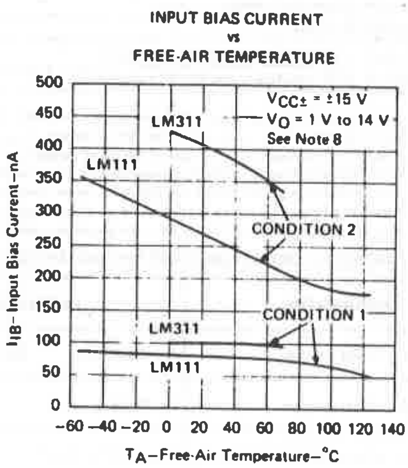


FIGURE 2

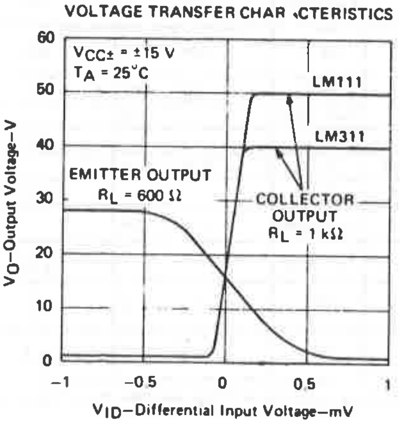
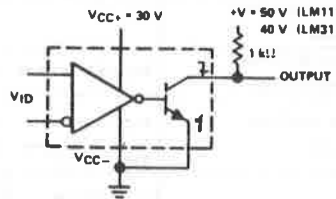
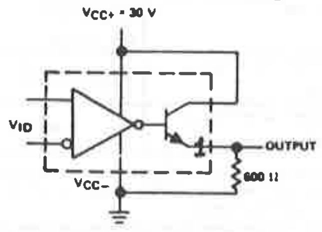


FIGURE 3



COLLECTOR OUTPUT TRANSFER CHARACTERISTIC TEST CIRCUIT FOR FIGURE 3



EMITTER OUTPUT TRANSFER CHARACTERISTIC TEST CIRCUIT FOR FIGURE 3

NOTE 8: Condition 1 is with the balance and balance/strobe terminals open. Condition 2 is with the balance and balance/strobe terminals connected to V_{CC+}.

TYPES LM111, LM311
DIFFERENTIAL COMPARATORS WITH STROBE

TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR VARIOUS INPUT OVERDRIVES

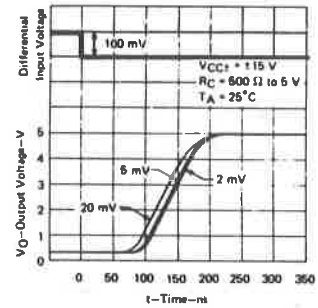
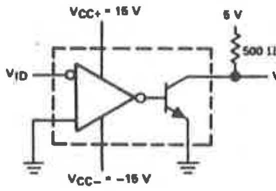


FIGURE 4



TEST CIRCUIT FOR FIGURES 4 AND 5

OUTPUT RESPONSE FOR VARIOUS INPUT OVERDRIVES

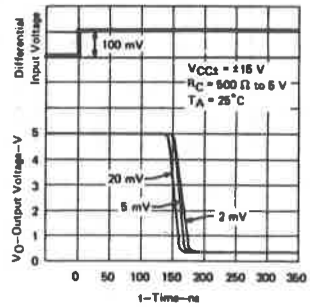


FIGURE 5

OUTPUT RESPONSE FOR VARIOUS INPUT OVERDRIVES

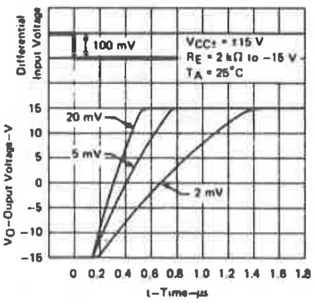
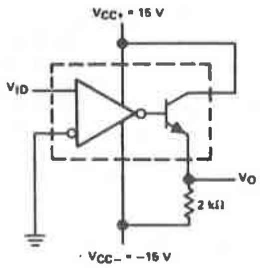


FIGURE 6



TEST CIRCUIT FOR FIGURES 6 AND 7

OUTPUT RESPONSE FOR VARIOUS INPUT OVERDRIVES

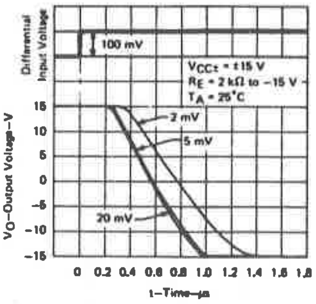


FIGURE 7

OUTPUT CURRENT and DISSIPATION vs OUTPUT VOLTAGE

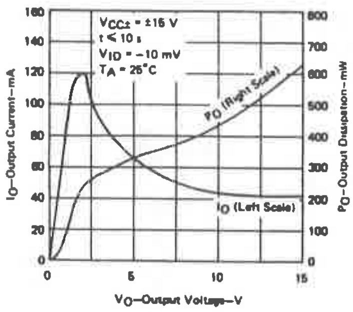


FIGURE 8

SUPPLY CURRENT FROM VCC+ vs SUPPLY VOLTAGE VCC+

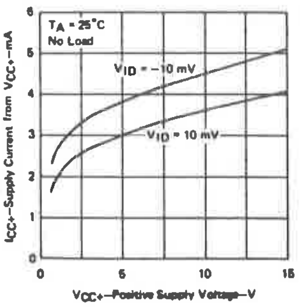


FIGURE 9

SUPPLY CURRENT FROM VCC– vs SUPPLY VOLTAGE VCC–

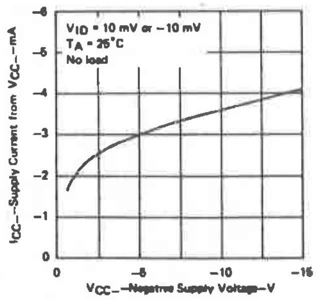


FIGURE 10

TYPICAL APPLICATION DATA

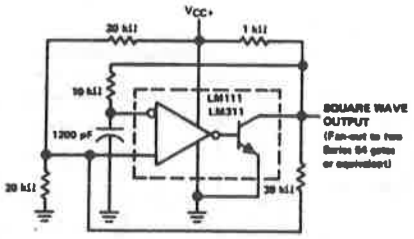


FIGURE 11—100-kHz FREE-RUNNING MULTIVIBRATOR

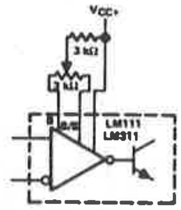


FIGURE 12 OFFSET BALANCING

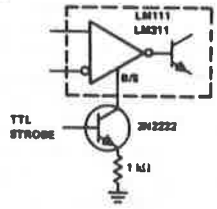


FIGURE 13—STROBING

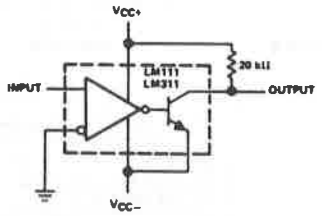
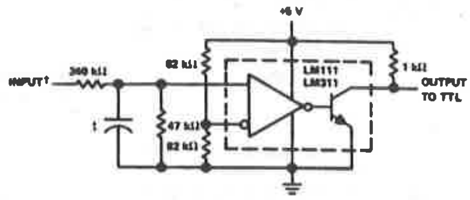


FIGURE 14—ZERO-CROSSING DETECTOR



†Resistor values shown are for a 0-to-30-V logic swing and a 15-V threshold.
‡May be added to control speed and reduce susceptibility to noise spikes.

FIGURE 15—TTL INTERFACE WITH HIGH-LEVEL LOGIC

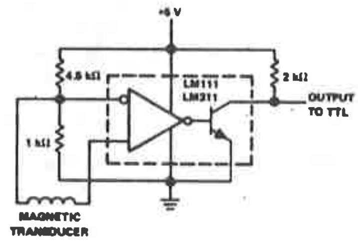


FIGURE 16—DETECTOR FOR MAGNETIC TRANSDUCER

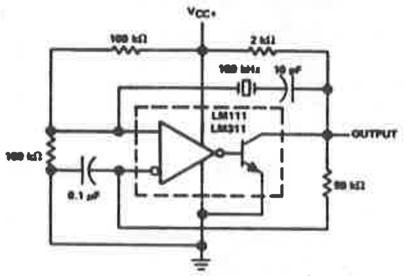


FIGURE 17—100-kHz CRYSTAL OSCILLATOR

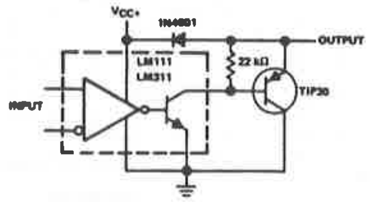
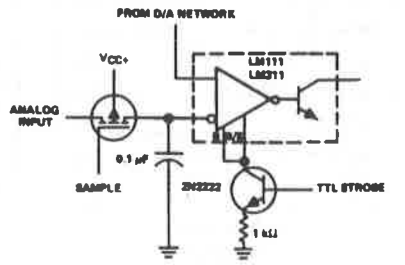


FIGURE 18—COMPARATOR AND SOLENOID DRIVER



Typical input current is 50 pA with inputs strobed off.

FIGURE 19—STROBING BOTH INPUT AND OUTPUT STAGES SIMULTANEOUSLY

TYPES LM111, LM311
DIFFERENTIAL COMPARATORS WITH STROBE

TYPICAL APPLICATION DATA

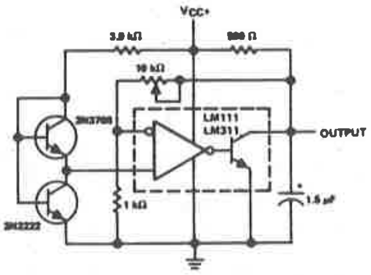


FIGURE 20—LOW-VOLTAGE ADJUSTABLE REFERENCE SUPPLY

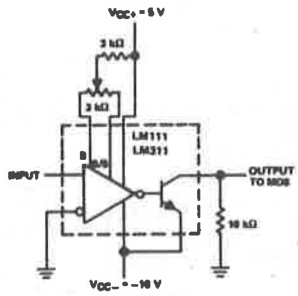
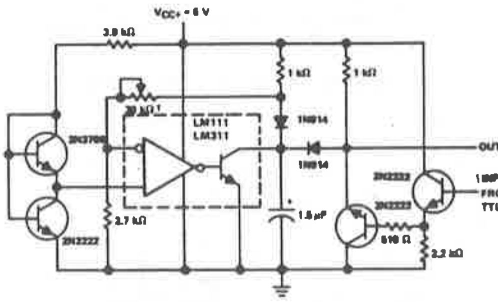


FIGURE 21— ZERO-CROSSING DETECTOR DRIVING MOS LOGIC



†Adjust to set clamp level.

FIGURE 22—PRECISION SQUARER

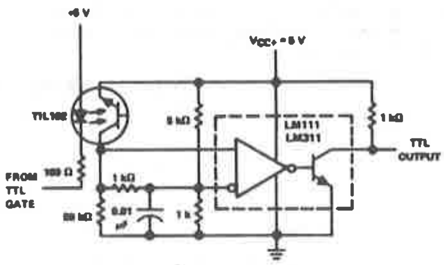


FIGURE 23—DIGITAL TRANSMISSION ISOLATOR

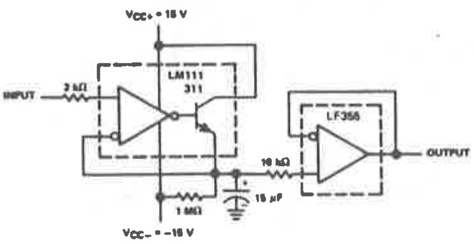


FIGURE 24—POSITIVE-PEAK DETECTOR

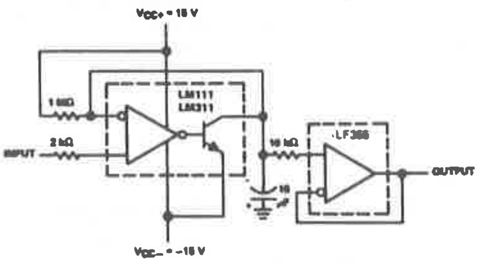
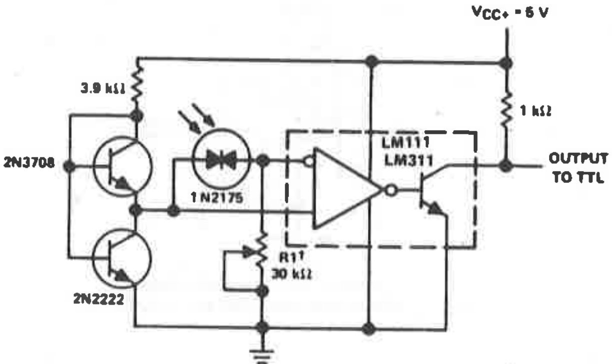


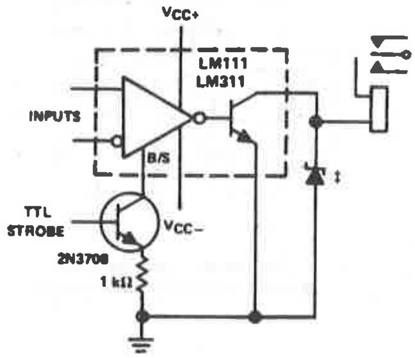
FIGURE 25— NEGATIVE-PEAK DETECTOR

TYPICAL APPLICATION DATA



† R1 sets the comparision level. At comparision, the photodiode has less than 5 mV across it, decreasing dark current by an order of magnitude.

FIGURE 26—PRECISION PHOTODIODE COMPARATOR



‡ Transient voltage and inductive kickback protection.

FIGURE 27—RELAY DRIVER WITH STROBE

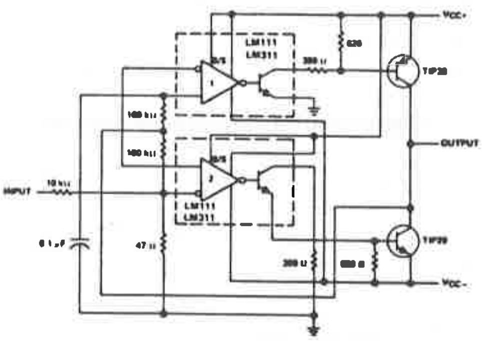


FIGURE 28—SWITCHING POWER AMPLIFIER

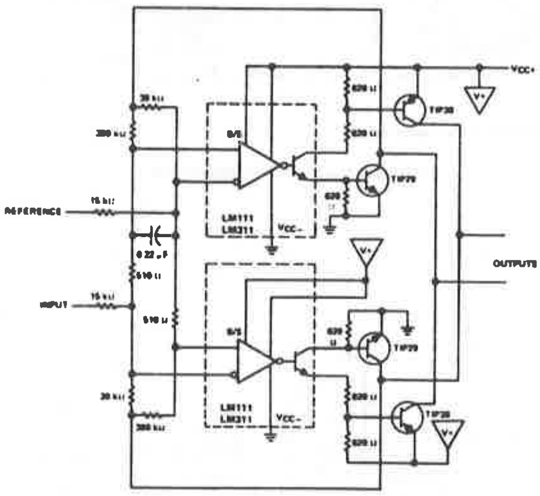


FIGURE 29—SWITCHING POWER AMPLIFIERS

2.3 Device for generating the actuator displacement and measuring its distance from the sensor

Obviously, for an exhaustive examination of the proximity sensors, it is necessary to have a device for moving the actuator and measuring its distance from the sensor.

This function is carried out by the unit TY29.

This device allows to change (considerably) the distance of the actuator from the sensor and also to obtain its (standard) measure with a gage.

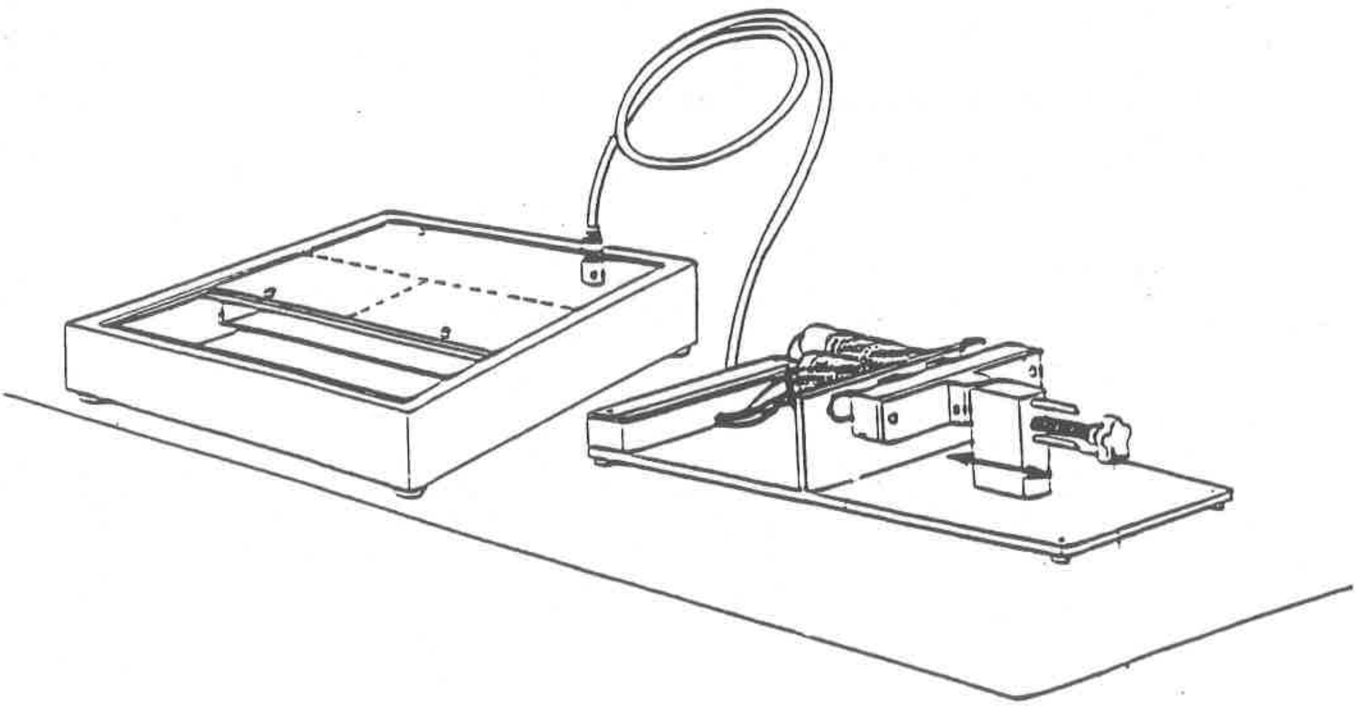


FIG. 2.4

3. EXERCISES

The characteristics and the operation of the proximity sensors and of the signal conditioners can better be understood through some exercises.

Note that the intervention distance is measured with a 1/20 gage.

The following exercises can be carried out with these instruments:

- digital voltmeter (3 digits and 1/2 - e.g.: our digital multimeter -);
- regulated power supply: ±12 Vd.c., +5 Vd.c.
- gage (1/10 or 1/20).

INDUCTIVE PROXIMITY SENSOR (LINEAR OUTPUT)

3.1 Calibration of the signal conditoner

Exercise object:

to calibrate the signal conditioner until an output voltage of 3 V corresponds to a distance of 1 mm and an output voltage of +5 V corresponds to a distance of 4 mm.

Necessary instrument:

- digital voltmeter (3 digits and 1/2).

Operating mode:

- Connect the terminals ±12 V, 0 V, +5 V of the panel to a regulated power supply.
- Connect the panel to the unit TY29 through the proper cable.
- Place the actuator 1 mm far from the sensor S1, measure the exact distance with the gage.
- Adjust RV1 until a voltage of 0 V can be read on the digital voltmeter, at the terminal 2.
- Check that there is 0 V also at the standard output.
- Adjust RV3 to obtain 1 V at the proportional output.

- Place the actuator 4 mm far from the sensor S1, measure the exact distance with the gage.
- Adjust RV2 until a voltage of - 3 V can be obtained at the terminal 2.
- Check that there is a value of +8 V at the standard output and +4 V at the proportional output.

3.2 "Distance-vs-voltage (sensor)" characteristic

Exercise object:

to determine the curve corresponding to the distance range (actuator/sensor) versus the output voltage of the sensor (terminal 1).

Necessary instrument:

- digital voltmeter (3 digits and 1/2).

Operating mode:

- Calibrate the conditioner as explained in the exercise 3.1
- Insert the voltmeter between the terminal 1 and the ground.
- Vary the distance of the actuator through the proper knob (starting from a distance of 1 mm) by steps of 0.5 mm; then measure the corresponding actual distance with the gage reading the value of the output voltage on the digital voltmeter.
- Write the resulting data on the table 3.1.

N	L [mm]	Vout [mV]

TABLE 3.1

Fig. 3.1 shows the characteristic curve of the sensor: the values of the distance (mm) are indicated on the axis of abscissas, whereas the values of the output voltage (mV) of the sensor S1 are indicated on the axis of ordinates.

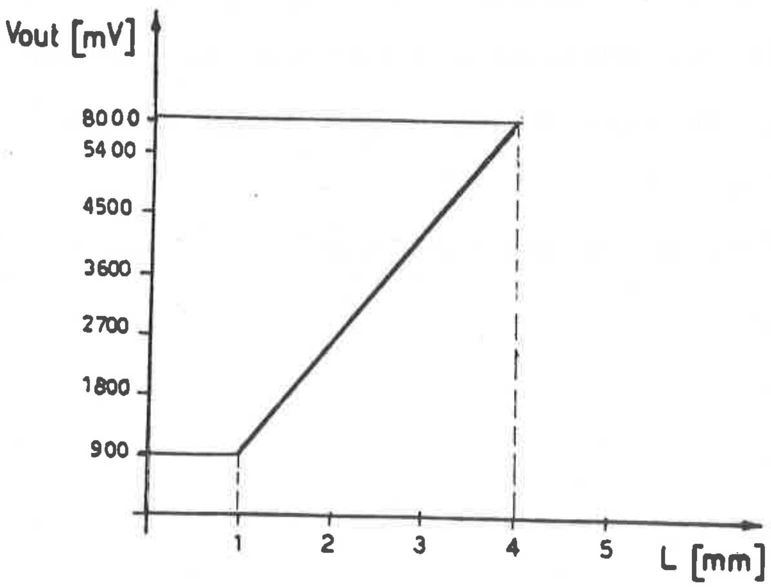


FIG. 3.1

3.3 "Distance-vs-voltage (sensor + conditioner)" characteristic

Exercise object:

to determine the curve corresponding to the distance range (actuator/sensor) versus the voltage measured at the proportional output of the conditioner (terminal 3).

Necessary instruments:

- digital voltmeter (3 digits and 1/2)
- gage.

Operating mode:

- Carry out the same operations of the exercise 3.2 changing the scale of the output voltage (from mV to V).

  Using the resulting data, it is possible to plot the characteristic curve of the sensor+conditioner.

3.4 Best fit straight line of the sensor

Exercise object:

to plot the best fit straight line of the sensor, that is, the ideal straight line which best represents the actuator displacement versus the output voltage of the sensor.

Necessary instruments:

- digital voltmeter (3 digits and 1/2)
- gage

Operating mode:

- Calibrate the conditioner as explained in the exercise 3.1.
- Insert the digital voltmeter between the terminal 1 and the ground.
- Move the actuator starting from a distance of 4 mm., by steps of 0.5 mm.; then measure the corresponding actual distance with the gage reading the output voltage on the digital voltmeter.

The resulting data must be written on the table 3.2.

N	L [mm]	Vout [mV]

TABLE 3.2

Fig. 3.2 shows a graph obtained indicating the values of the displacement (mm.) on the axis of abscissas and the values of the voltage measured on the central terminal of the potentiometric transducer, on the axis of ordinates.

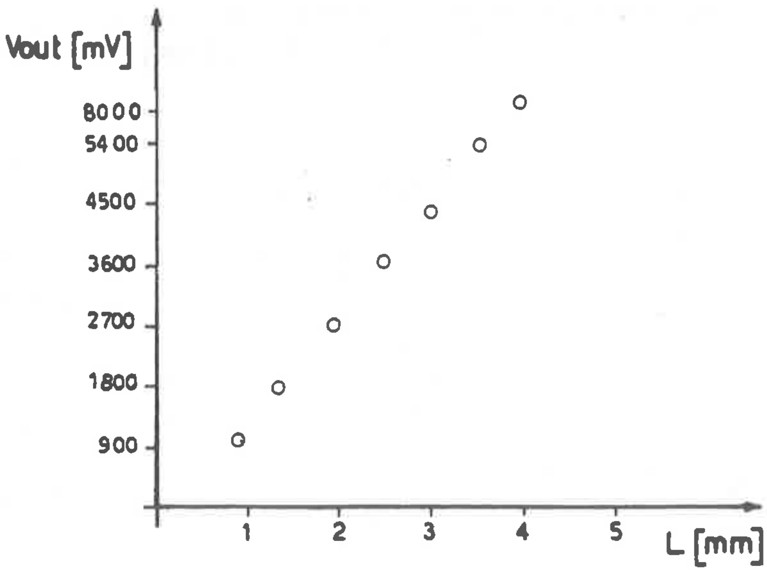


FIG. 3.2

Joining the points of this graph (fig. 3.2) it is possible to plot the best fit straight line of the sensor (fig. 3.3).

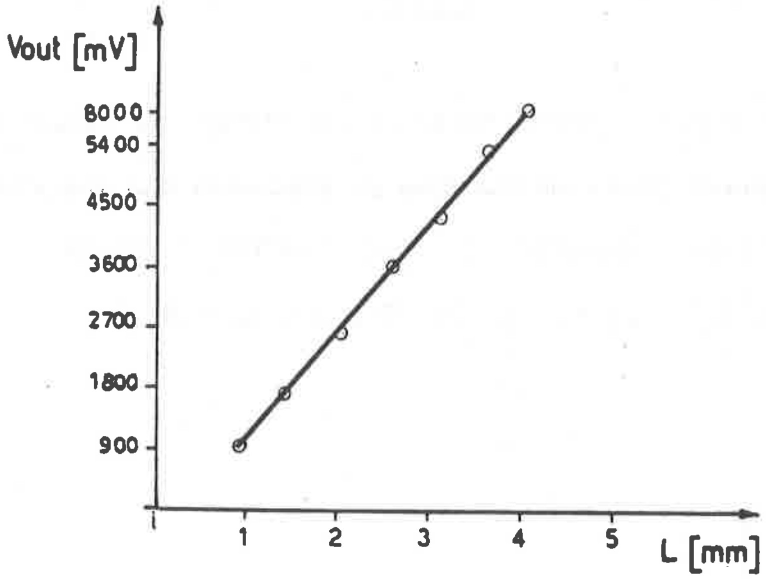


FIG. 3.3

3.5 Linearity of the sensor-conditioner

Exercise object:

to determine the value of linearity of the system sensor-conditioner.

Necessary instrument:

- digital voltmeter (3 digits and 1/2).

Operating mode:

- Calibrate the conditioner as explained in the exercise 3.1.
- Plot the best fit straight line of the sensor as indicated in the exercise 3.4.(fig. 3.4).

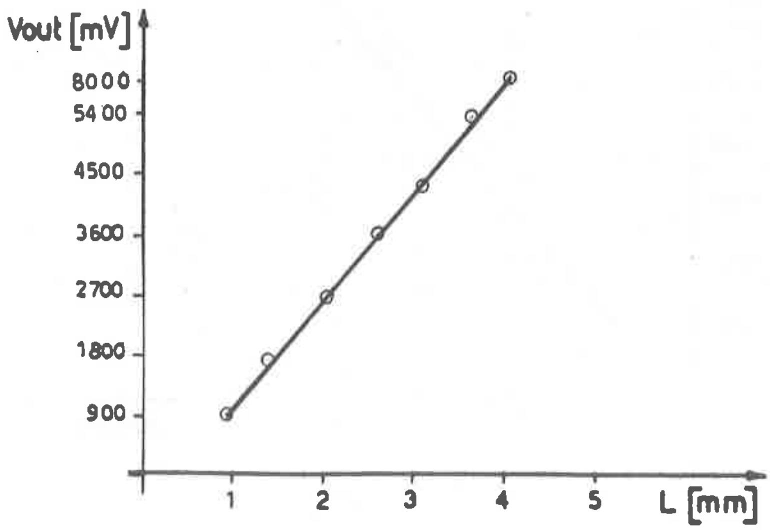


FIG. 3.4

Then plot two other lines, parallel and equidistant to the best fit straight line, so that they can include all the measuring points of the diagram.

Plot a line parallel to the axis of ordinates and measure the voltage values corresponding to the intersections with the two lines including all the measuring points (fig. 3.5). Then, it is possible to determine the value of linearity referred to the full-scale value:

$$\pm \frac{1}{2} \frac{|V_1 - V_2|}{F.S.O.} = \text{linearity};$$

This value is normally expressed in percent values.

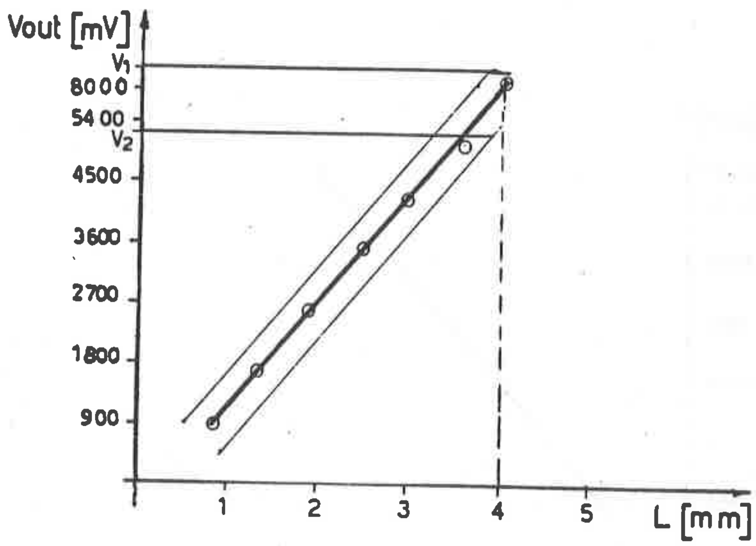


FIG. 3.5

F.S.O. is the abbreviation of "Full Scale Output": it indicates the variation of the output voltage corresponding to a variation of the displacement equal to its whole range.

INDUCTIVE PROXIMITY SENSOR (TWO-LEVEL OUTPUT)

3.6 Measurement of the current with and without actuator

Exercise object:

to check whether the values of the current crossing the sensor, with and without the actuator, correspond to those of the data sheets.

Necessary instrument:

- digital voltmeter (3 digits and 1/2).

Operating mode:

- Insert the digital voltmeter between the terminals 5 and 6, measure the voltage value across R1, with and without the actuator.
- Knowing that R1 is aqual to 2200 Ω, calculate the values of the two currents and compare them with those of the data sheets.

3.7 Intervention distance

Exercise object:

to determine the distance (mm) between the actuator and the sensor S_2, at which the output 9 switches from the high state (led out) to the low state (led on).

Necessary instruments:

- digital voltmeter (3 digits and 1/2)
- gage.

Operating mode:

- This exercise can be carried out measuring the output voltage of the conditioner (terminal 9) or visualizing the led connected to the output of IC1.
- Place the actuator 10 to 15 mm. far from the sensor (led out).
- Approach the disk slowly to the sensor S_2 until the led starts emitting light.
- Measure the distance between actuator and sensor with the gage, compare this datum with the value indicated in the data sheets.

3.8 Hysteresis

Exercise object:

to check whether there is some hysteresis (1/10 mm) between the intervention threshold (when the led starts emitting light) and the releasing threshold (when the led is out).

Necessary instrument:

- gage.

Operating mode:

- Place the actuator 10 to 15 mm far from the sensor (led out).
- Approach the actuator slowly to the sensor S_2 until the led starts emitting light.
- Measure the distance between actuator and sensor with the gage.

"Intervention threshold"

- Remove the actuator slowly from the sensor S_2 until the led stops emitting light.
- Measure the distance between actuator and sensor with the gage.

"Releasing threshold"

- The result of the difference between intervention and releasing thresholds is the hysteresis.

3.9 Repeatability accuracy

Exercise object:

to determine the intervention distance (mm) with "n" different tests and to check how it differs from its nominal value.

Necessary instrument:

- gage.

Operating mode:

- Place the actuator 10 to 15 mm far from the sensor (led out).
- Approach the actuator slowly to the sensor S_2 until the led starts emitting light.
- Measure the distance between actuator and sensor with the gage: write this value on the table 3.3.

N	L [mm]	ΔL [mm]

$\Delta L = L - L_{NOM.}$

TABLE 3.3

- Place the actuator again in the original position (10 to 15 mm far from the sensor) and repeat the above-mentioned operations 5-6 times.
- ΔL is the result of the difference between the measured value and the nominal value.

  The maximum absolute value of ΔL defines the repeatability accuracy; compare this value with that of the date sheets.

CAPACITIVE PROXIMITY SENSOR (TWO LEVEL OUTPUT)

The exercises described at the paragraphs 3.7, 3.8 and 3.9 can also be carried out following the same operating modes, with this sensor.

Screwing the plexigless plate supplied with the unit TY29!, on the actuator, it is possible to check that the only operating sensor is the capacitive one.