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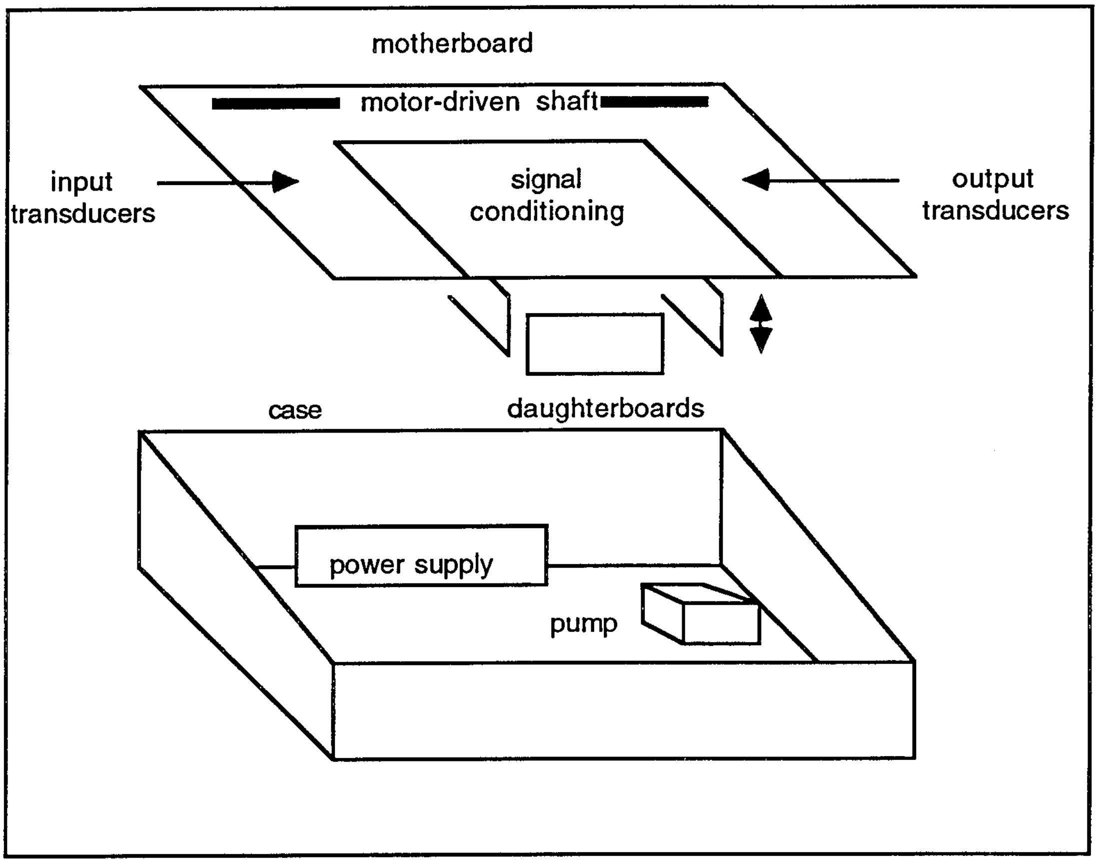
Digiac 1750
Transducers and Instrumentation Trainer
Technical Manual

Issue: ME132/B

CONSTRUCTION OF THE 1750



The DIGIAC 1750 is a self-contained trainer designed to introduce students to many of the techniques involved when working with transducers. The unit allows the investigation of the properties of various input and output devices and of the various methods of signal-conditioning required.

The unit comprises the following items:

- **MOTHERBOARD** - This is the main printed circuit board . On its top surface are most of the transducers and also the input/output sockets and mimic diagrams giving access to these and to the signal-conditioning blocks. On the underside are the pin headers for the power supply and four daughterboards together with a few potentiometers,switches and transducers which could not be accommodated on the top surface.

- **DAUGHTERBOARDS** - Most of the circuitry within the 1750 is accommodated on four small daughterboards mounted vertically on the lower surface of the motherboard. Connections are made via 0.1" right-angled pin headers and the boards are retained in position with aluminum pillars.

- **POWER SUPPLY** - All the components associated with the power supply are located to the rear of the case. On the back panel are the power inlet socket, fuse and voltage selector. Inside the case are the power supply PCB and the transformer. The PCB is a self-contained unit incorporating rectifier and regulators on an aluminum heat-sink which is also used to support the module vertically . Connections are made via screw terminals and 0.1" IDC wafers.

- **PNEUMATIC SYSTEM** - A small pump is mounted on the baseplate and provides air for flow and pressure sensors and a control valve via small-bore plastic tubing. The pump is of the type used to aerate aquarium water and it is very quiet in operation. It is operated via a switch on the motherboard.

- **CASE** - The unit is housed in a two-part case consisting of a welded steel console and an aluminum baseplate.

TRANSDUCERS

Many types of transducer are included on the 1750. They are loosely grouped into input and output devices with input transducers (sensors) mostly on the left of the motherboard and output transducers (actuators) on the right. The following input devices are provided:

INPUT TRANSDUCERS

POTENTIOMETERS

- CARBON TRACK POTENTIOMETER
- WIREWOUND TRACK POTENTIOMETER
- SLIDE POTENTIOMETER
- PRECISION TEN-TURN POTENTIOMETER
  (In Wheatstone bridge circuit)
- PRECISION SINGLE-TURN POTENTIOMETER
  (part of servo mechanism)

TEMPERATURE SENSORS

- NTC THERMISTORS
- PLATINUM R.T.D.
- I.C. TEMPERATURE SENSORS
- TYPE K THERMOCOUPLES

LIGHT LEVEL SENSORS

- PHOTOCONDUCTIVE CELL
- PHOTOTRANSISTOR
- PHOTOVOLTAIC CELL
- P.I.N. PHOTODIODE

DISPLACEMENT SENSORS

- LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (LVDT)
- LINEAR VARIABLE CAPACITOR
- STRAIN GAUGE

ROTATION SENSORS

- MOTOR CURRENT SENSING
- SLOTTED OPTO SENSOR
- REFLECTIVE OPTO SENSORS
- INDUCTIVE PROXIMITY SENSOR
- HALL EFFECT MAGNETIC FIELD SENSOR
- SERVO MECHANISM
- TACHOGENERATOR

ENVIRONMENTAL SENSORS

- AIR FLOW SENSOR
- AIR PRESSURE SENSOR
- HUMIDITY SENSOR

SOUND SENSORS

- ULTRASONIC RECEIVER
- DYNAMIC MICROPHONE

OUTPUT TRANSDUCERS AND ACTUATORS

The 1750 carries a range of output transducers. Those of an electromechanical nature are sometimes referred to as **actuators**.

HEAT OUTPUT

- HEATER RESISTOR

LIGHT OUTPUT

- FILAMENT LAMP

ROTATIONAL OUTPUT

- D.C. MOTOR

SOUND OUTPUT

- ULTRASONIC TRANSMITTER
- BUZZER
- LOUDSPEAKER

LINEAR MOVEMENT

- SOLENOID
- RELAY
- AIR VALVE AND ACTUATOR

EVENT COUNT/TIME INDICATION

- COUNTER/TIMER UNIT WITH 7-SEGMENT L.E.D. DISPLAY

VOLTAGE INDICATION

- MOVING-COIL METER
- L.E.D. BARGRAPH DISPLAY

SIGNAL-CONDITIONING CIRCUITRY

A wide range of signal-conditioning circuitry is provided:

AMPLIFIERS

- AMPLIFIERS #1,#2
- X100 AMPLIFIER
- BUFFERS #1,#2
- INVERTER
- CURRENT AMPLIFIER
- SUMMING AMPLIFIER
- DIFFERENTIAL AMPLIFIER
- INSTRUMENTATION AMPLIFIER
- A.C. COUPLED AMPLIFIER
- ELECTRONIC SWITCH

OSCILLATORS AND FILTERS

- 40kHz OSCILLATOR
- 40kHz FILTER
- LOW-PASS FILTER
- ALARM OSCILLATOR

MATHEMATICAL OPERATIONS

- FULL-WAVE RECTIFIER
- SAMPLE AND HOLD
- INTEGRATOR
- DIFFERENTIATOR
- COMPARATOR

CONVERTERS

- V/F CONVERTER
- F/V CONVERTER
- V/I CONVERTER
- I/V CONVERTER

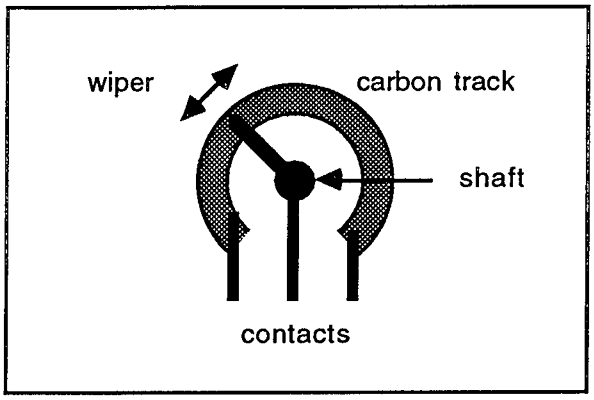
MISCELLANEOUS

- POWER AMPLIFIER

SECTION 1: POTENTIOMETERS

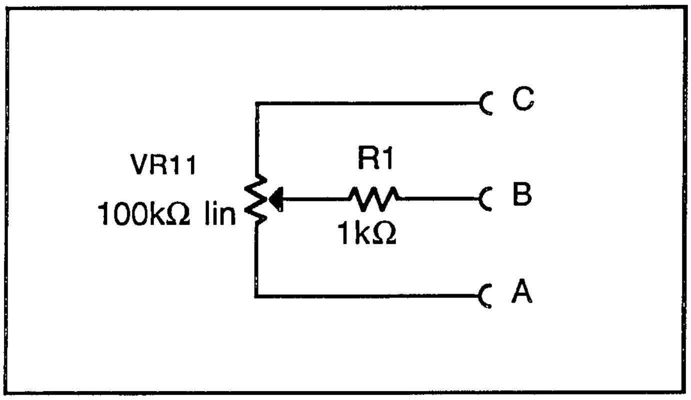
1.1 CARBON TRACK POTENTIOMETER

CONSTRUCTION



The resistance element is a 270° substrate on which a film of graphite is deposited. A fingered metal wiper moves around the track when the shaft is turned. If the wiper and one end contact are used the device is strictly-speaking called a **variable resistor**. If a voltage is applied across the ends and 'tapped off' by the wiper the device is properly termed a **potentiometer**.

CIRCUIT DETAILS



VR11 is a 100kΩ carbon-track potentiometer. The track is protected by R1 which limits the worst-case power dissipation to 288mW. When used as a variable resistor rather than a potentiometer the minimum resistance will be 1kΩ accordingly.

Continued overleaf

CHARACTERISTICS

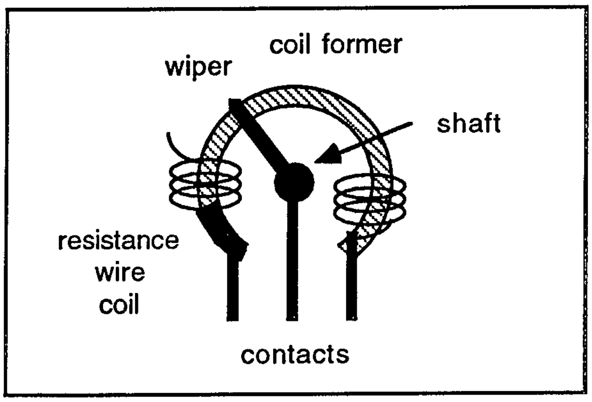
PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Resistance A-C		80kΩ	100kΩ	120kΩ
Resistance A-B	A-C = 100kΩ	1kΩ		101kΩ
Power dissipation	A-B = 24V			288mW
Electrical rotation			270°	280°
Mechanical rotation			270°	315°

SETUP PROCEDURE

The control knob marker should move symmetrically between the graduations.

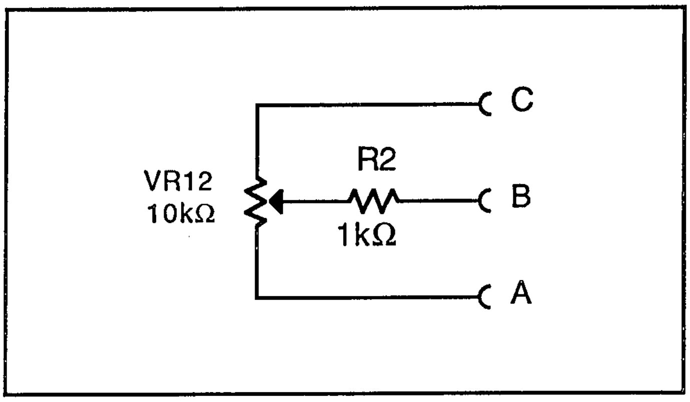
1.2 WIREWOUND TRACK POTENTIOMETER

CONSTRUCTION



The track consists of a closely-wound coil of resistance wire over which a fingered metal wiper travels when the shaft is turned. The resolution is limited to the resistance of one turn of the coil and is therefore much lower than that of a carbon-track device. This is offset by improvements in other parameters such as stability, temperature coefficient and power-handling.

CIRCUIT DETAILS



VR12 lis a 10kΩ wirewound-track potentiometer with nominal 270° rotation.R2 protects the track from excessive dissipation and limits the minimum resistance to 1kΩ.

Continued overleaf

CHARACTERISTICS

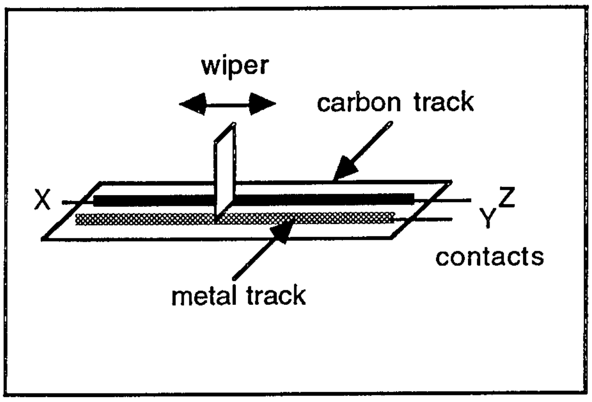
PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Resistance A-C		9KΩ	10kΩ	11kΩ
Resistance A-B	A-C = 10kΩ	1kΩ		11kΩ
Power dissipation	A-B = 24V			288mW
Electrical rotation		260°	265°	270°
Mechanical rotation		280°	285°	290°

SETUP PROCEDURE

As 1.1

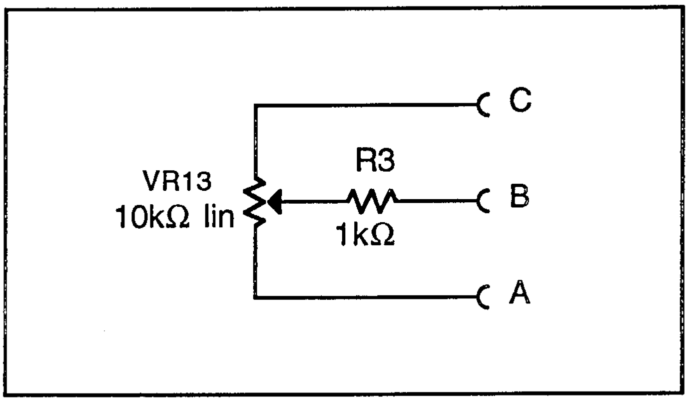
1.3 SLIDE POTENTIOMETER

CONSTRUCTION



The operating shaft is joined to a metal wiper. This makes contact with the carbon track resistance element X-Z and also to a metal track running alongside which provides the wiper contact Y.

CIRCUIT DETAILS



VR13 is a 10kΩ carbon-track slide potentiometer with a travel of 55mm. approx. The track is protected by R3.

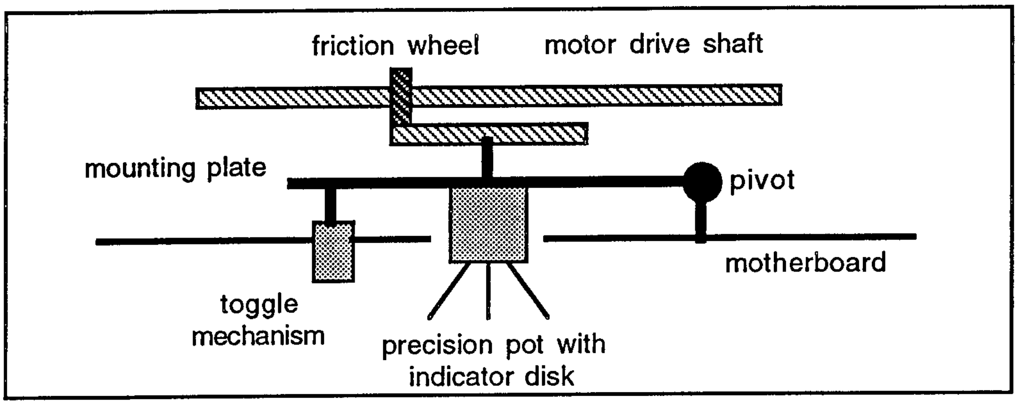
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Resistance A-C		8kΩ	10kΩ	12kΩ
Resistance A-B	A-C = 100kΩ	1kΩ		11kΩ
Power dissipation	A-B = 24V			288mW
Electrical travel			55mm	
Mechanical travel			58mm	

1.4 SERVO MECHANISM

CONSTRUCTION

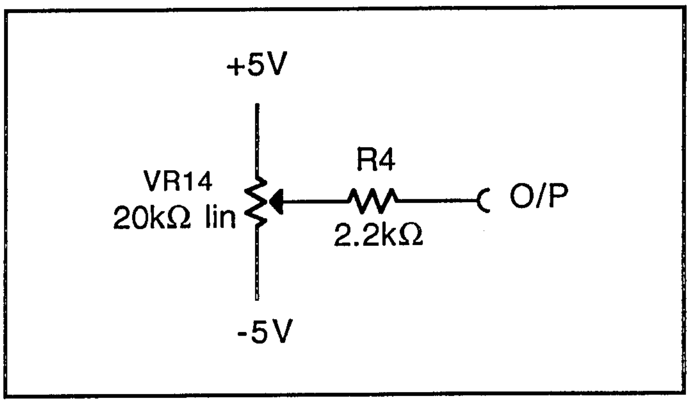


A precision potentiometer is mounted on a moveable plate. This plate is fixed to a sprung toggle mechanism which allows the potentiometer to be operated by the drive shaft via an aluminum disk and rubber friction ring.. The plate is pressed down once to engage the mechanism and again to release. The shaft reduction ratio of this arrangement is 4:1. The potentiometer itself is similar in construction to the carbon pot but it has a 360° conductive plastic track and precision bearings.

N.B.

The construction of the potentiometer permits continuous rotation. To avoid excessive wear of the track ends the mechanism should be **disengaged when not in use**.

CIRCUIT DETAILS



VR14 is a precision 20kΩ potentiometer designed for use in servo mechanisms. The track is connected permanently between -5V and +5V. The maximum permissible wiper current is 10mA. With a worst-case applied voltage of 17V the 2.2kΩ series resistor R4 limits the current to 7.7mA.

Continued overleaf

CHARACTERISTICS

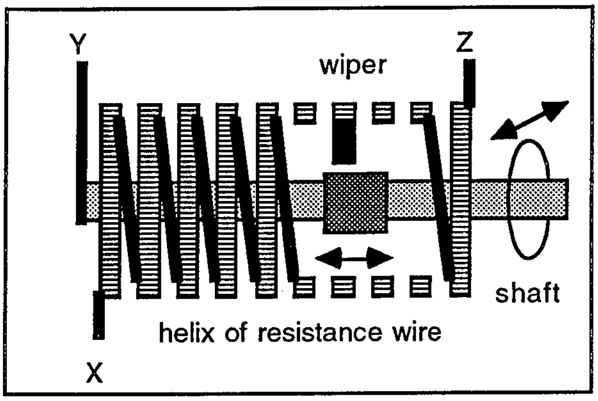
PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Track resistance		16KΩ	20KΩ	24KΩ
Linearity			0.5%	
Smoothness			0.1%	
Wiper current	Track-wiper 17V			10mA
Electrical rotation			360°	
Mechanical rotation		336°	340°	344°
Track life	<360° rotation >360°	10^7 20000		
Output voltage	circuit above	-5V		+5V
Output resistance	circuit above	2.2kΩ		7.2kΩ

SETUP PROCEDURE

With power applied, monitor the output voltage. Rotate the indicator disk to zero and fix in position temporarily with plasticine, Blu-tak or similar material. Loosen the clips holding the potentiometer in place and rotate it until the output voltage is 0V. Tighten the retaining clips and free the indicator disk.

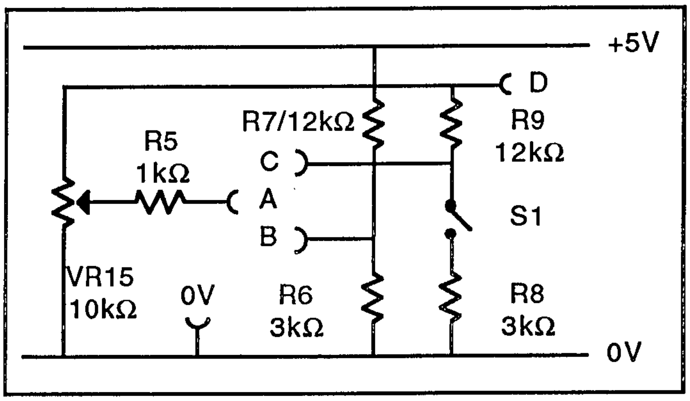
1.5 WHEATSTONE BRIDGE USING A TEN-TURN POTENTIOMETER

CONSTRUCTION OF THE TEN-TURN POTENTIOMETER



When the shaft is turned a wiper spirals along a track wound helically with resistance wire. X and Z are the track contacts and Y is the wiper contact.

CIRCUIT DETAILS



VR15 is a precision ten-turn potentiometer with protection resistor R5. The wiper output is available on socket A. The junction of R6 and R7 (socket B) provides a stable 1V reference which functions as the "standard cell" of the classical Wheatstone bridge circuit. R8 and R9 form the right-hand arms of the bridge. The value of R9 is given to the student but it is left as an exercise to find the value of R8. Switch S1 allows R9 to be switched out allowing an external device to be connected between socket C and 0V. Voltage measurements can also be made - the unknown voltage is connected between socket D and 0V and the bridge balanced for zero volts between A and B. A ten-turn counting dial is fitted to allow the potentiometer position to be ascertained.

Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
VR5 non-linearity				0.25%
VR5 rotation		3600°		3610°
Output resistance, A		1kΩ		3.5kΩ
Output resistance, B			2.4kΩ	
Output voltage, B	V+ = 5.00V, no load	0.98V	1.00V	1.02V
Ratio R9/R8		3.92	4.00	4.08

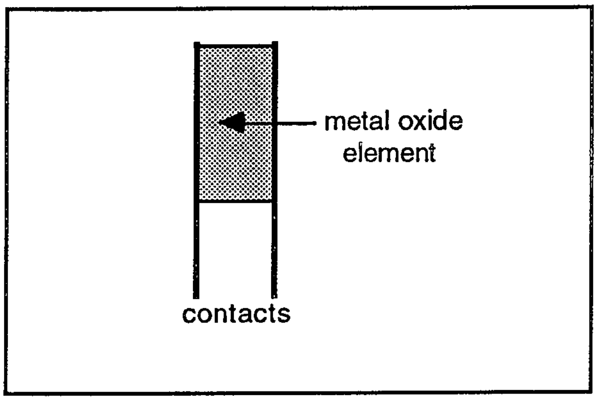
SETUP PROCEDURE

Align turns counting dial on 5.00. Connect socket D to +5V and measure the voltage between D and 0V. Adjust VR15 so that the voltage between socket A and 0V is exactly half this figure. Without moving the dial or the potentiometer, place the dial on the pot shaft and tighten the grubscrew in the knob. After this adjustment the dial may not stop at precisely 0.00 or 10.00.

SECTION 2 : TEMPERATURE SENSORS

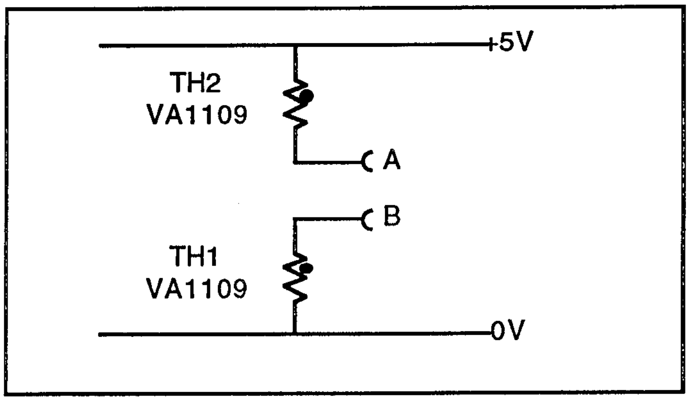
2.1 N.T.C. THERMISTORS

CONSTRUCTION



The NTC thermistor is a two-terminal semiconductor device with an element made from sintered oxides of metals such as nickel,manganese and cobalt.

CIRCUIT DETAILS



Two negative-temperature-coefficient thermistors are provided; TH1 is connected to 0V and TH2 to +5V Each requires a suitable load resistor to the other power rail and the wirewound-track potentiometer is recommended for this purpose. TH2 is located inside the heater compartment while TH1 is outside and accessible. Their resistance will be about 4.7kΩ at room temperature and this will fall in a non-linear manner as the temperature rises. Differential temperature measurements inside and outside the heater compartment can be made by connecting A to B.

Continued overleaf

The resistance R2 at temperature T2 can be calculated provided the following parameters are known:

Resistance R1 at temperature T1
B (characteristic temperature)

R2 can now be calculated from this formula:

$$R2 = R1\, e^{\left(\frac{B}{T2} - \frac{B}{T1}\right)}$$

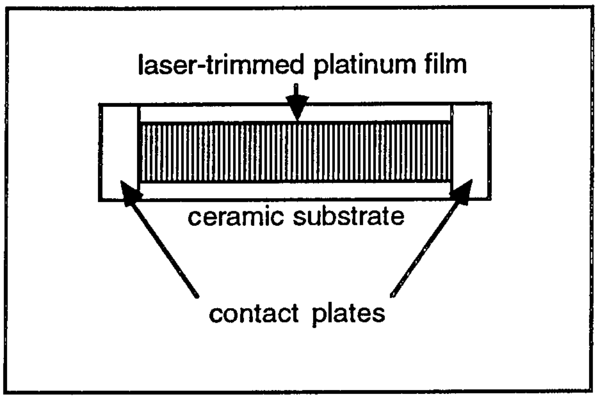
All temperatures in Kelvin.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Resistance R1	T1=298K	4230Ω	4700Ω	5170Ω
Characteristic temp. (B)			4350K	

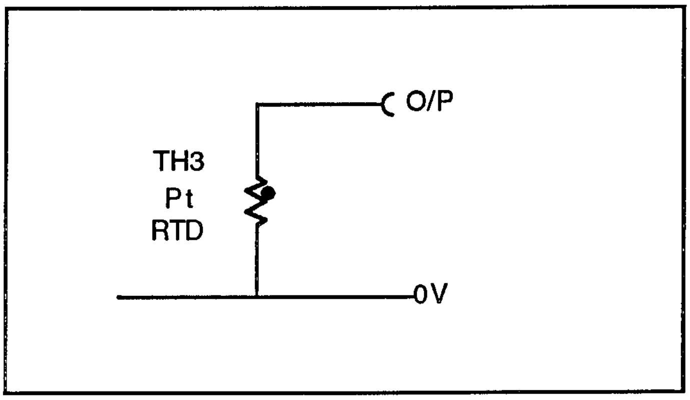
2.2 PLATINUM R.T.D.

CONSTRUCTION



The RTD consists of a thin film of platinum deposited on a ceramic substrate with gold contact-plates on each end. The film is laser-trimmed to precisely 100Ω at 0°C.

CIRCUIT DETAILS



The platinum resistance temperature detector is a highly stable and accurate sensor.The resistance increases linearly at 0.385Ω/°C. To develop a voltage a suitable resistance should be connected between O/P and +5V and the wirewound potentiometer is recommended. A series resistance of 1.8kΩ gives a voltage change of about 1mV/°C. The RTD is located in the transparent plastic heating compartment.Its resistance is given by the following formula (T in °C):

$$R = R_{(0)} + 0.385T$$

where $R_{(0)}$ is the resistance at 0°C, 100Ω in this case.

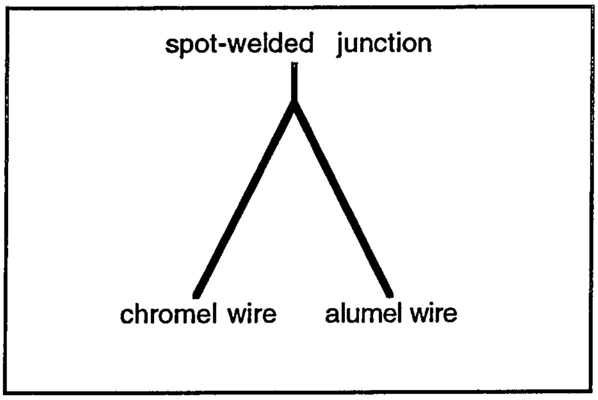
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Resistance	T=0°C (273K)	99.9Ω	100Ω	100.1Ω
Temp. coefficient			+0.385Ω/°C	
Self-heating			0.2°C/mW	

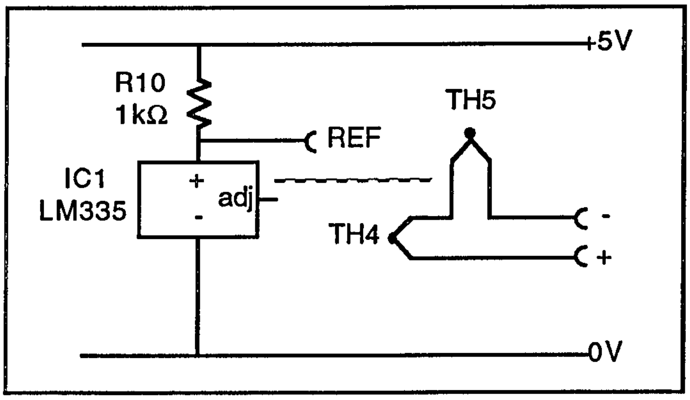
2.3 TYPE K THERMOCOUPLES

CONSTRUCTION



Thermocouples consist of junctions between dissimilar metals. A small but predictable voltage is generated when the junction is heated. To eliminate dissimilar junctions at the soldered ends, two junctions are placed in series.This also gives the opportunity to monitor the absolute temperature of one of the junctions and on the 1750 this is accomplished with a LM335 Kelvin temperature sensor mounted in an aluminium block with one of the the thermocouples.

CIRCUIT DETAILS



Type K thermocouples are made from chromel and alumel alloy wires. The temperature coefficient of a type K thermocouple is fairly linear in the 0-100°C range at 40.28μV/°C. Due to the very small voltage the use of the instrumentation amplifier followed by several high-gain amplifier stages is recommended.A gain of 248 will provide 10mV/°C

N.B. The thermocouple output is related to the **temperature difference** between the junctions and the temperature of one must be established before the temperature of the other can be determined, hence the need for the LM335.

The output voltage is given by the following expression :

$$V_{out} = k(T_{hot} - T_{cold})$$

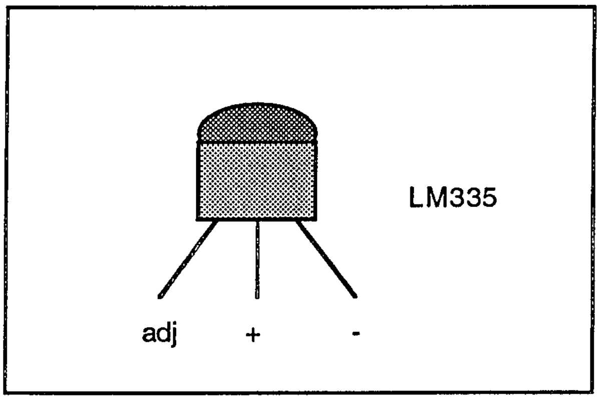
where **k** is the temperature coefficient 40.28µV/°C and **$T_{(hot)}$ - T(cold)** is the temperature difference between hot and cold junctions.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Thermocouple T.C.	T = 0-100°C		40.28µV/°C	
REF voltage (LM335)	T= 25°C (298K)	2.92V	2.98V	3.04V
LM335 T.C.			10mV/°C	

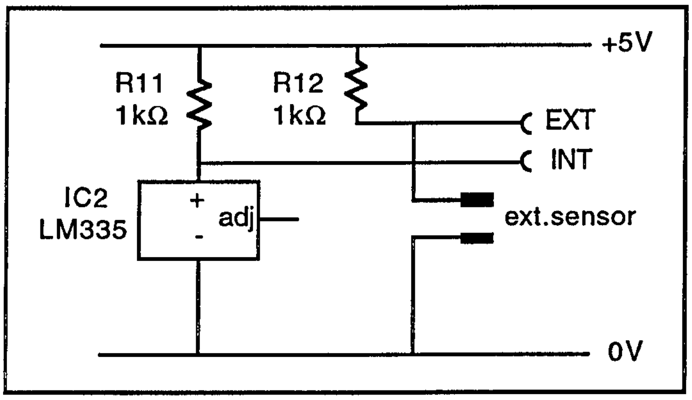
2.4 I.C. TEMPERATURE SENSORS

CONSTRUCTION



The LM335 temperature sensor is a three-terminal silicon integrated circuit in a plastic TO-92 transistor package. Despite its apparent simplicity it actually contains 16 transistors,9 resistors and 2 capacitors.

CIRCUIT DETAILS



This LM335 provides a linear output of +10mV/°C and the output voltage directly represents the temperature in Kelvin e.g. at 20°C (293K) it will be 2.93V. The chip has an adjustment pin for trimming this voltage but it is not used in this application. A two-pin socket is provided for the connection of an external LM335 probe.

Continued overleaf

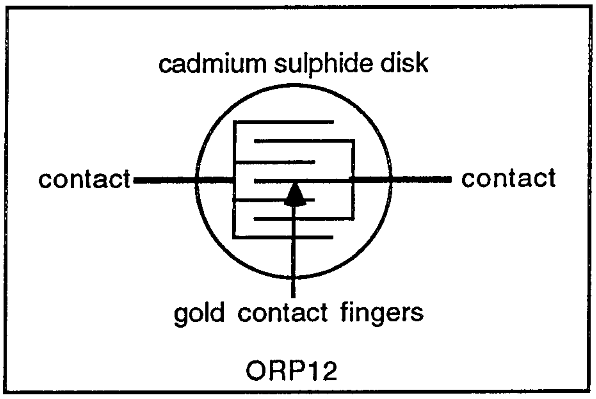
CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Output voltage	T = 25°C (298K)	2.92V	2.98V	3.04V
Uncalibrated temp. error	T = 25°C (298K)		1K	3K
Operating current	Circuit above		2mA	
Dynamic impedance			0.5Ω	
Time constant			80s	

SECTION 3: LIGHT SENSORS

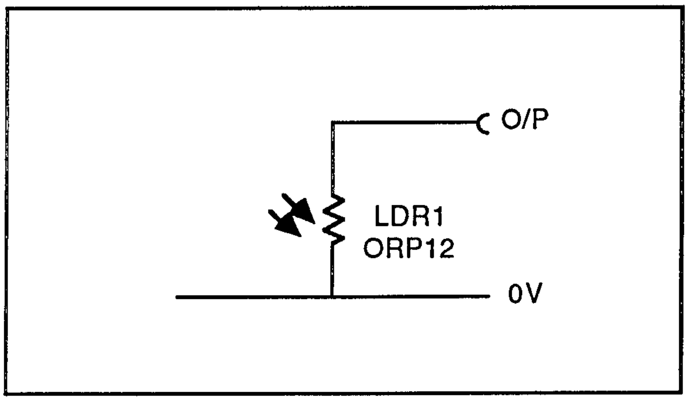
3.1 PHOTOCONDUCTIVE CELL

CONSTRUCTION



Photoconductive cells are made from cadmium sulphide doped with silver,antimony or indium chemically deposited on a substrate with interleaved gold contact fingers formed on top. Light falling on the sensitive area breaks chemical bonds. The resulting electrons and holes become available to increase the conductivity. These bonds are slow to re-form when light is removed and the response time is sluggish.

CIRCUIT DETAILS



The resistance of the ORP12 drops dramatically as the incident light increases. The device requires a suitable load resistor to provide a voltage output which then falls with increasing illumination.

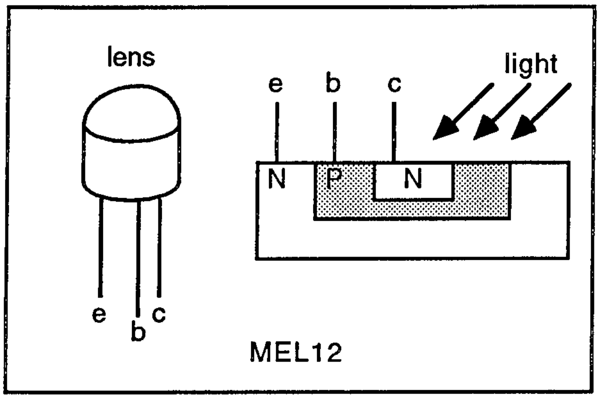
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Cell resistance	50 lux		2.4kΩ	
	1000lux		130Ω	
	typical ambient		500Ω	
Dark resistance		10MΩ		
Rise time			75ms	
Fall time			350ms	
Peak spectral response			610nm (red)	

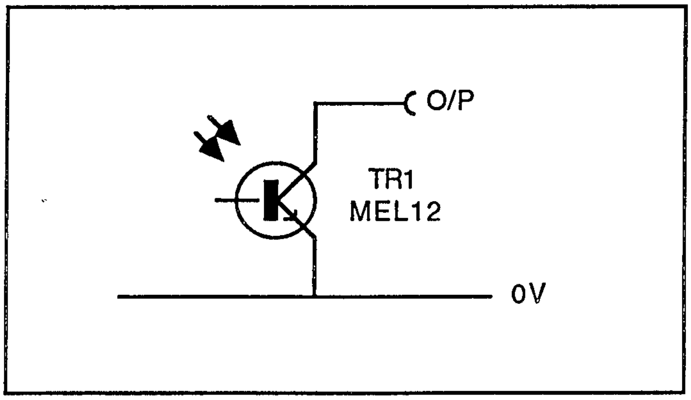
3.2 PHOTOTRANSISTOR

CONSTRUCTION



The phototransistor has three layers of silicon containing tiny amounts of impurities. These layers are termed **emitter,base** and **collector.** When a positive voltage is applied between collector and emitter a tiny **reverse saturation current** flows. This current is due to electrons and holes created by warmth. The geometry of a phototransistor allows light to shine on the collector-base junction and this creates additional current carriers. This current is amplified by transistor action.

CIRCUIT DETAILS



TR1 is a high-gain phototransistor in which the collector current is proportional to the incident light intensity as in the following formula:

$$I_C = (1 + h_{fe})(I_{CO} + I_L)$$

Continued overleaf

h_{fe} is the small-signal current gain. The MEL12 is a special type of transistor with a very high **h_{fe}** (>1000)
I_{co} is the reverse-saturation current which is due to thermally-generated minority carriers and is therefore temperature-dependent.
I_L is the additional saturation current generated by incident light on the collector/emitter junction.
A suitable load resistor to +5V must be provided to obtain a voltage output. The base terminal is unused and left open-circuit in this application. With a resistor of value **R_C** the output voltage **V_{out}** will be:

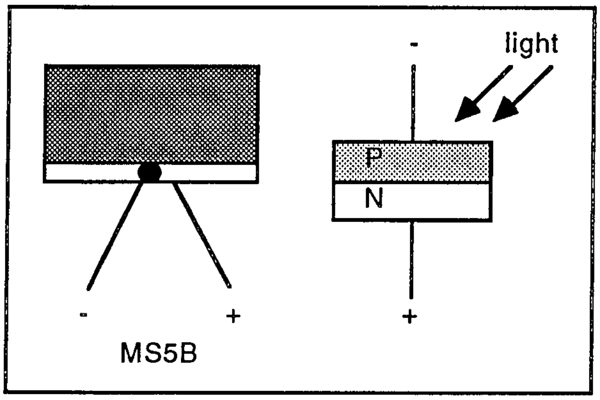
$$V_{out} = 5 - I_C R_C$$

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Dark current (I_{co})	V_{ce} = 5V		100nA	
Light current (I_L)	H_{IL} = 2mW/cm^2		3mA	
	typical ambient		3.5mA	

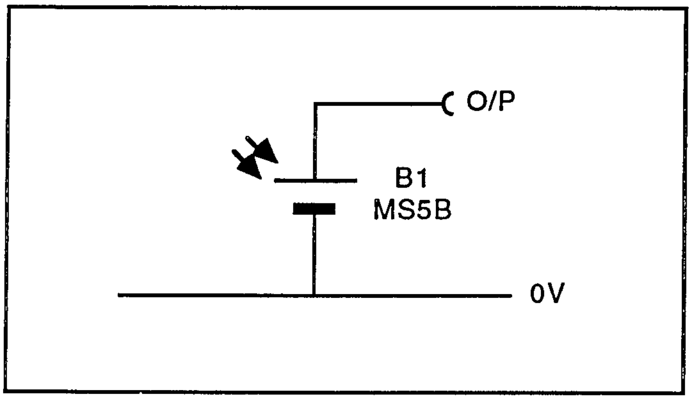
3.3 PHOTOVOLTAIC CELL

CONSTRUCTION



The photovoltaic cell is a two-layer silicon device. It generates a voltage by electron/hole pair production when the junction is exposed to light. These diffuse across the junction to set up a voltage. A current will flow if a resistance is placed across the terminals. Devices optimized for energy production are often called **solar cells**.

CIRCUIT DETAILS



The MS5B has an active area of about 5mm X 13mm.The main parameters of interest are the open-circuit voltage V_o and short-circuit current I_s. The open-circuit voltage initially rises logarithmically with increasing light towards a limit of 0.6V. The short-circuit current rises linearly under the same conditions and is also proportional to surface area.

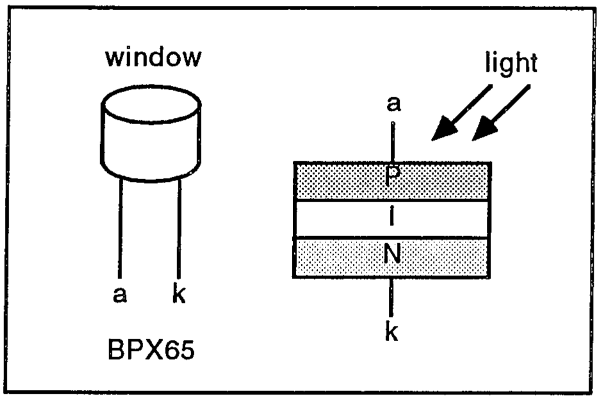
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Surface area			$65.75mm^2$	
Open-circuit voltage	sunlight		500mV	
	typical ambient		300mV	
Short-circuit current	sunlight		10mA	
	typical ambient		50µA	
Peak spectral response			840nm (I.R.)	
Response time			10µs	

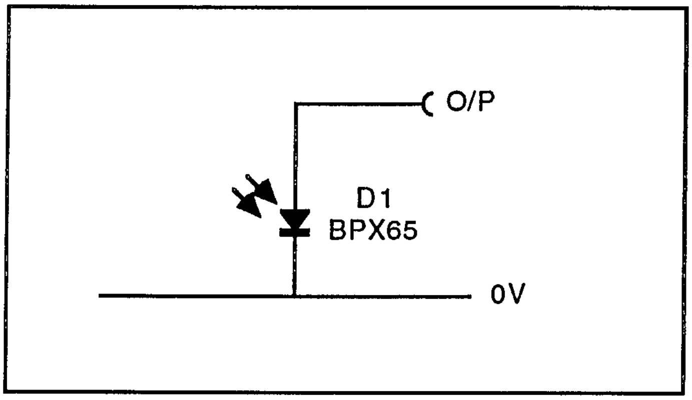
3.4 P.I.N. PHOTODIODE

CONSTRUCTION



One of the problems with P-N junction photodevices is the electric field which forms across the junction. This manifests itself as a capacitance of typically 100pF which limits the rise and fall time of the photocurrent. To minimize this effect a third layer of **intrinsic** or very lightly-doped silicon can be incorporated. This separates the charged regions and greatly reduces the capacitance to typically 15pF.

CIRCUIT DETAILS



A PIN photodiode can be operated in two ways. The tiny photocurrent can be amplified by a high-gain current/voltage converter whose output can then be converted to a voltage. A suitable circuit with a gain of 10,000 is provided on the 1750 and the output will rise linearly with increasing illumination. Alternatively the device can be connected via a buffer to a high-gain voltage amplifier; the output from this will rise logarithmically with increasing irradiance. In this mode it works as a photovoltaic cell.

Continued overleaf

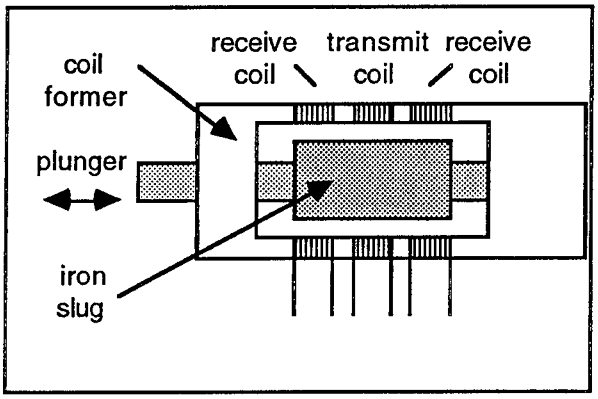
CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Dark current				1nA
Light current		7nA/lux	10nA/lux	
	typical ambient		1μA	
Peak spectral response			850nm (I.R.)	
Capacitance			15pF	
Response time	R_L= 5kΩ		50ns	100ns

SECTION 4: LINEAR DISPLACEMENT SENSORS

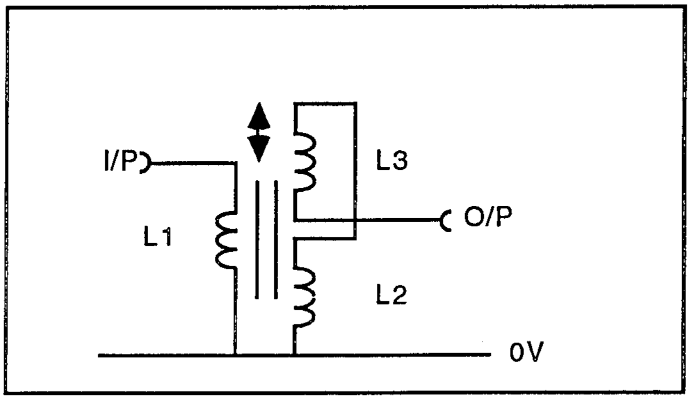
4.1 LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (L.V.D.T.)

CONSTRUCTION



The L.V.D.T. consists of three coils wound side-by-side on a plastic former. An iron slug attached to an operating plunger slides between the coils. A signal is applied to the **transmit** coil. The two **receive** coils are connected in antiphase and the signal picked up changes in amplitude and phase with the slug position. When the slug is centered between the coils the amplitude falls to near zero. The phase reverses through 180° around this point.A **phase-sensitive rectifier** is often used in practice to extract both phase and amplitude information from the received signal. This circuit block is not provided on the 1750 but the phase reversal can be monitored with an oscilloscope.

CIRCUIT DETAILS



On the 1750 a knurled knob operates a screw which moves the plunger in and out.L1 is the **transmit** coil and L2 and L3 are the **receive** coils.The input should be driven by the 40kHz oscillator. The output should be boosted by the A.C. amplifier and then cleaned up with the 40kHz filter.

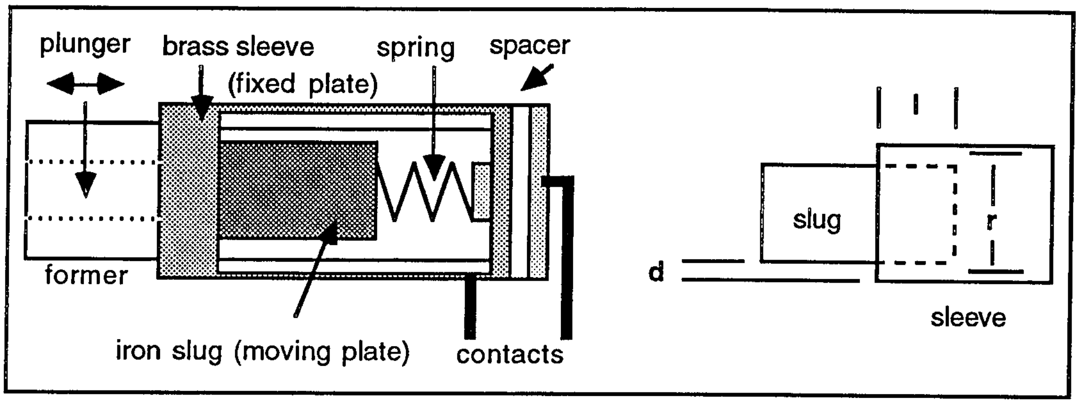
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Turns per coil			75	
Inductance per coil			68μH	
Impedance at 40kHz			17Ω	
Output voltage	balance		<5mV	
	1mm from bal.		10mV	
Mechanical travel			15mm	

4.2 LINEAR VARIABLE CAPACITOR

CONSTRUCTION



This transducer shares the coil former and plunger with the L.V.D.T. The end of the former is shrouded by a brass sleeve which forms the **fixed plate** of the capacitor. The end of the plunger is joined to an iron slug which moves within the sleeve while insulated from it by the former.The slug is the **moving plate** and electrical contact is made by a spring and endplate. The spring also serves to keep the plunger in tension against its operating screw.

An approximate formula (ignoring end effects) can be derived for a capacitor of this construction. The geometry is shown on the right of the diagram above; the relevant parameters are listed below with actual measurements in mm:

l is the overlap between plates	(10mm)
r is the average radius of the former	(4.175mm)
d is the thickness of the former	(1mm)

Other parameters required:

e_0 is the permittivity of free space	(8.85×10^{-12})
e_r is the relative permittivity of the former	(5.1)
π is the circumference / diameter	(3.1416)

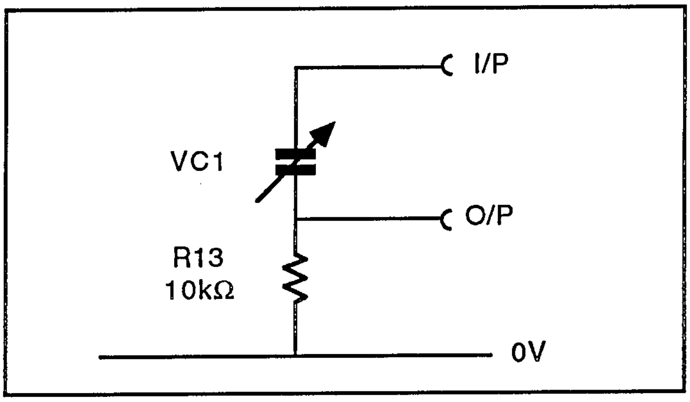
The capacitance **C** can then be calculated:

$$C = \frac{2\pi e_0 e_r r l}{1000d}$$

Substituting the values in parentheses gives a capacitance of 15pF. The measured value will be larger (perhaps 30pF) due to edge effects ,strays etc.

Continued overleaf

CIRCUIT DETAILS



The input should be driven by the 40kHz oscillator and the output boosted by the A.C. amplifier.

The output voltage V_{OUT} is related to the input voltage V_{IN} by the following formula:

$$V_{OUT} = \frac{R}{\sqrt{R^2 - \frac{1}{\omega^2 C^2}}} V_{IN}$$

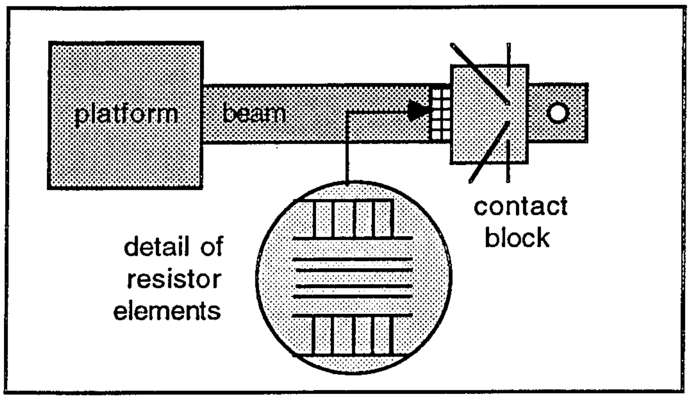
where ω is the angular frequency and is equal to 251,327 at 40kHz and **C** is the capacitance of the assembly as calculated above. **R** is R13 (10kΩ)

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Capacitance		25pF		50pF
Output voltage	40kHz, 6V p-p	0.38V p-p		0.7V p-p
Mechanical travel			15mm	

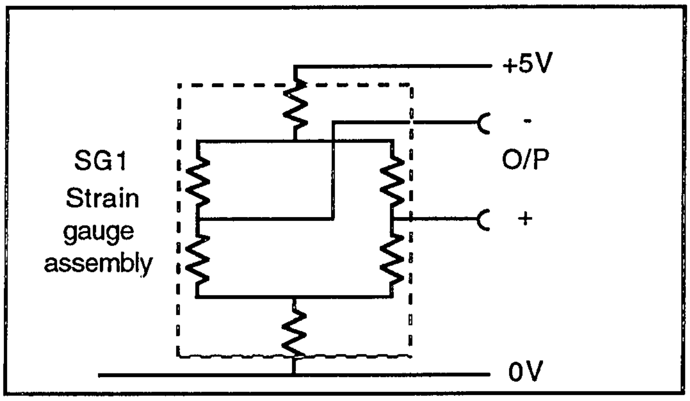
4.3 STRAIN GAUGE

CONSTRUCTION



The 1750 strain gauge is a metal beam with a contact block at one end. It has a thin section over which is electro-deposited a network of resistors. Some of these are formed along the axis of the beam and become elongated when it is stressed, thereby increasing in resistance. Others are deposited perpendicular to the beam and provide a reference. The elements are connected in a **bridge** circuit as shown below. Temperature effects are minimized since all the elements are in thermal contact.

CIRCUIT DETAILS



The strain gauge is connected across the +5V supply.When the beam is loaded the **(+)** output voltage rises and the **(-)** output falls. Damage due to over-bending is prevented by a restraining bridge. The output is typically a few microvolts and the use of the instrumentation amplifier followed by high-gain stages is recommended.

Continued overleaf

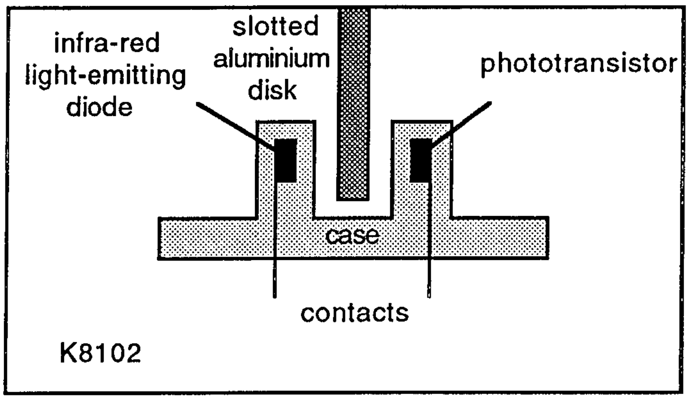
CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Standard capacity			100g	
Deflection				0.5mm
Non-linearity				0.025%
Hysteresis				0.05%
Creep				0.05%
Output voltage	no load		2.35V	
Sensitivity			25µV/g	

SECTION 5: ROTATION SENSORS

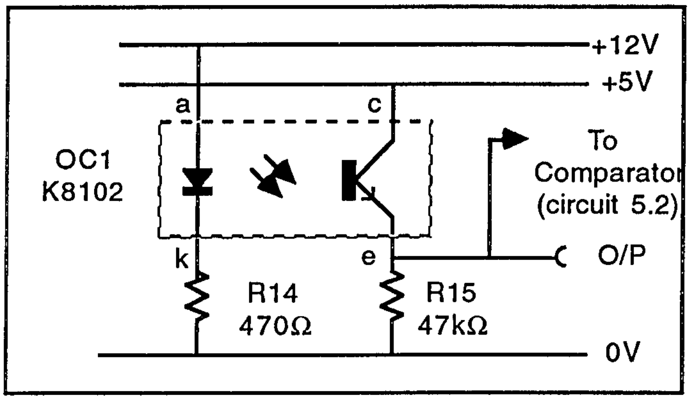
5.1 SLOTTED OPTO SENSOR

CONSTRUCTION



This device consists of a gallium arsenide infra-red L.E.D. and silicon phototransistor mounted in a special plastic case which is transparent to light of this wavelength. The elements are separated by a slot which allows the beam to be broken when an infrared-opaque object is inserted. On the 1750 the obstruction is provided by a slotted aluminium disk on the motor drive shaft.

CIRCUIT DETAILS



The infra-red L.E.D. has a larger **forward voltage drop** than a silicon diode (1.7V instead of 0.6V) The operating current is set to about 21mA by R14. The phototransistor collector current rises when the beam is admitted and the voltage across R15 rises. A series of positive pulses is generated when the slotted disk is rotated. A comparator monitors the output voltage and lights an indicator L.E.D. This circuit will be found in section 5.2.

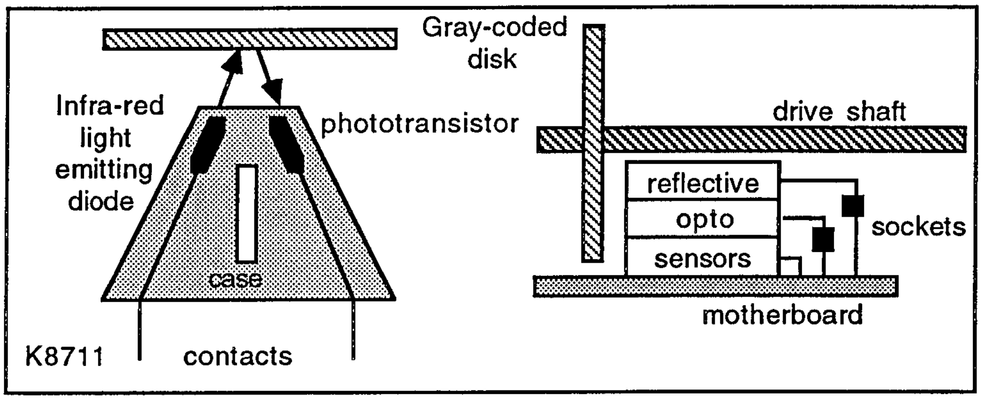
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Output voltage	beam broken		0.1V	
	beam admitted		4.9V	

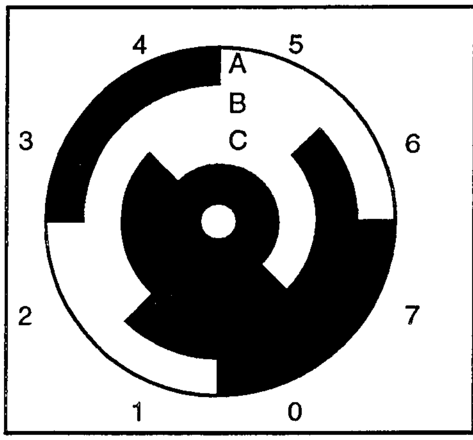
5.2 REFLECTIVE OPTO SENSORS

CONSTRUCTION



The reflective opto sensor is another device employing an infrared L.E.D. and phototransistor. The components are arranged so that the beam is returned if a reflective surface is placed at the correct distance. For the K8711 this is about 4mm. The 1750 employs three devices mounted in a sandwich with the top pair socketed. The reflective surface is a Gray-coded adhesive overlay on an aluminium disk which revolves with the drive shaft

GRAY-CODED DISK

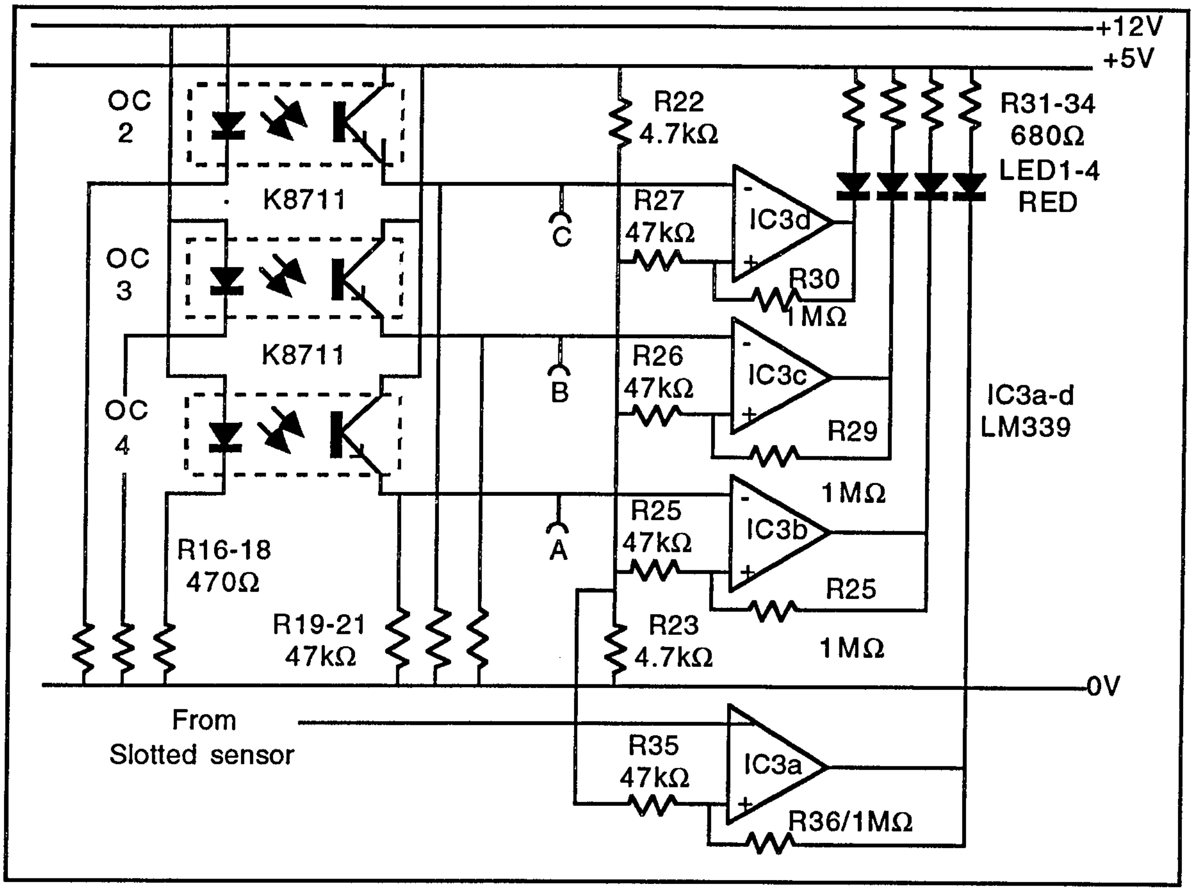


POSITION	C	B	A
0	0	0	0
1	0	0	1
2	0	1	1
3	0	1	0
4	1	1	0
5	1	1	1
6	1	0	1
7	1	0	0

The Gray code is preferred to straight binary for encoded disks because only one bit ever changes at a time, thereby reducing the error that can occur at a segment boundary. The disk used on the 1750 is shown above; black areas produce a low-voltage output from the associated reflective opto sensor while white areas reflect infra-red and produce a high voltage.

Continued overleaf.

CIRCUIT DETAILS



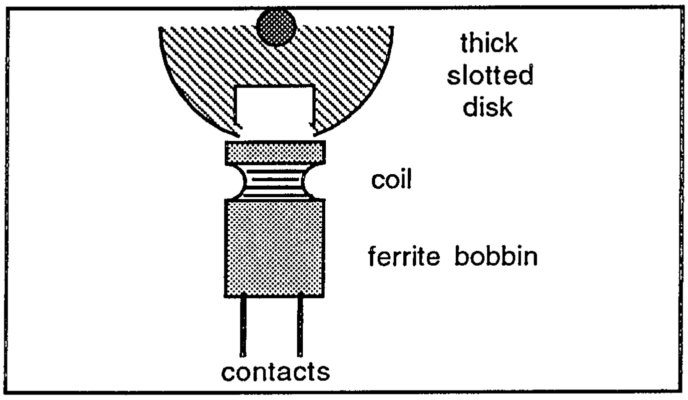
Each device has an infra-red L.E.D. operating at about 21mA and a phototransistor with 47kΩ emitter resistor.The output voltage rises when the sensor is over a reflective part of the Gray-coded disk.The three outputs and the output from the slotted sensor connect to LM339 comparators. The reference voltage is set at about 2.5V by R22 and R23 and a small amount of hysteresis is provided by the 1MΩ resistors. The L.E.Ds are turned on when the sensor outputs exceed 2.5V. The outputs are labelled A (L.S.B.) to C (M.S.B.)

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Output voltage	beam broken		1V	1.5V
Output voltage	beam reflected	3V	4V	

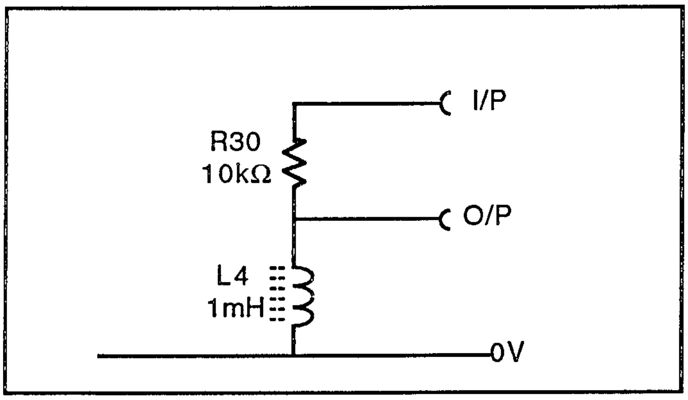
5.3 INDUCTIVE SENSOR

CONSTRUCTION



In its simplest form an inductive proximity detector consists of a coil whose inductance changes when a metallic object is brought close. The 1750 employs a 1mH radio-frequency choke coil wound on an open ferrite bobbin. A thick slotted aluminium disk on the drive shaft rotates above the sensor. Commercial inductive sensors use more complex coil arrangements and often include the necessary circuitry within the unit.

CIRCUIT DETAILS



The coil L4 forms a potential divider with R30. If an alternating voltage is applied to the input there will be an output voltage given by the following formula:

$$V_{OUT} = \frac{wL}{\sqrt{R^2 + w^2L^2}} V_{IN}$$

ω is the angular frequency (251,327 at 40kHz)
R is the series resistance (10kΩ)
L is the series inductance (1mH)

Continued overleaf

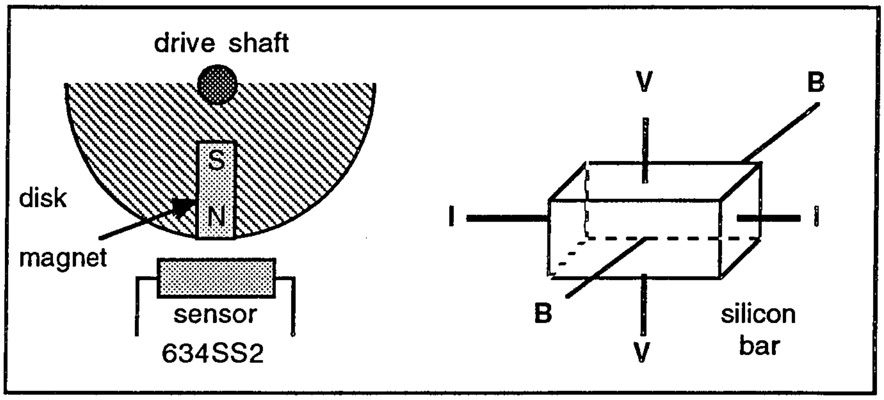
The input should be driven by the 40kHz oscillator and the output amplified by the A.C. amplifier then rectified and smoothed. The resulting signal should be amplified and the offset removed. Despite (or perhaps because of) its simplicity the inductive sensor requires considerable signal conditioning to obtain a useful output.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Inductance	under slot	0.9mH	1mH	1.1mH
Inductance change	under disk		15µH	
Output voltage	under slot		130mV	
Output voltage change	under disk		2mV	

5.4 HALL EFFECT SENSOR

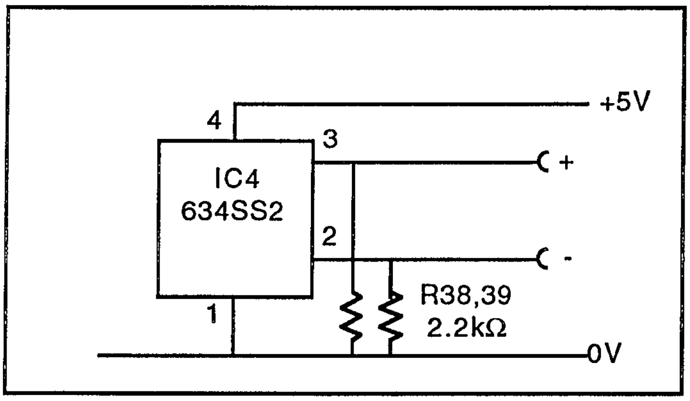
CONSTRUCTION



Integrated circuits are available which sense the **presence** or **strength** of magnetic fields and these are known respectively as **Hall effect switches** or **linear Hall effect sensors.** The 1750 employs one of the latter (634SS2) to detect when a small bar magnet is above the chip. This magnet is buried in a thick aluminium disk on the drive shaft.

The Hall effect is a property of metals and especially doped semiconductors whereby a voltage **V** is developed across a bar of the material if a current **I** and a magnetic field **B** pass through the two perpendicular axes. The geometry is shown above. The voltage is directly proportional to the field strength multiplied by the current.

CIRCUIT DETAILS



The 634SS2 provides two outputs. The voltage on pin 3 **rises** when a **south** pole is brought close while pin 2 **falls.**The reverse is true for a **north** pole. R38 and R39 match the 2kΩ output impedance.

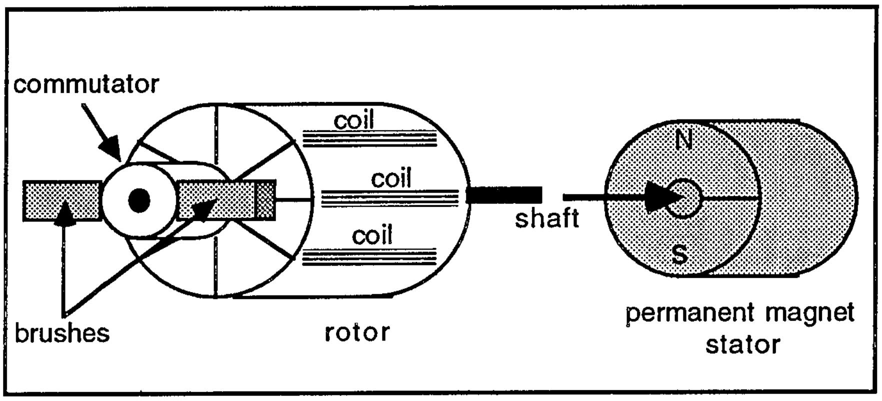
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Output voltage,(+)	no field		1.75V	
Output voltage,(-)	no field		1.6V	
Output voltage change		7.5mV/mT	9mV/mT	10.6mV/mT
Output voltage change	under magnet		600mV	

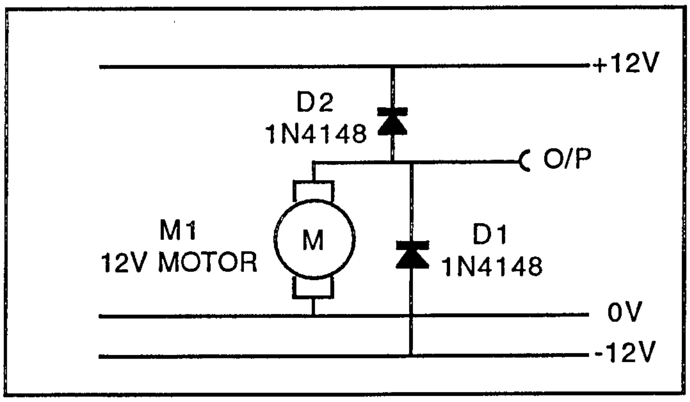
5.5 TACHOGENERATOR

CONSTRUCTION



On the 1750 a small and very efficient D.C. motor is used as a tachogenerator.The diagram above shows the main components removed from the case. The rotating part **(rotor)** consists of four coils carefully formed into a cup shape and securely lacquered together. The eight ends of the coils are connected to the poles of the **commutator** to which electrical contact is made by two spring-loaded carbon **brushes.** The rotor fits over a powerful cylindrical permanent magnet **stator.** When the rotor is turned the coils cut the magnetic field and a voltage is induced which is directly proportional to shaft speed.The commutator ensures that the voltage is always of the same polarity when picked up by the brushes.

CIRCUIT DETAILS



Diodes D1 and D2 clamp commutating spikes to ±12.7V. The output may require low-pass filtering to remove noise.

Continued overleaf

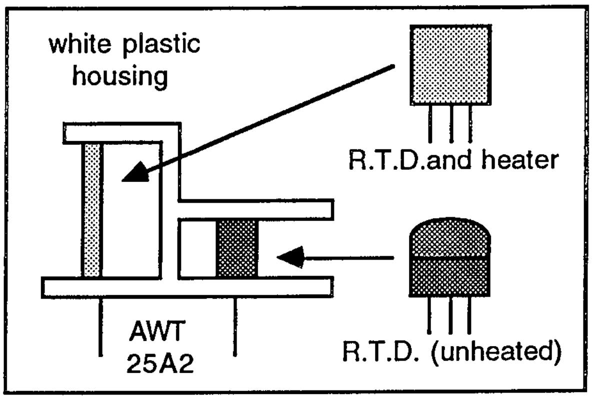
CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Open-circuit O/P voltage	12V to motor		10.5V	
Short-circuit O/P current	12V to motor		750mA	
Output impedance			7Ω	
Output noise			200mV p-p	

SECTION 6: ENVIRONMENTAL SENSORS

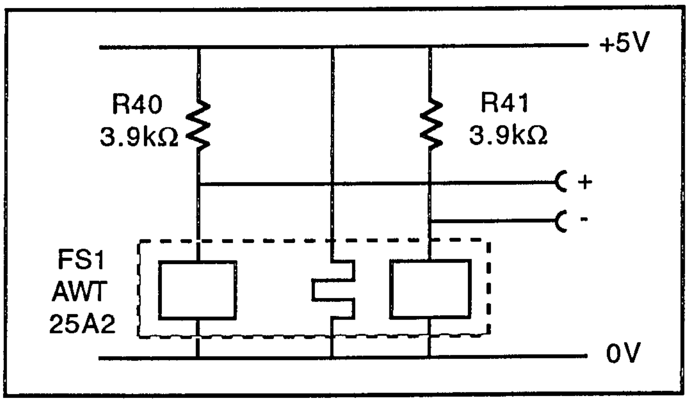
6.1 AIR FLOW SENSOR

CONSTRUCTION



This comprises two **resistance temperature detectors (R.T.D)** with similar properties in a plastic housing. One of the devices is formed with an integral heating element on a thin ceramic substrate. The other is housed in a TO-92 plastic transistor case. The unit is contained within a transparent plastic box with an air supply piped from the pump. It works on the principle that the temperature of the heated sensor will fall much more than that of the unheated reference sensor when air flows over them. The resultant difference in resistance is related to flow rate.

CIRCUIT DETAILS



Both sensors have 3.9kΩ load resistors. The heated sensor drives the (-) output. Since it has a positive temperature coefficient the output voltage will fall when air flows past.

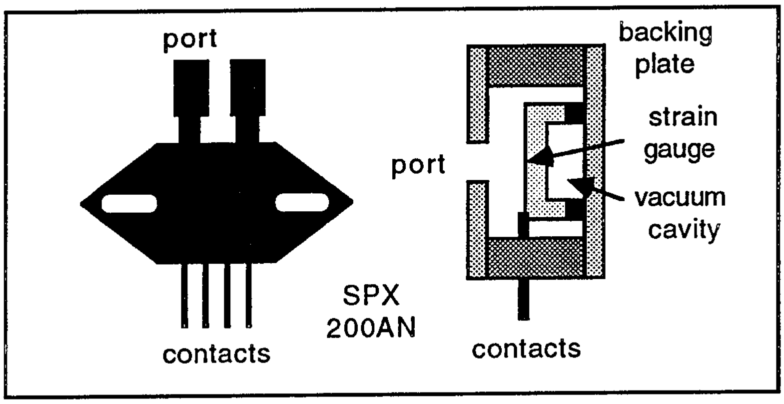
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Heater power			1W	
Output impedance			1.7kΩ	
Output voltage,(-)	pump off		2.1V	
Output voltage,(+)	pump off		1.7V	
Voltage change,(-)	max. air flow		-0.06V	

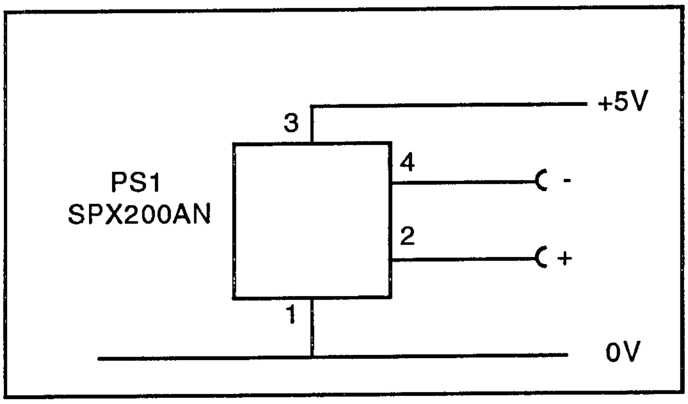
6.2 AIR PRESSURE SENSOR

CONSTRUCTION



This consists of a plastic case enclosing the sensor element. Air from the pump enters via a port. The construction of the sensor is shown on the left. The element is a strain gauge constructed from resistors etched in a Wheatstone bridge pattern. This is mounted in front of a cavity from which the air has been evacuated. The sensor will therefore be stressed by an amount which will vary with barometric pressure and altitude in addition to any change due to the pump. This type of sensor is termed an **absolute pressure transducer.**

CIRCUIT DETAILS



No external components are required. The output voltage will show a permanent differential which varies with barometric pressure and altitude.

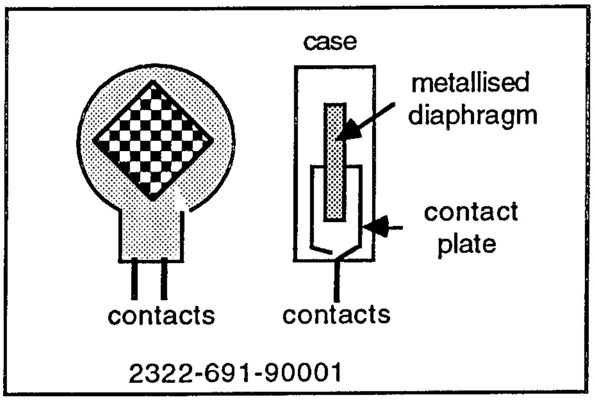
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Sensitivity		200µV/kPa	300µV/kPa	425µV/kPa
Repeatability			±0.5%	
Temperature coefficient			1350ppm/•C	
Output impedance			1.6kΩ	
Output voltage,(-)	pump off		2.48V	
Output voltage,(+)	pump off		2.51V	
Voltage difference	pump off		35mV	
Voltage difference	pump on		39mV	

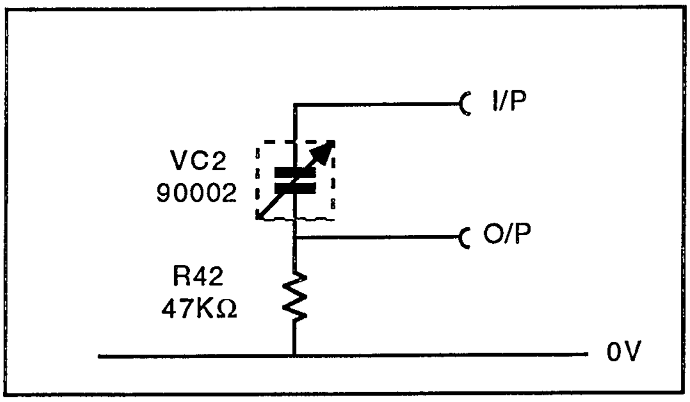
6.3 HUMIDITY SENSOR

CONSTRUCTION



This device comprises a very thin diaphragm constructed from a special dielectric material whose properties change with atmospheric humidity. The diaphragm is metallized on both sides to form a capacitor which changes in value with the dampness of its surroundings. The element is housed in a slotted plastic case.

CIRCUIT DETAILS



The sensor forms a potential divider with R42. When an alternating voltage is applied to the input an output voltage of the following form is obtained:

$$V_{OUT} = \frac{R}{\sqrt{R^2 - \frac{1}{\omega^2 C^2}}} V_{IN}$$

ω is 251,327 at 40kHz
R is R42 (47kΩ)
C is the sensor capacitance (120pF approx.)

Continued overleaf

The humidity around the sensor can be increased by breathing on the device. It is slow to respond, taking several minutes to stabilize. This is of no consequence in practice as natural changes in humidity are very slow.

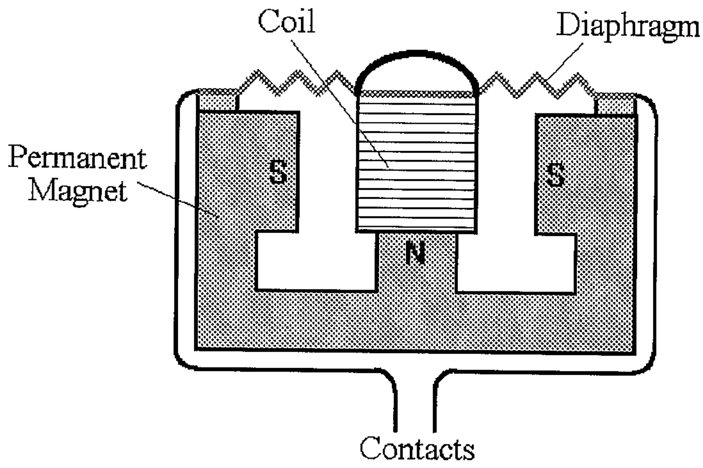
CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Capacitance	25°C,45% R/H		122pF	
Sensitivity			0.4pF/% R/H	
Humidity range		10% R/H		90% R/H
Output voltage	typical ambient		340mV	
Output voltage change	after breath		20mV	

SECTION 7: SOUND SENSORS

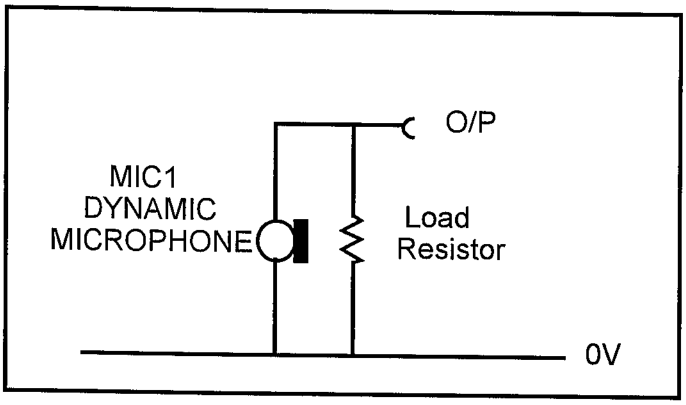
7.1 DYNAMIC MICROPHONE

CONSTRUCTION



The dynamic microphone operates on the principle that a magnet moved within a coil generates a voltage. In this case the magnet is fixed and the coil is the moving part. The coil is attached to a thin diaphragm which moves in response to sound vibrations in the air.The resulting alternating voltage is supplied to the contacts via very fine wires running along the diaphragm.

CIRCUIT DETAILS



The microphone used on the 1750 has a nominal coil impedance between 200 - 600Ω and it is important to match this correctly to meet the frequency response specification. Matching is performed by a load resistor. The AC amplifier on maximum gain will be required to obtain a useful signal. Owing to its proximity to the power transformer a certain amount of interference at power line frequency (or harmonics of it) will be induced.

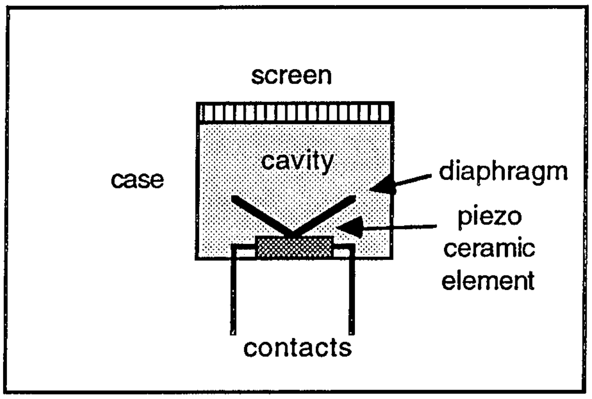
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Output impedance			200 - 600Ω	
Frequency response	-3dB	100Hz		10000Hz
Output voltage	order of mag.		5mV	

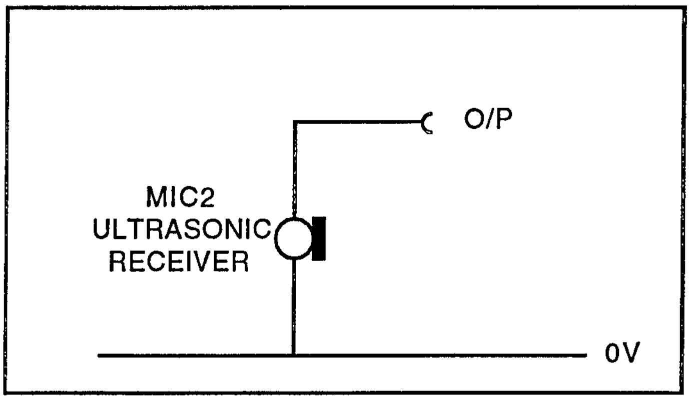
7.2 ULTRASONIC RECEIVER

CONSTRUCTION



The ultrasonic receiver operates on the **piezo-electric** principle. The piezo-electric effect is a property of certain crystals whereby a voltage is generated across the facets when the material is stressed. Certain synthetic ceramics such as lead zirconate titanate also exhibit this effect. In the ultrasonic receiver the element is fixed to a small diaphragm inside the cavity of the sensor. The dimensions of all the component parts are optimized so that the diaphragm shows a strong resonance around 40kHz.

CIRCUIT DETAILS



The ultrasonic receiver is mounted in close proximity to the ultrasonic transmitter on the PCB and this results in direct pickup of signals through the board. When an object moves towards the pair the reflected signal is Doppler-shifted so that its frequency changes slightly. The result is a low-frequency modulation of the received signal which can be filtered out and used to detect movement. The receiver has a high output impedance.

Continued overleaf

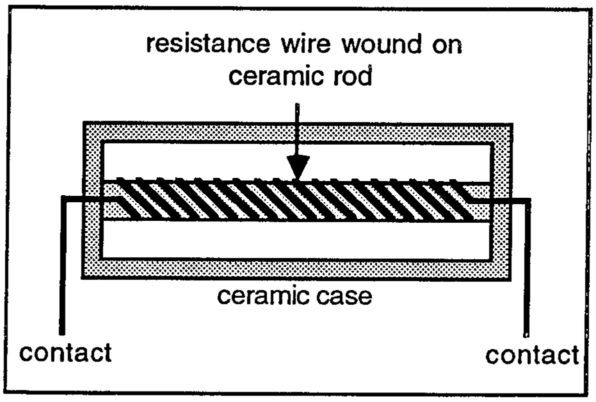
CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Peak resonance		39kHz	40kHz	41kHz
Sensitivity			-65dB	
Directional angle			20°	
Impedance			30kΩ	
Output amplitude	order of mag.	5mV		60mV

OUTPUT TRANSDUCERS

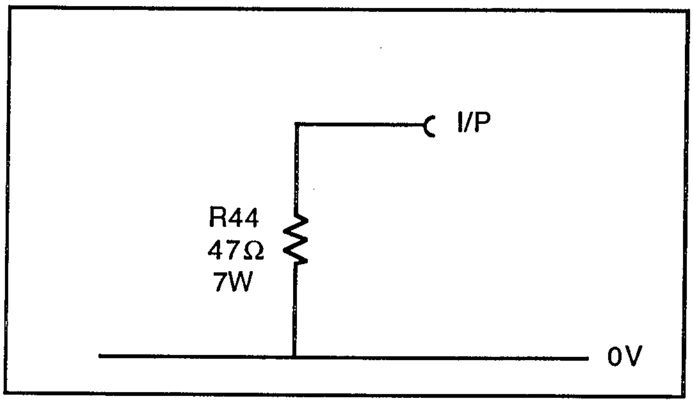
SECTION 8.1: HEATER

CONSTRUCTION



The heater employed by the 1750 is a 47Ω wirewound resistor. Its construction is identical to many industrial heating elements; it consists of a ceramic rod on which is wound a coil of resistance wire made from a poorly-conducting alloy such as Nichrome or Constantan. The assembly is sealed inside a ceramic case. On the 1750 the heater resistor is mounted inside a clear plastic cover with some temperature sensors.

CIRCUIT DETAILS



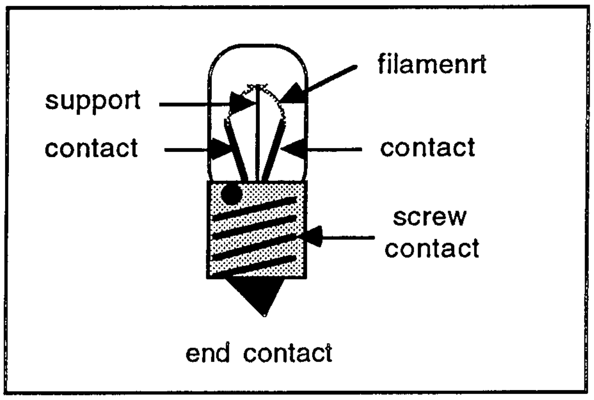
With the maximum applied voltage of 12V the output power will be 3W. The temperature rises to about 40°C above ambient, taking about 5 minutes before levelling out.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Resistance		45Ω	47Ω	49Ω
Power output	R=47Ω,V=12V		3.06W	
Temperature rise	above ambient		40°C	

SECTON 9.1: FILAMENT LAMP

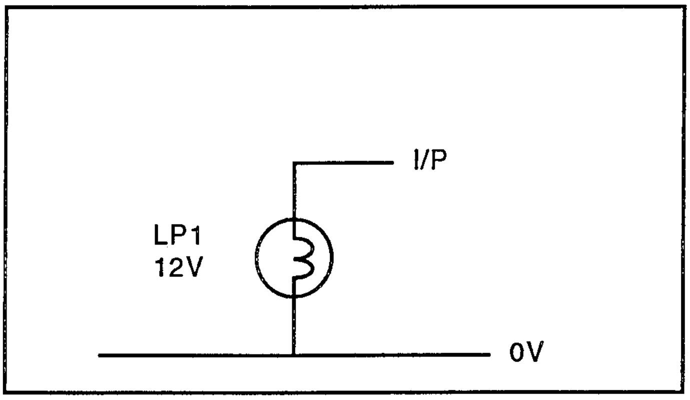
CONSTRUCTION



The lamp uses a very fine tungsten filament supported in a mixture of nitrogen and argon gas under low pressure in a glass bulb. The resistance of the filament rises dramatically with increasing temperature and therefore the power dissipation tends to be self-limiting.

The lamp on the 1750 is fitted in a panel-mounting holder with clear bezel and housed within a clear plastic compartment containing the light sensors.

CIRCUIT DETAILS

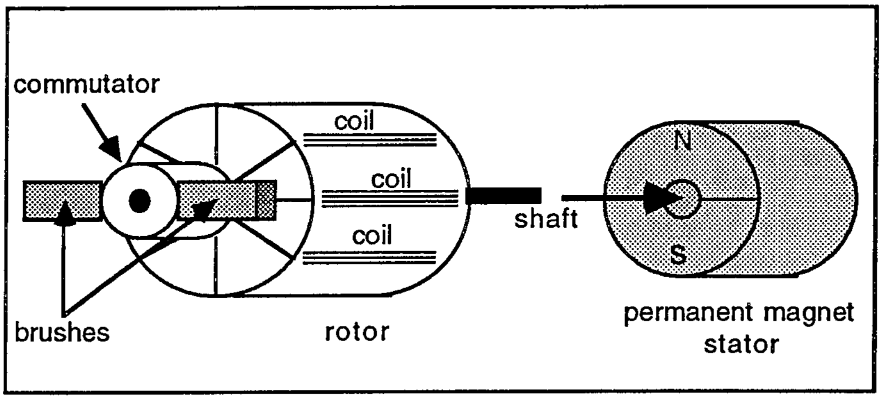


CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Rated voltage			12V	
Rated power			1W	
Resistance	open-circuit		17Ω	
Resistance	5V applied		110Ω	
Resistance	12V applied		160Ω	

SECTION 10.1: D.C. MOTOR

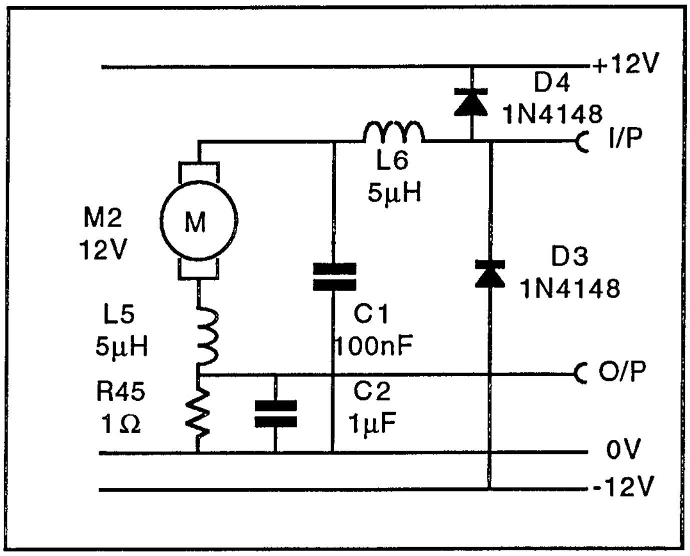
CONSTRUCTION



The D.C. motor employed by the 1750 is identical to the unit which was described in its other guise as a tachogenerator. In this application current is supplied to the coils via the brushes and commutator and this causes forces to be exerted on the rotor which make it spin. Please refer to **section 5.5,Tachogenerator** for a fuller description of the component parts. Note the very high efficiency shown in the table of characteristics.

The motor drives a shaft running along the top of the motherboard. This shaft carries disks which operate various transducers.

CIRCUIT DETAILS



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The motor current passes through R44 and develops a voltage across it which is proportional to the torque loading. C2 provides a small amount of noise filtering.L5 ,L6 and C1 reduce radiated R.F. noise and D3 and D4 clamp commutating spikes The voltage across R45 is accessible via the **O/P** socket.

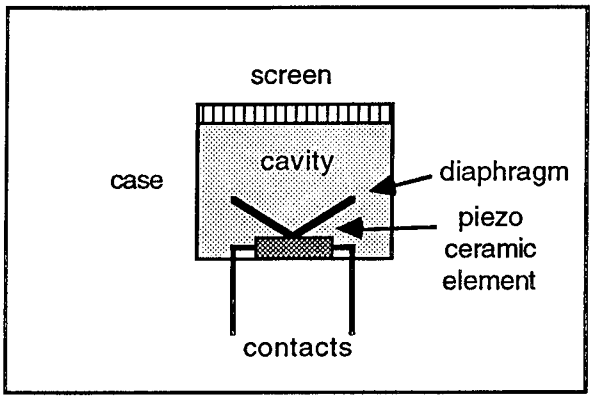
CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
D.C. resistance			6.2Ω	
No-load current	12V applied		120mA	
Stall current	12V applied		1.93A	
Shaft speed	12V,no load			2400rpm
Starting torque			7Ncm/A	
Torque constant			3.5Ncm/A	
Time constant			19.6ms	
Efficiency			70%	82%

SECTION 11: SOUND OUTPUT DEVICES

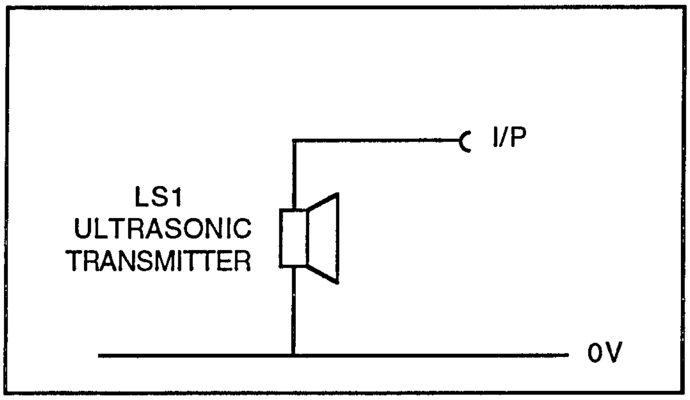
11.1 ULTRASONIC TRANSMITTER

CONSTRUCTION



The ultrasonic transmitter contains a piezo-electric element similar to that in the receiver described previously. However, the transmitting device has a lower impedance to permit greater output power for a given input voltage (the devices will in fact work in reverse, but not very well!). Please refer to **section 7.7,Ultrasonic receiver.**

CIRCUIT DETAILS



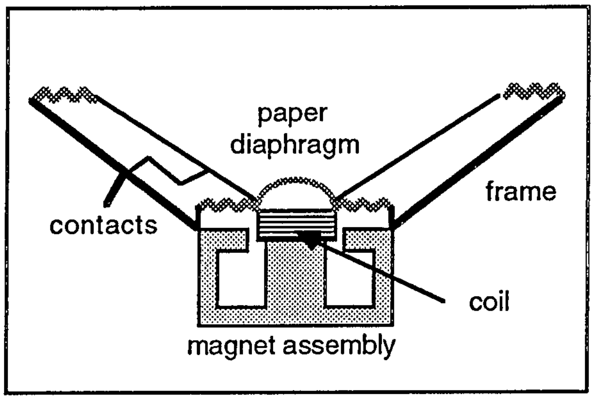
The device should be driven directly by the 40kHz oscillator.

CHARCTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Peak resonance		39kHz	40kHz	41kHz
Directional angle			20°	
Input impedance			500Ω	
Sensitivity			106dB	

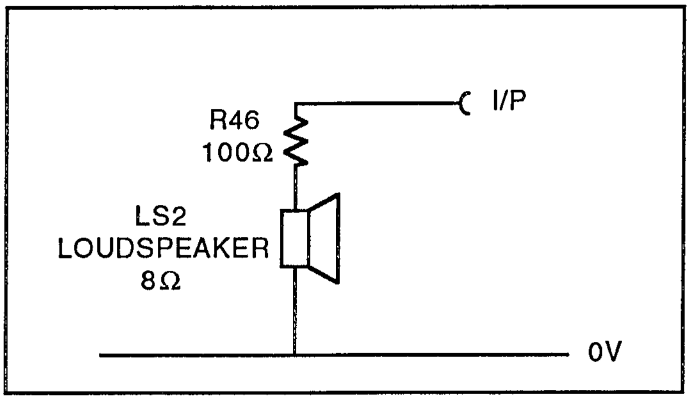
11.2 LOUDSPEAKER

CONSTRUCTION



The moving-coil loudspeaker is in many ways a complementary device to the dynamic microphone. The coil is attached to a diaphragm which is extended into a large paper cone supported on a frame. When an electrical signal is applied to the coil a magnetic field is generated. Depending on whether this opposes or reinforces the field from the permanent magnet , the coil will move in or out of the magnet poles carrying the cone with it. If the loudspeaker is fed by an alternating current of between 50-16,000Hz an audible tone will be produced.

CIRCUIT DETAILS

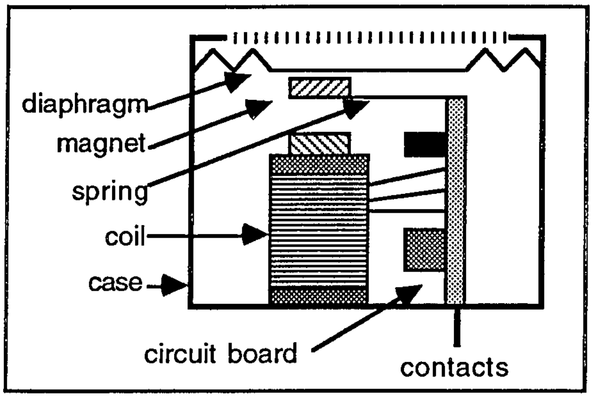


LS2 is an 8Ω, 200mW loudspeaker with the maximum power dissipation limited to 98mW by R46.

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Impedance			8Ω	
Power rating			100mW	200mW
Frequency response	-3db	400Hz		5kHz

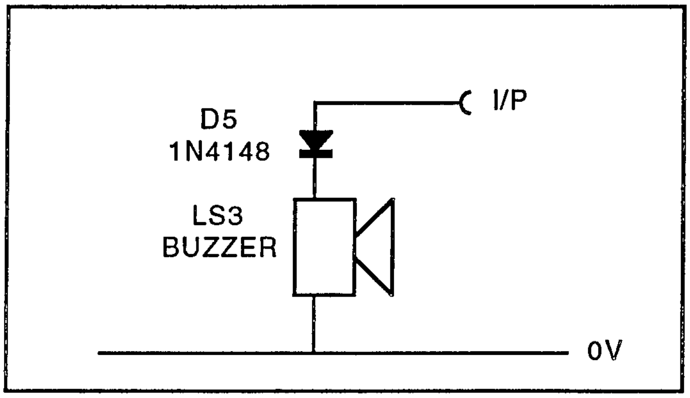
11.3 BUZZER

CONSTRUCTION



There are many different kinds of buzzer. The device used by the 1750 employs a small transistorized oscillator to generate an alternating magnetic field in a coil. This coil has an iron pole-piece which attracts and repels a small permanent magnet attached to a spring. The magnet vibrates against a diaphragm and creates a very loud noise.

CIRCUIT DETAILS



LS3 is a 12V buzzer. Diode D5 is included to protect against reverse voltages.

Continued overleaf

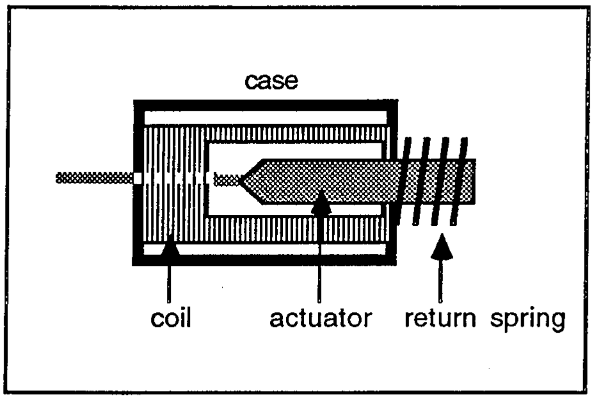
CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Supply voltage	recommended	8V	12V	16V
Supply current	12V applied		11mA	18mA
Frequency		350Hz	400Hz	450Hz
Output	12V,3m away		80dB	

SECTION 12: LINEAR MOTION ACTUATORS

12.1 SOLENOID

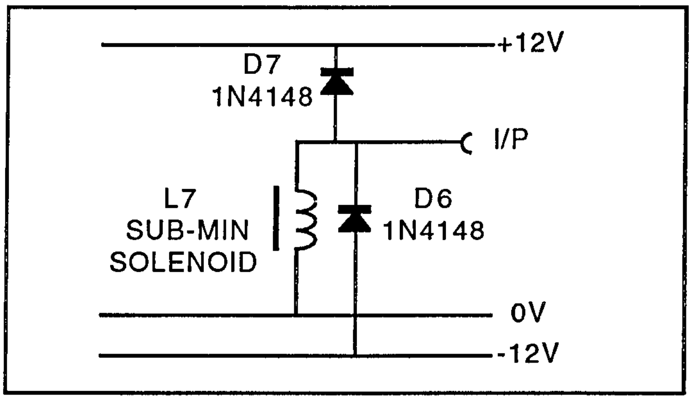
CONSTRUCTION



The solenoid takes many different forms. The unit used on the 1750 is a miniature pull-in type. The actuator is a soft iron core which moves inside a high-inductance coil. When the coil is energized the core becomes magnetized in the opposite sense and this causes it to be attracted into the solenoid. When power is removed the core is released by a return spring. A pillar limits the travel on the 1750.

Note that when any coil is open-circuited a large reverse voltage (back e.m.f.) spike is generated and steps must be taken to prevent damage to the driver circuitry. This is usually done with diodes.

CIRCUIT DETAILS



Diodes D6 and D7 clamp the back E.M.F. when power is removed.

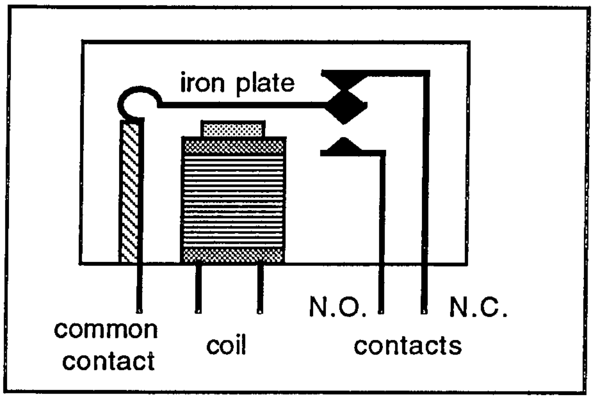
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX
Coil resistance			50Ω	
Coil power	12V applied		3W	
Pull-in voltage			6V	
Release voltage			0.8V	

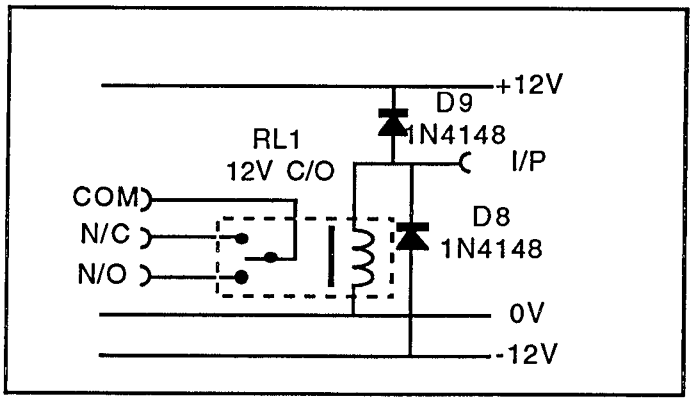
12.2 RELAY

CONSTRUCTION



A miniature changeover relay is used on the 1750. It has a common terminal which is attached to a springy contact strip. The **common** contact is on the end of this strip and is held against the **normally closed (N.C.)** contact by the spring. When power is applied to the coil it attracts the iron plate and causes the common contact to engage the **normally open (N.O.)** contact. The contacts 'bounce' for a short period each time they **make** and **break**.

CIRCUIT DETAILS



Back E.M.F. spikes when power is removed are clamped by D8 and D9.

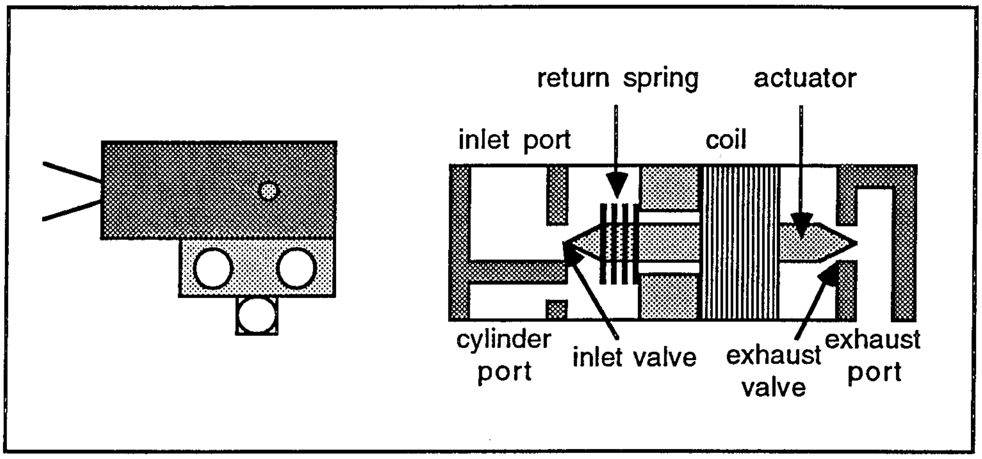
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Coil voltage	proper operation	8.4V	12V	14.4V
Coil resistance			320Ω	
Contact rating	switching 12V			1A
"Operate" voltage			7.5V	
"Release" voltage			1.8V	
Operate/release time	12V applied			5mS
Lifetime,cycles		5×10^6		

12.3 SOLENOID VALVE

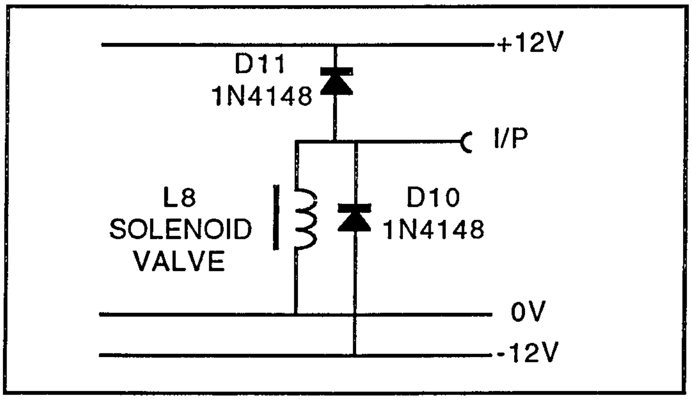
CONSTRUCTION



A much-simplified diagram of the air valve is shown above. An actuator operates one of two valves. With no current in the coil the actuator is forced against the inlet valve by a spring. Air can now flow back through the cylinder port and leave via the open exhaust valve and port. If the coil is now energized the actuator is pulled to the right, closing the exhaust port and opening the inlet port. Air can now enter via the inlet port and proceed to the cylinder port.

On the 1750 the inlet port is connected to the pump and the cylinder port to a pneumatic actuator.

CIRCUIT DETAILS



L8 is a 12V solenoid valve. Back E.M.F. spikes are clamped by D10 and D11.

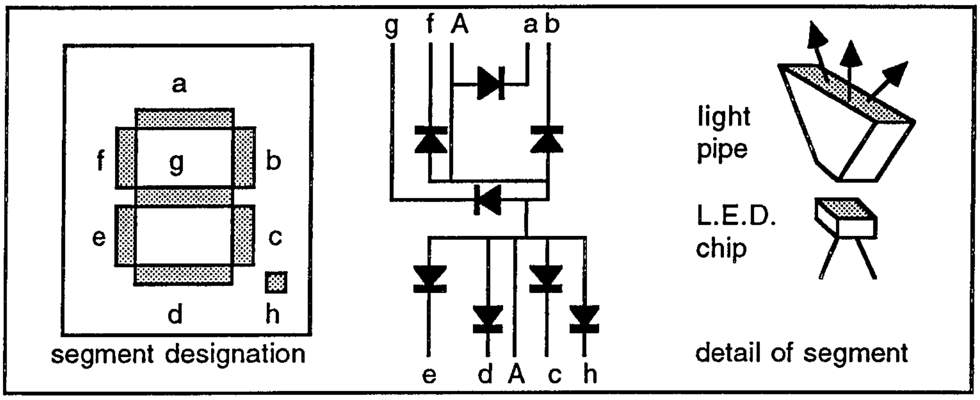
Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Coil voltage		10.8V	12V	13.2V
Coil resistance			140Ω	
'Operate' voltage			8.3V	
'Release' voltage			1.7V	

SECTION 13.1: COUNTER/TIMER USING SEVEN-SEGMENT DISPLAYS

CONSTRUCTION OF THE SEVEN-SEGMENT DISPLAY

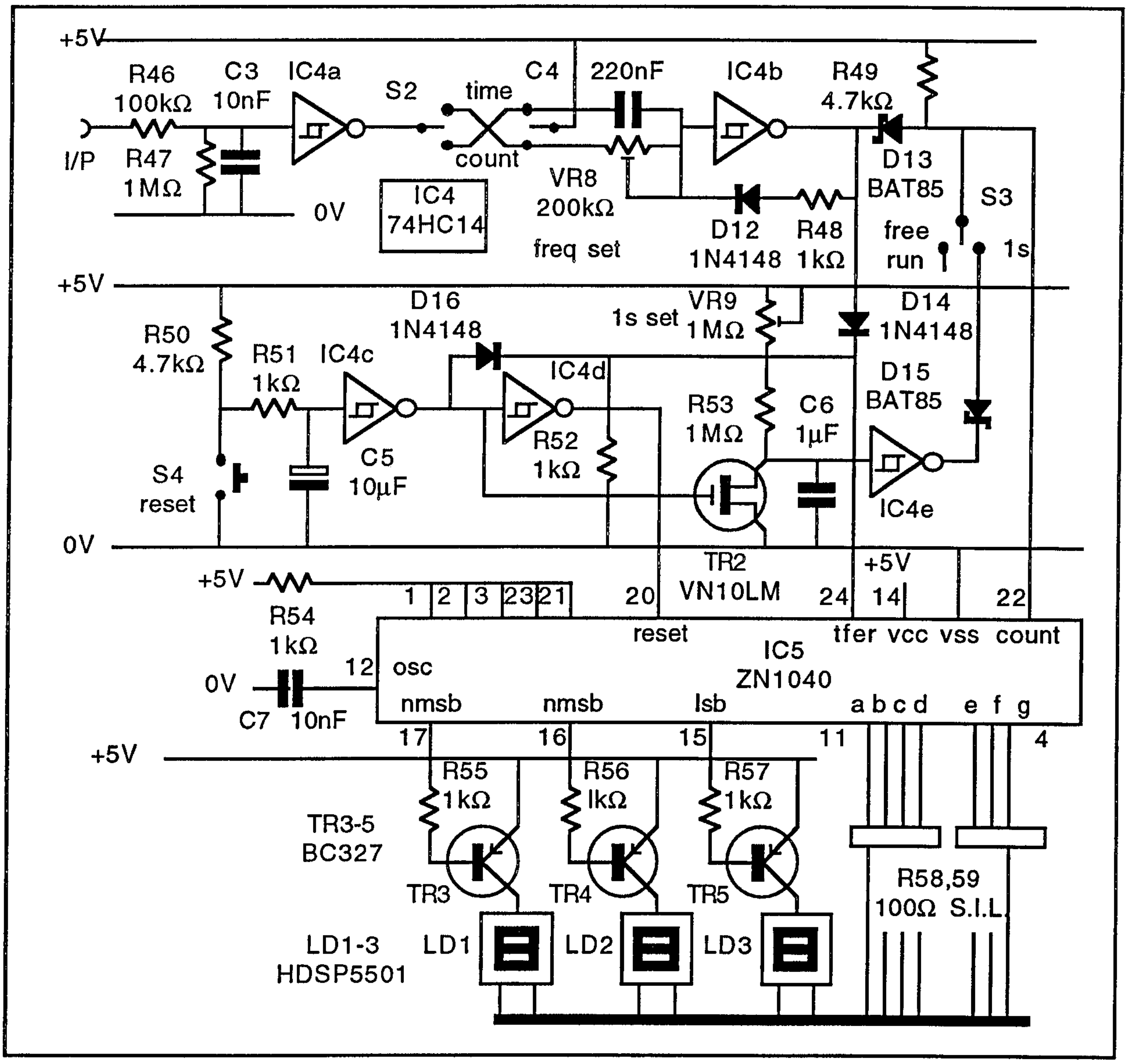


A seven-segment display uses an array of light-emitting diodes to produce the numerals 0-9 and other characters. The standard segment lettering is shown on the left and the corresponding pattern of diodes in the center. Note how all the anodes are joined; this is a **common-anode** display. The visible segments are the ends of translucent plastic light-pipes which funnel up the light from the L.E.D. chips in the base of the display.

L.E.D's were encountered with the slotted and reflective opto sensors; visible L.E.D's employ semiconductor alloys of gallium,arsenic and phosphorus in varying proportions. Changing the constituents determines the color in the range infra-red to green.

Continued overleaf

CIRCUIT DETAILS



This unit is not a transducer in the accepted sense, although it does use L.E.D. seven-segment displays. However, the counting of events and the measurement of time are often important considerations when working with transducers. This unit provides three basic functions; counting up to 999 events,counting number of events in one second and timing an event in multiples of 10ms. A single active-high input is provided and count/time are shown on three seven-segment L.E.D. displays.

Continued overleaf

IC4a buffers the input signal. R47 keeps the input low with no applied signal. R46 allows the input to go outside the 0V/+5V rails and C3 removes unwanted signals such as switch bounce. The output of IC4a goes low when the input is taken high. The signal passes via S2 to IC4b. This part of the circuit behaves quite differently when the switch position is changed.
When S2 is in the **count** position signals are fed to IC4b via C4 while VR8 is connected to +5V. In this situation each falling edge from IC4a generates a spike on the input of IC4b which is converted to a positive pulse on the output.

When S2 is in the **time** position C4 is connected to 5V and signals are fed via VR8. The circuitry around IC4b now functions as a pulse train generator as long as the output of IC4a is low. C4 charges through VR8 until the threshold of IC4b is reached, whereupon its output changes state and rapidly discharges C4 through D12 and R48. The cycle then repeats. VR8 is used to set the output frequency to 100Hz.

IC5 is the counter/timer I.C. The **count** input is fed by IC4b via D13 and IC5 counts up on the rising edge. The **transfer** pin is also driven by IC4b via D14 and the count is transferred to the display while high.

S4 is the **reset** push-button. IC4c,IC4d and associated components provide a debounced **reset** signal for IC5. D16 and R52 allow the display to be zeroed when IC5 is reset.

When S4 is pressed , TR2 is turned on, discharging C6. The output of IC4e goes high. When S3 is in the **free run** position it has no effect but when on **1s** the output is ANDed with the **clock** signal. When S4 is released, C6 starts to charge through R53 and VR9. Clock pulses are allowed through to IC5 until the output of IC4e goes low. VR9 is adjusted so that IC5 counts for one second each time S4 is pressed with S3 in the **1s** position.

The remaining circuitry drives the L.E.D. displays. The pins labelled **LSB** and **NMSB** drive the common anodes of DSP1-3. Multiplexing is performed inside IC5 by an oscillator whose frequency is controlled by C7. The display cathodes **a-g** are driven directly by IC5 via 100Ω resistor packs R58 and R59.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Count rate	TTL levels		0-500Hz	600Hz
Timing accuracy		-5%		+5%

Continued overleaf

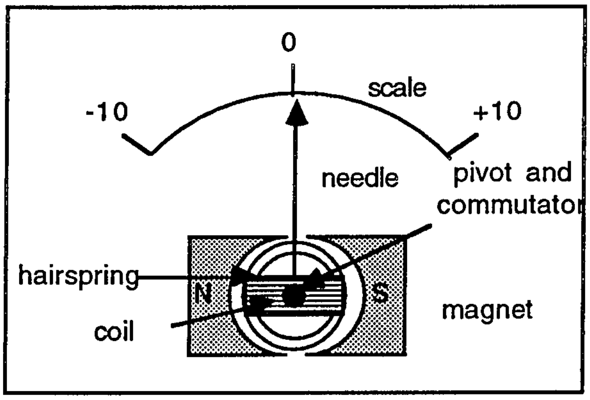
SETUP PROCEDURE

Connect the counter/timer I/P to +5V. Switch to **TIME** and **FREE RUN.** The display should start to increment. Have a stopwatch ready and **RESET** both units. The most significant display should change from 4 to 5 after five seconds. Adjust the preset marked **VR8** on the daughterboard and repeat the **RESET** procedure until the display agrees with the stopwatch. Switch to **1s** and press **RESET.** The display should advance then stop. Repeat the procedure and adjust the preset marked **VR9** until the display stops on 100.

SECTION 14: VOLTAGE DISPLAY DEVICES

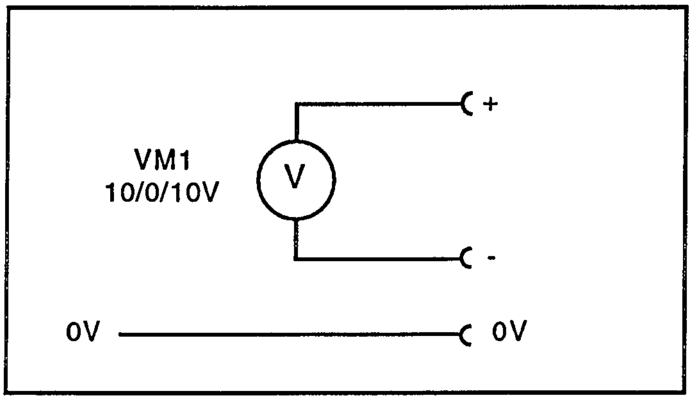
14.1 MOVING COIL METER

CONSTRUCTION



The unit employed by the 1750 is a -10 / 0 / +10V center-zero moving-coil meter. A pivot supports a coil in a magnetic field and also supplies current to the windings. The coil is held in its central position by a hairspring. When the coil is energized a turning force is induced which works against the spring to produce a deflection proportional to current. The meter scale is traversed by a needle which is attached to the coil.A moving-coil voltmeter is actually an ammeter with a suitable series **multiplier** resistor. The 1750 instrument is a ±500µA meter with a 10kΩ multiplier resistor.

CIRCUIT DETAILS



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CHARACTERISTICS

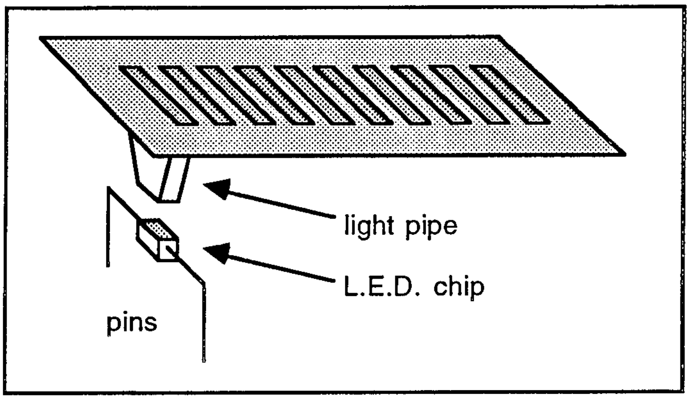
PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Applied voltage		-15V	-10...+10V	+15V
D.C. resistance			19.16kΩ	
Full-scale current		-500μA		500μA
Accuracy			1.5%	

SETUP PROCEDURE

A screw just below the meter scale should be adjusted so that the needle is pointing to zero with no applied voltage.

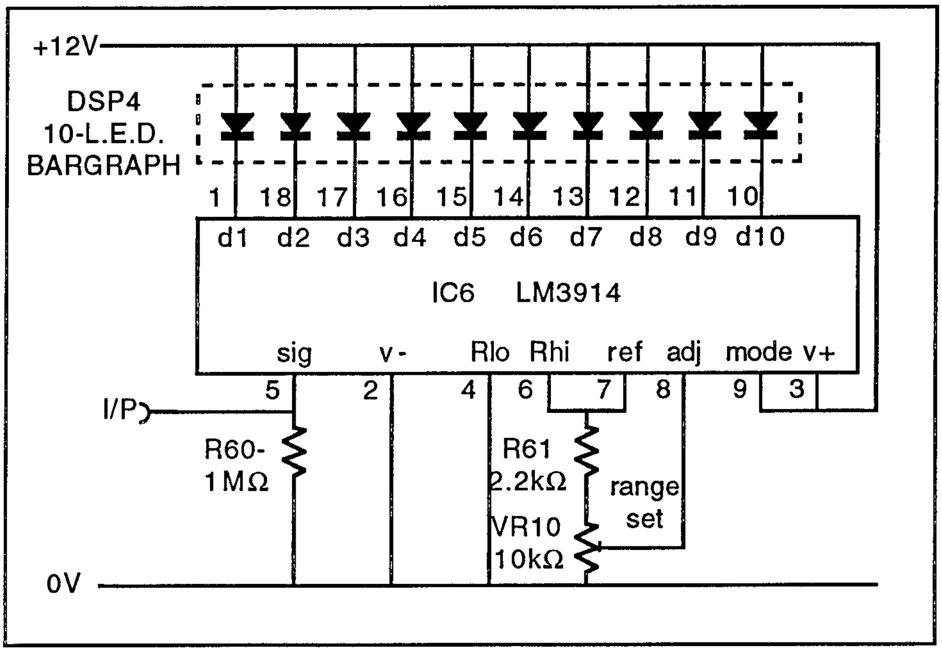
14.2 L.E.D. BARGRAPH DISPLAY

CONSTRUCTION OF BARGRAPH



This consists of ten gallium arsenide/phosphide light-emitting diodes in a 20-pin I.C. package. The light from each chip is collected by a light-pipe and emitted as a bar.

CIRCUIT DETAILS



IC6 (LM3914) is a dedicated bargraph driver chip. It compares the input voltage with ten internal references and turns on the corresponding number of L.E.Ds. R60 grounds the input with no signal applied. R61 sets the display current and VR10 sets the voltage increment between L.E.Ds.

Continued overleaf

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage range		-35V		35V
Accuracy				2%
Segment overlap			1mV	

SETUP PROCEDURE

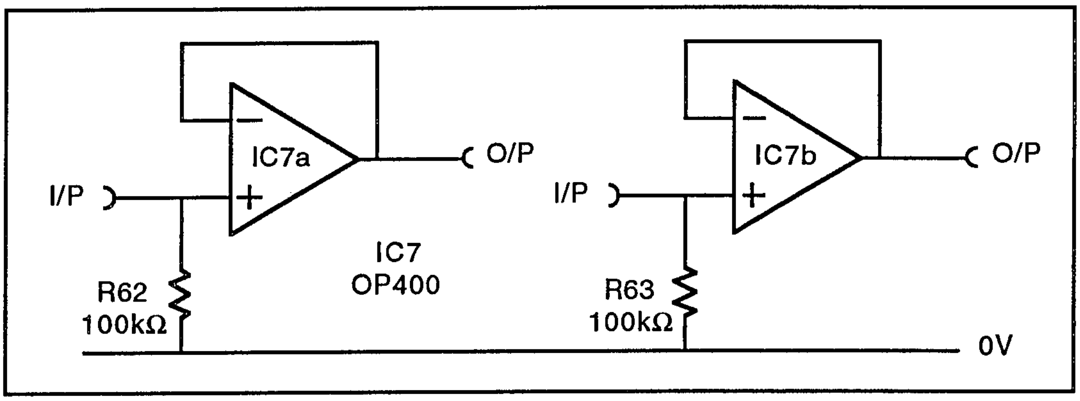
Connect **I/P** to +5V and adjust VR10 until the last segment is just lit.

SIGNAL-CONDITIONING CIRCUITRY

SECTION 15: AMPLIFIERS

15.1 BUFFER #1
15.2 BUFFER #2

CIRCUIT DETAILS

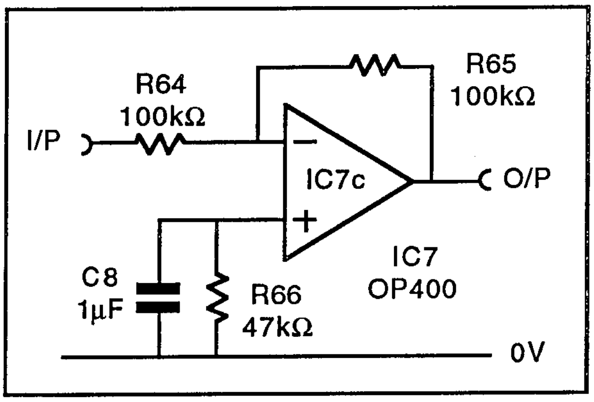


IC7a and IC7b are wired as unity-gain buffers with the outputs connected to the inverting inputs. The circuit performs the task of changing an input signal from high to low impedance while keeping all its other characteristics. The very high input impedance is reduced to 100kΩ by R62 and R63.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-9V...+9V	+12V
input offset voltage				300µV
Input impedance			100kΩ	
Voltage gain			1.00	

15.3 INVERTER



CIRCUIT DETAILS

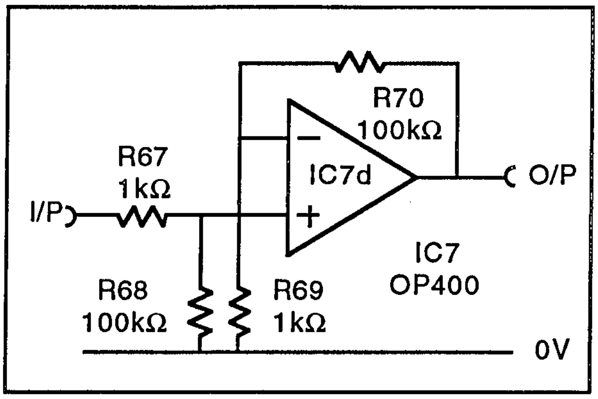
IC7c is in the normal inverter configuration with input resistor R64 and feedback resistor R65. Since these are of equal value the gain will be -1. R66 balances the input current and C8 removes unwanted signals.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-9V...+9V	+12V
input offset voltage				300µV
Voltage gain	1% resistors	-0.98	-1.00	-1.02
Input impedance			100kΩ	

15.4 x100 AMPLIFIER

CIRCUIT DETAILS



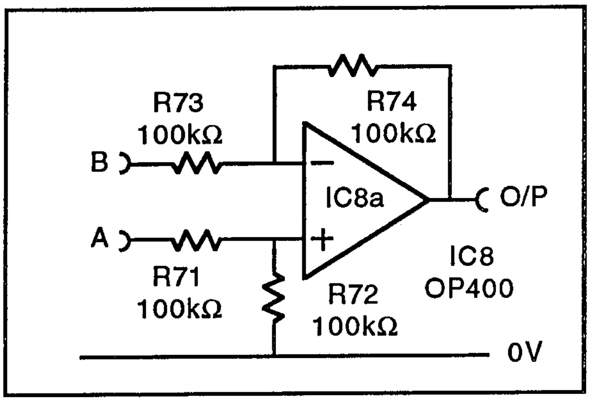
IC7d is wired in the configuration of a non-inverting amplifier. If R67 were omitted the gain would be **1 + R70 / R69**, i.e. 101. However, R67 and R68 provide an attenuation of **R68 / (R68+R69)**, i.e. 100/101. The total gain is therefore the product of these which is 100.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-9V...+9V	+12V
Output voltage	input grounded			30mV
Voltage gain	1% resistors	96	100	104
Input impedance			101kΩ	

15.5 DIFFERENTRIAL AMPLIFIER

CIRCUIT DETAILS



IC8a is wired in the standard differential amplifier configuration. If the voltage on **A** is held constant while **B** is varied the gain will be **- (R74 / R73)**, i.e. -1. If **B** is now held constant and **A** varied the gain will be:

(R72 / (R71 + R72)) x (1 + (R74 / R73)) = +1.

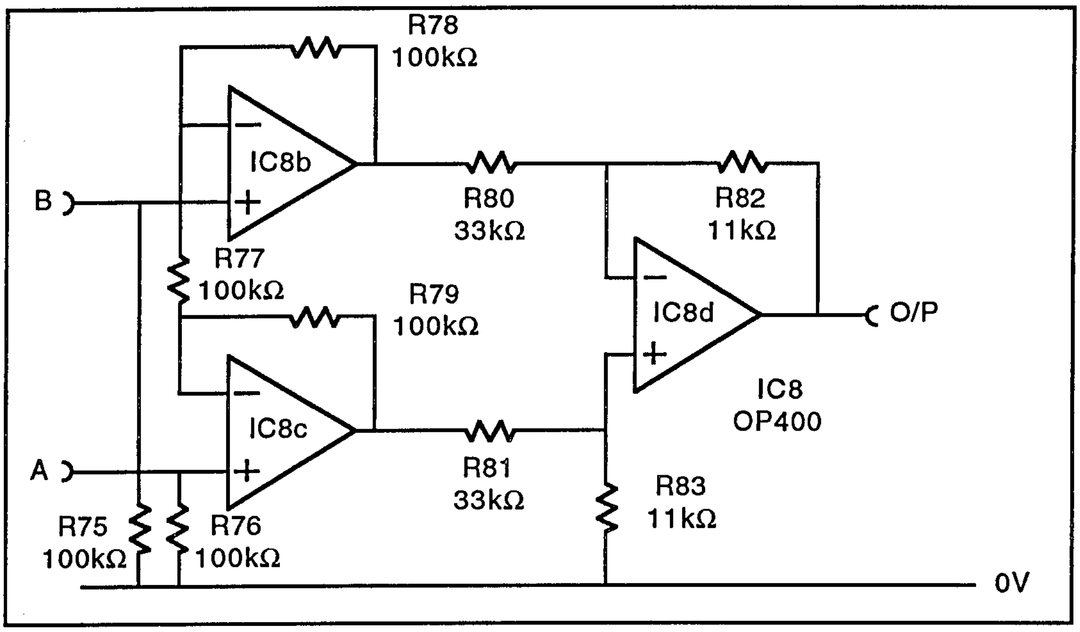
By superposition it can be shown that the output voltage is simply $V_A - V_B$. From this it would appear that if both inputs varied by the same amount the output voltage would not change. However, inaccuracies in the values of the resistors results in a small residual **common mode gain.**

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-9V...+9V	+12V
Differential gain	1% resistors	0.98	1.00	1.02
Common-mode gain	1% resistors	-0.02	0	0.02
Input impedance	Input B		100kΩ	
Input impedance	Input A		200kΩ	

15.6 INSTRUMENTATION AMPLIFIER

CIRCUIT DETAILS



This is one of the standard configurations for an instrumentation amplifier. It is basically a differential amplifier but it scores over circuit 15.5 on several counts; it presents the same impedance on both inputs and the common-mode gain is typically three times lower.

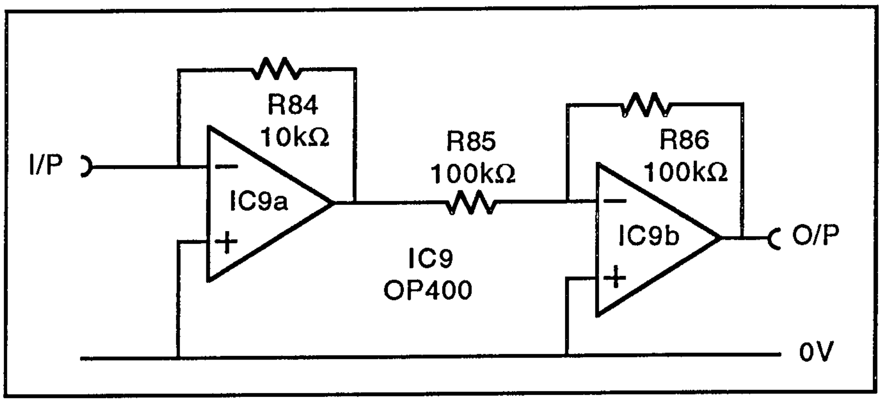
The input signals are applied to **A** and **B** which both have 100kΩ resistors to 0V, thereby ensuring equal input impedances. The unusual arrangement of IC8b and IC8c produces two outputs whose difference is three times the difference in input voltage. This can be shown in a simple example. If **A** were at some voltage V_A and **B** were held at 0V there would be V_A volts on the inverting input of IC8b by op-amp action. Similarly there would be 0V on the inverting input of IC8c. There would therefore be V_A volts across **R77**. The current flowing in R77 must also flow through R78 and R79 and therefore the op-amp outputs must differ by $3V_A$. A detailed analysis shows that the factor of 3 is maintained for differential input voltages. The arrangement has zero common mode gain. The second stage around IC8d is a standard differential amplifier with a gain of 1/3. The common-mode gain is reduced over circuit 15.5 by a factor of three.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-9V...+9V	+12V
Differential gain	1% resistors	0.98	1.00	1.02
Common-mode gain	1% resistors	-0.006	0	0.006
Input impedance	Input B		100kΩ	
Input impedance	Input A		100kΩ	

15.7 CURRENT AMPLIFIER

CIRCUIT DETAILS



This circuit, which is intended primarily for use with the P.I.N. photodiode, is strictly-speaking a current-to-voltage converter. If a current $\mathbf{I_{IN}}$ is fed into the input the output of IC9a will be $\mathbf{-I_{IN} \times R84}$. This is inverted by IC9b to provide a final output:

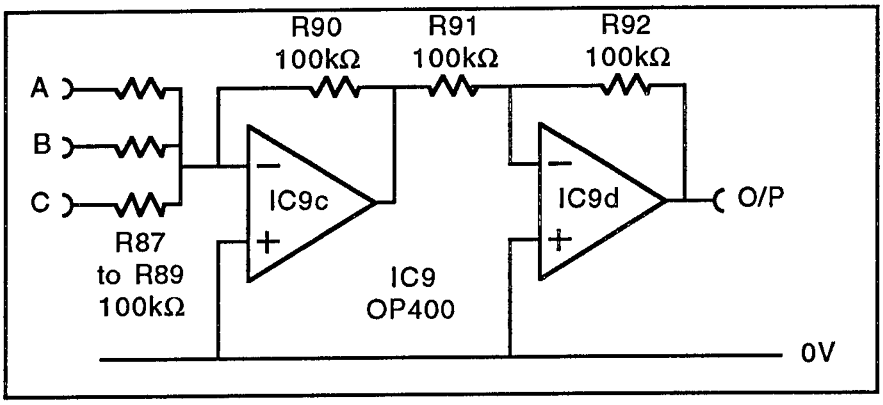
$$V_{OUT} = 10^4 I_{IN}$$

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-9V...+9V	+12V
Input current	before saturation			1mA
Transfer ratio		9700	10000	10300

15.8 SUMMING AMPLIFIER

CIRCUIT DETAILS



IC9c is a conventional inverting summer providing an output of **- ($V_A + V_B + V_C$).** This is inverted by IC9d so that :

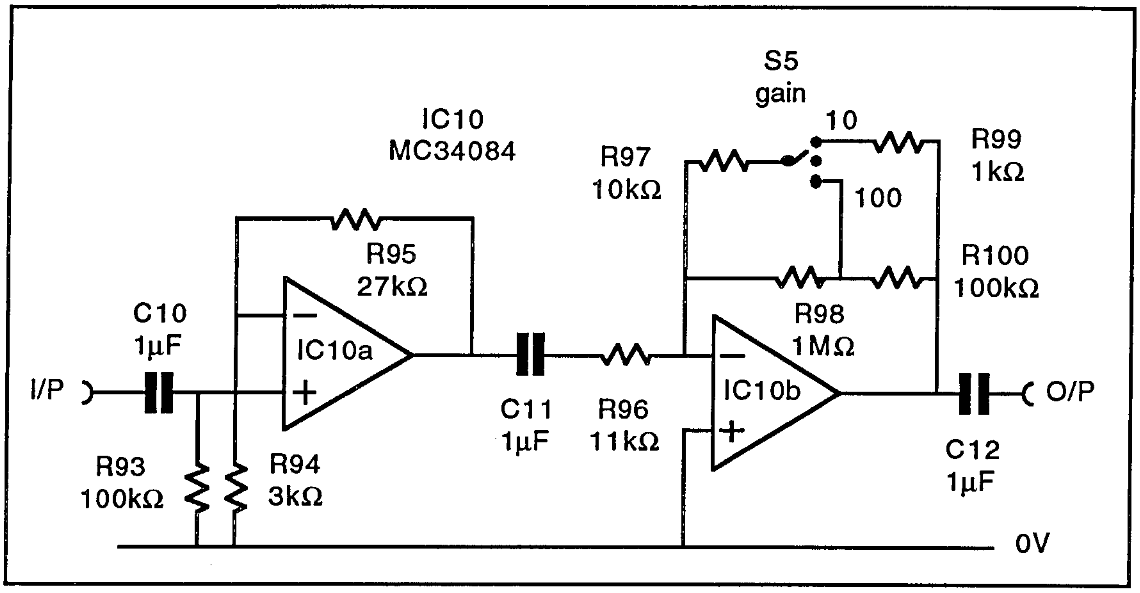
$$V_{OUT} = V_A + V_B + V_C$$

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-9V...+9V	+12V
Voltage gain		0.96	1.00	1.04

15.9 A.C AMPLIFIER

CIRCUIT DETAILS



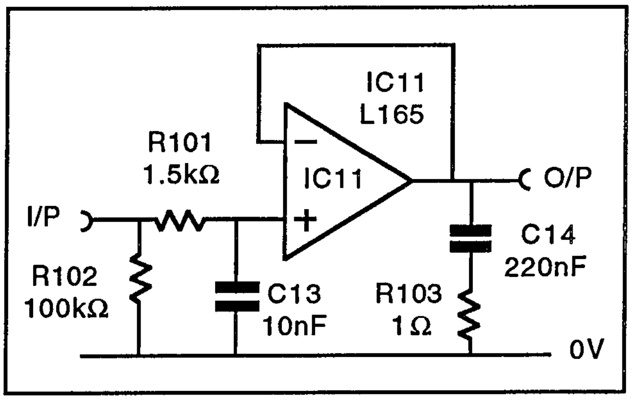
This two-stage amplifier is capacitor-coupled throughout and can therefore amplify signals with large D.C. offsets. The use of high-frequency op-amps permits operation at 40kHz although some gain reduction is inevitable. The signal enters via C10 and is amplified by IC10a. This stage has a fixed gain of 10. The output passes to the second stage via C11. Switch S5 provides three switched gain values 10, 1000 and 100 by selecting different resistors in the feedback network. C12 removes any D.C. offset from the output.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-8V...+8V	+12V
-6dB bandwidth	Switch = 1000	10Hz		16kHz
Gain at 40kHz	Switch = 1000		225	
Output noise voltage	Switch = 1000		100mV	

15.10 POWER AMPLIFIER

CIRCUIT DETAILS



IC11 is a power operational amplifier in a five-pin TO-220 plastic case. It requires a heatsink and for this reason the circuit is included on the power supply P.C.B. with connection made to the motherboard by a five-way cable. IC11 is configured as a unity-gain buffer. C14 and R103 are a **Zobel network** and are essential for stability. R101 and C13 form a filter with a 10kHz break to attenuate 40kHz signals.

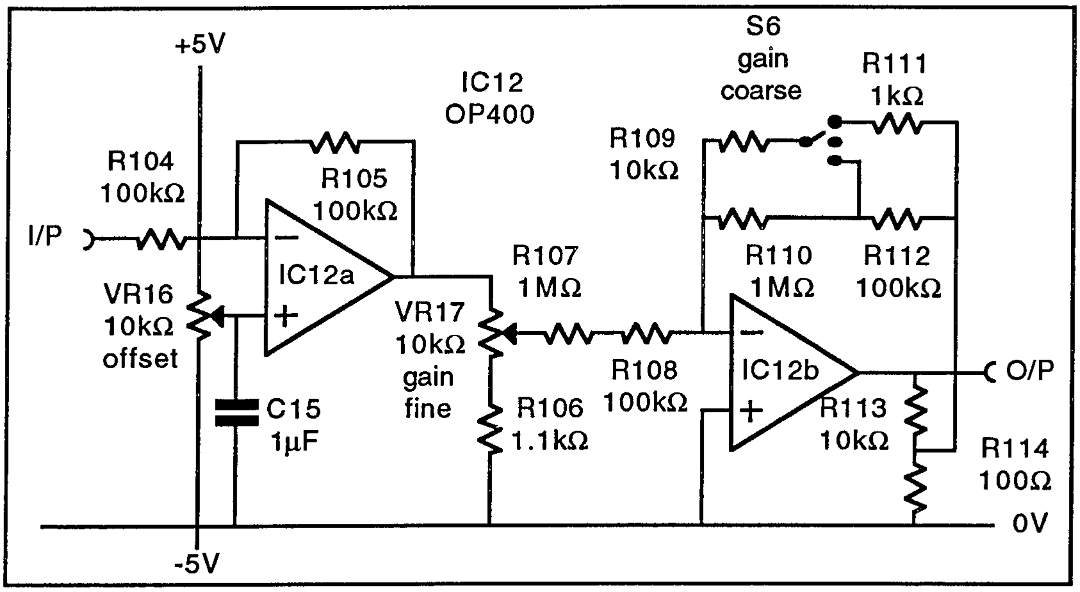
CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-9V...+9V	+12V
Output current				1.5A
Output power				9W*
Upper -3dB frequency			10610Hz	

* These figures are limited by the capacity of the power supply rather than the L165. Actual values will vary with the supply loading.

15.11 AMPLIFIER #1

CIRCUIT DETAILS



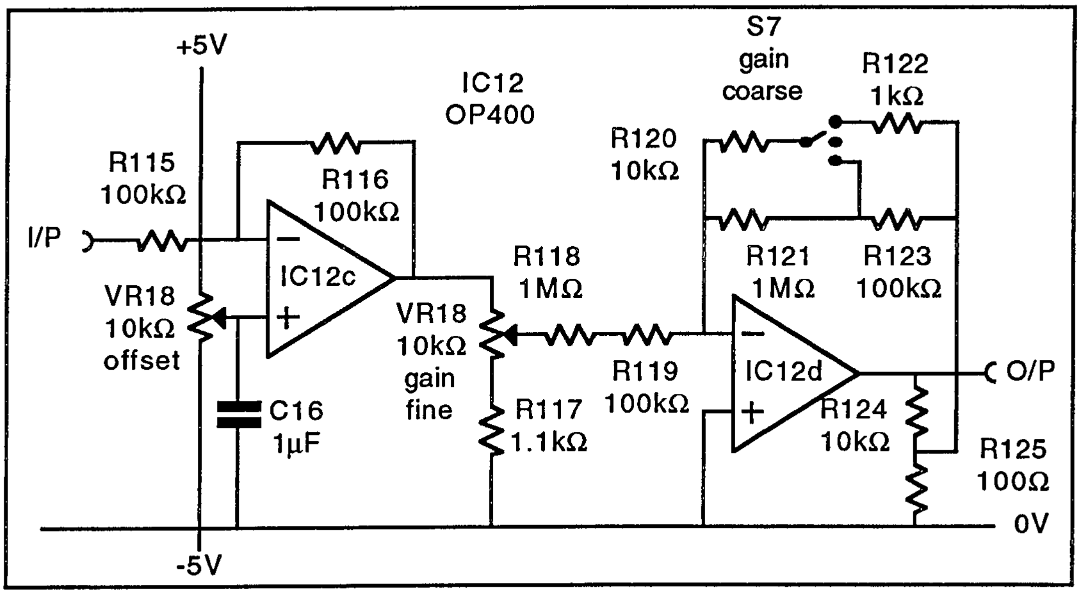
This circuit is the main linear element on the 1750. It is an amplifier with fully-variable gain from 0.1 to 100 and offset from -5V to +5V. IC12a is a unity-gain inverter with **offset** control provided by VR16.The non-inverting input is decoupled by C15. The output feeds the **fine gain** control VR17 with its series resistor R106. The graduations on the scale are approximate only. VR17 feeds the inverting amplifier stage IC12b via input resistors R107 and R108. The gain of this stage is selected by S6 which switches in various combinations of feedback resistors. To avoid the need for excessively high values the feedback is taken from the junction of R113 and R114. These attenuate the output signal by a factor of 100 and thus allow the same reduction in the feedback resistors.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-9V...+9V	+12V
Offset voltage range		-5V		+5V
Voltage gain error	From scale	-30%	±10%	+30%
Input impedance			100kΩ	
Output noise voltage	Gain = 100		10mV	

15.12 AMPLIFIER #2

CIRCUIT DETAILS

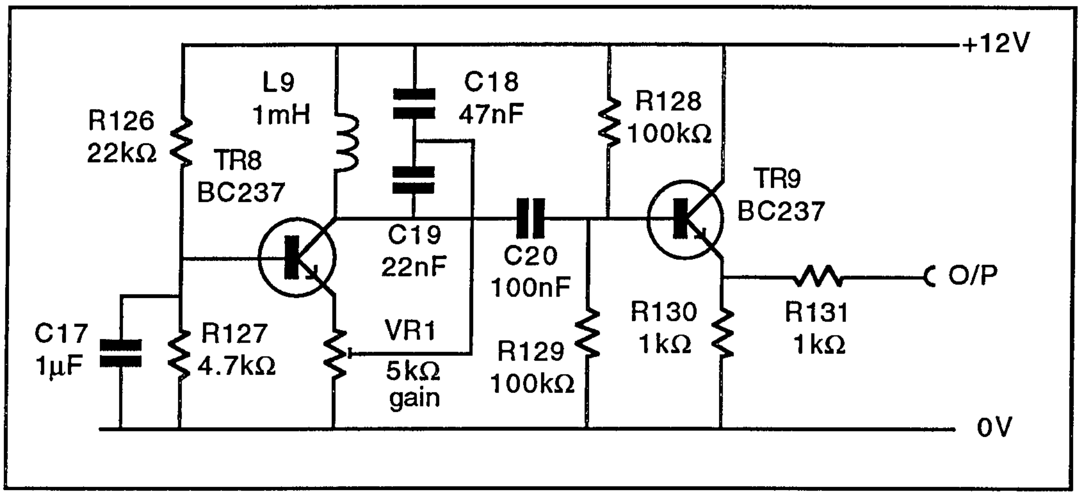


This circuit is functionally a duplicate of Amplifier #1. For circuit description and characteristics please see previous section **15.11, Amplifier #1.**

SECTION 16: OSCILLATORS AND FILTERS

16.1 40kHz OSCILLATOR

CIRCUIT DETAILS



This circuit generates a low-distortion 40kHz sine-wave for many of the A.C.-driven transducers. TR1 is wired as a common-base Colpitts oscillator with base bias set by R126 and R127 and decoupled by C17. The operating frequency f_{osc} is set by L9 and the effective series capacitance of C18 and C19 which is 15nF :

$$f_{osc} = \frac{1}{2\pi\sqrt{LC}}$$

Substituting **L** = 1mH and **C** = 15nF gives a center frequency of 41.093kHz.

The **gain** preset VR1 allows the output amplitude to be set. If too low the circuit will stop oscillating and if too high the output waveform will be distorted. The output from the collector of TR8 is fed via C20 to the emitter-follower buffer stage TR9. The output current is limited by R131. The output voltage has an average level of about 3V.

CHARACTERISTICS

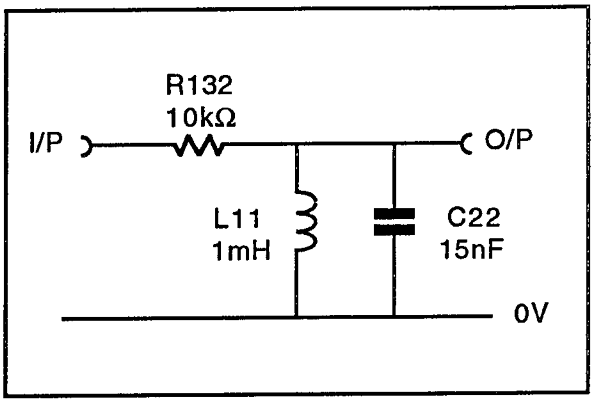
PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Output frequency		37357Hz	41093Hz	45659Hz
Output amplitude			6V p-p	
Output impedance			1.1kΩ	

SETUP PROCEDURE

Monitor the output voltage with an oscilloscope and adjust VR1 until the tops of the peaks reach +6V.

16.2 40kHz FILTER

CIRCUIT DETAILS



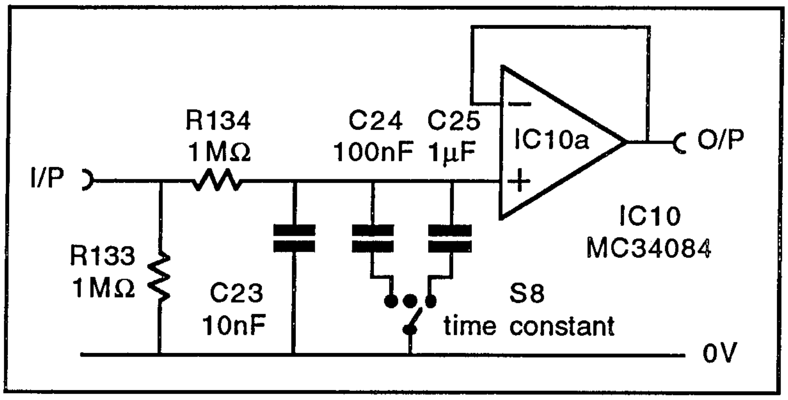
This circuit is a potential divider with a tuned circuit resonating around 40kHz as the filter element. At resonance the impedance of the tuned circuit increases to a high value given by **L / CR** where **R** is the series resistance of the coil. In this circuit the coil has a D.C. resistance of 6Ω, giving an impedance at resonance of 11.1kΩ. The attenuation at 40kHz is therefore 2x. At power line frequency the impedance of the capacitor is over 200kΩ but the impedance of the coil has fallen to just over 6Ω and the attenuation is a massive 1667x. The capacitor is similarly effective at removing radio-frequency interference. This arrangement is known as a **bandpass filter**.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Centre frequency		38236Hz	41093Hz	44442Hz
Attenuation factor	resonance		2	
Attenuation factor	55Hz		1667	
Attenuation factor	1MHz		1059	
Input impedance		10kΩ		
Output impedance				10kΩ

16.3 LOW-PASS FILTER

CIRCUIT DETAILS



Circuit 16.3 is a simple buffered single-pole low-pass filter. The time constant is determined by the product **CR** where **C** is C23 either on its own or in parallel with C24 or C25 dependant on switch position. **R** is R134 (1MΩ) giving approximate time constants of 10ms, 100ms and 1s. These could also be expressed as break frequencies given by :

$$f = \frac{1}{2\pi CR}$$

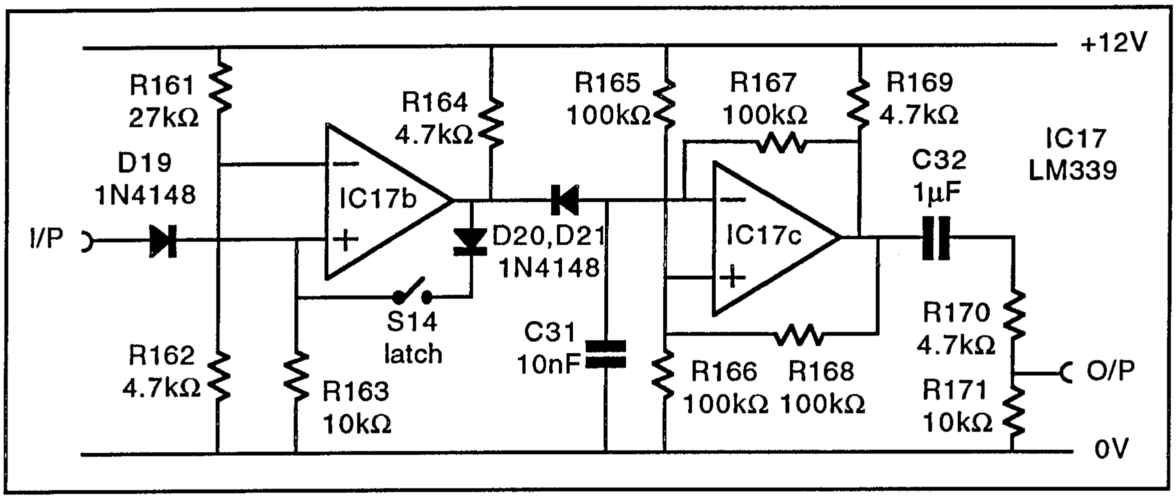
in which case **f = 16Hz, 1.44Hz or 0.14Hz.**

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-8...+8V	+12V
Input impedance		1MΩ		

16.4 ALARM OSCILLATOR

CIRCUIT DETAILS



The alarm oscillator consists of two stages. IC17b is wired as a **comparator**. Consider first the operation with S14 open. With no input connected, the output of IC17b will be near the negative rail and C31 will be discharged by D21. When **I/P** rises above about 2.3V the output of IC17b will go to near +12V and C31 is allowed to charge. If S14 is closed the non-inverting input of IC17b will be maintained near the positive rail by D20, even if the input signal is now removed. The circuit is said to be **latched.** For a full description of a comparator, and a discussion of **hysteresis** (on which the oscillator depends), please see **section 17.5, comparator.**

When C31 is allowed to charge through R167 and R169 the voltage on the inverting input of IC17c rises. When it exceeds about +8V the output will fall to -12V and C31 will discharge through R167.At the same time the voltage on the non-inverting input falls from 8V to just over 0V. When C31 has discharged to below this level the circuit flips and the process repeats. The result is a pulse train on the output of IC17c. This is D.C.-blocked by C32 and attenuated by R170 and R171.

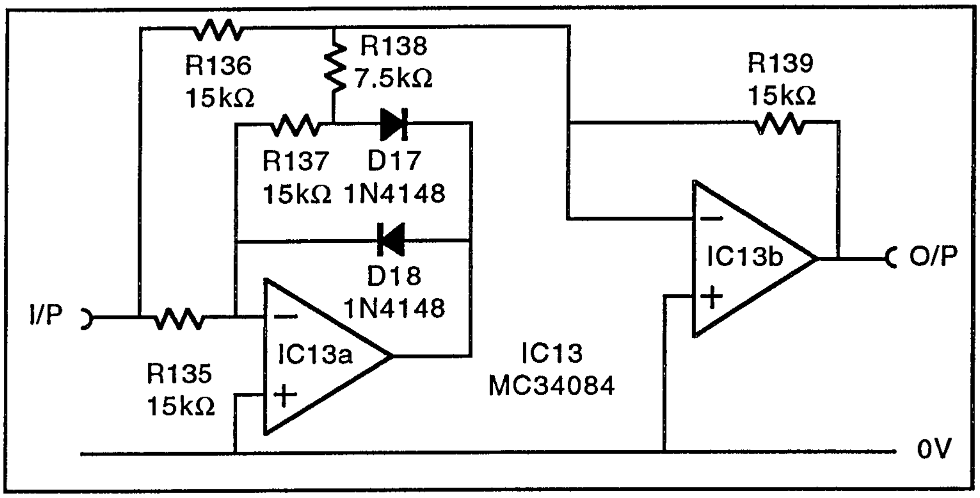
CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage		-12V	-12..+10.5V	+12V
Trip voltage			+2.3V	
Output frequency			540Hz	
Output voltage		-11V		+4V
Output impedance		3.2kΩ		4.8kΩ

SECTION 17: MATHEMATICAL OPERATIONS

17.1 FULL-WAVE RECTIFIER

CIRCUIT DETAILS



This circuit extracts the modulus of an input signal; i.e. an input signal of either **-V** or **+V** volts will produce an output of **+V** volts. Consider first a positive excursion $\mathbf{V_{in}}$ of the input Diode D18 will become reverse-biased and D17 will conduct. In order to balance the input current in R135 the voltage on the junction of D17 and R137 must fall to $\mathbf{-V_{in}}$. The second stage IC13b works as a summing inverter. From the main input the gain is -1 and from the D17/R137 junction it is -2. The output voltage is therefore given by:

$$V_{out} = -(V_{in} - 2V_{in}) = V_{in}$$

Now consider a negative excursion $\mathbf{-V_{in}}$. In this case D18 conducts while D17 is reverse-biased. By op-amp action the voltage on the R135/R137 junction will be 0V. Therefore the inputs to the summing amplifier are $\mathbf{-V_{in}}$ from the main input , and 0V via R137 and R138. The output from IC13b will be:

$$V_{out} = -(-V_{in}) = V_{in}$$

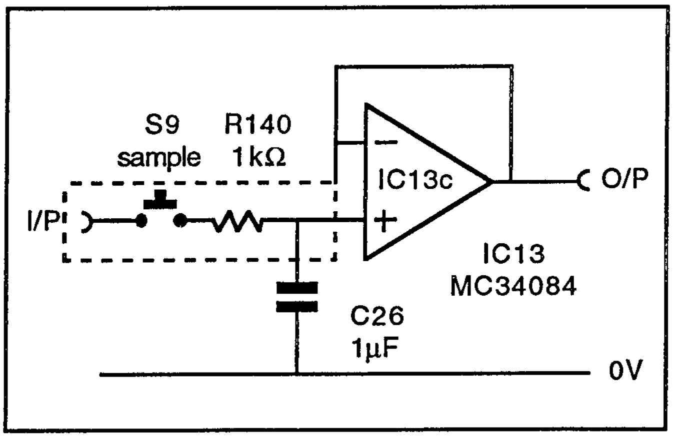
In practice there will be small inaccuracies due to diode voltage drops and resistor tolerances. The circuit will operate satisfactorily at 40kHz but there will be some distortion and negative-going spikes present on the rectified output.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage range		-12V	-8V...+8V	+12V
Output voltage error		-6%	±2%	6%

17.2 SAMPLE AND HOLD

CIRCUIT DETAILS



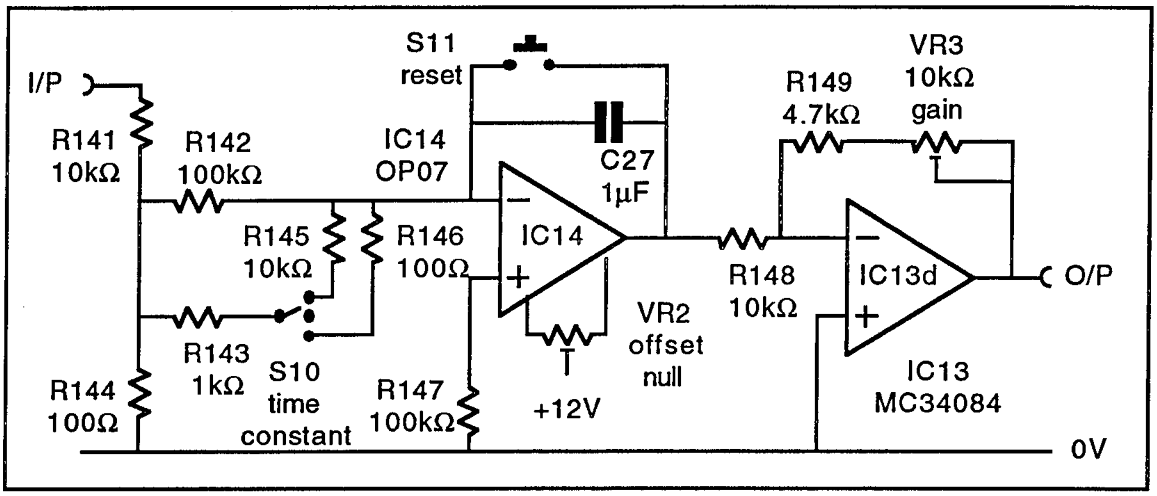
This circuit allows the level of an input signal to be stored on command. When switch S9 is closed the capacitor C26 charges up to the average level of the input signal. When the button is released the capacitor starts to discharge very slowly through stray leakage. IC13c buffers the capacitor voltage. Its output is connected to a **guard ring** P.C.B. track around all the input circuitry and this minimizes the discharge of C26. The circuit should be driven from a low source impedance, e.g. another op-amp.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage range		-12V	-8V...+8V	+12V
Input time constant			1ms	
Droop rate			10mV/min	

17.3 INTEGRATOR

CIRCUIT DETAILS



This circuit provides an output which is the mathematical integral of the input voltage multiplied by the reciprocal of a time constant. Integration is a process of incremental addition and in this circuit charge is added to the capacitor C27. The integrator has a time constant **RC** where **C** is C27 and **R** is the effective value of series input resistor chosen by switch S10. The attenuator formed by R141 and R144 reduces the value of input resistor required by a factor of 100. C27 can be discharged and the integrator reset by S11. Any input offset on IC14 will slowly charge C27 and this tendency can be removed by adjusting VR2. The output passes to the inverter stage around IC13d with gain controlled by VR3. This allows the errors in C27 and the input resistors to be trimmed out. The final output is of this form (**C** = C27) :

$$V_{out} = \frac{1}{RC} \int V_{in}\, dt$$

CHARACTERISTICS

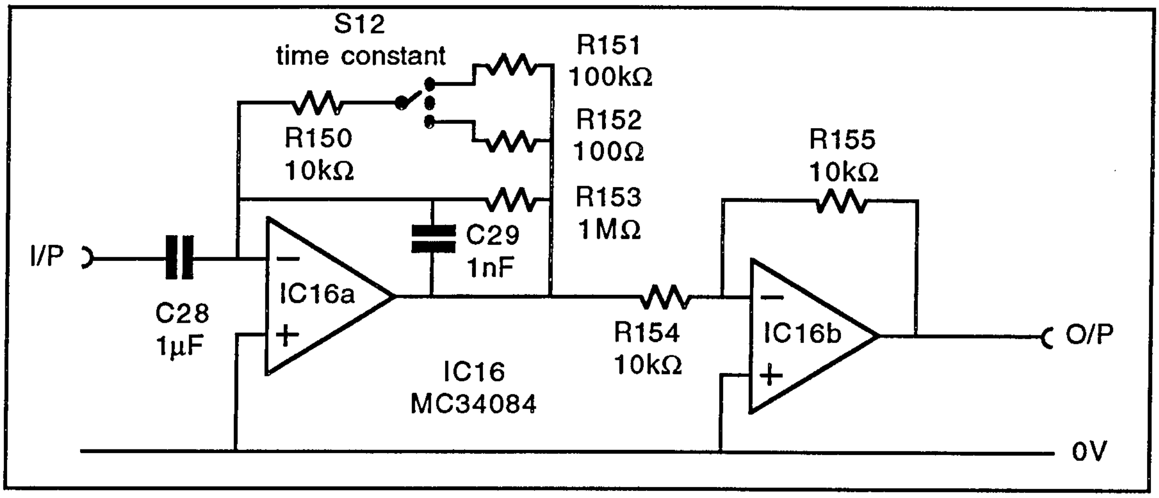
PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input impedance			10kΩ	
Untrimmable gain error			1%	

SETUP PROCEDURE

Switch the integrator **time constant** to **100ms**. Ground the input and **reset** with S11. Monitor the output and adjust **VR2** for zero drift with time. Switch the **time constant** to **10s** and apply +5V to the input. Press **reset** and note the time taken for the output to reach +5V. Adjust **VR3**, repeating the procedure until the output takes exactly 10 seconds to get to 5V.

17.4 DIFFERENTIATOR

CIRCUIT DETAILS



This circuit provides an output which represents the rate of change of the input signal . This is multiplied by a time constant **RC** that is determined by the input capacitor C28 and the feedback resistor combination selected by S12. The circuit is prone to noise pickup and this is reduced by C29. The signal is inverted by IC16b and associated components. The final output is of this form :

$$V_{out} = RC\frac{dV_{in}}{dt}$$

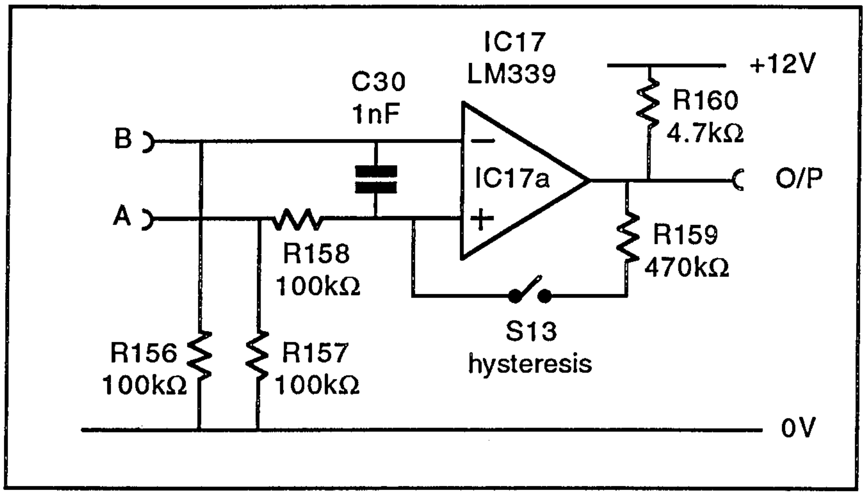
where **C** is C28 and **R** is the effective value of feedback resistor.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage range		-12V	-8V...+8V	+12V
Input rate of change	t.c. = 10ms			10^{-3}V/µs
Input impedance				
O/P saturation voltage				
Output noise	t.c. = 1s		50mV	

17.5 COMPARATOR

CIRCUIT DETAILS



This circuit compares the voltages on the **A** and **B** inputs and generates an output which is close to the **+12V** rail if **A** > **B** and the **-12V** rail if **A** < **B.** IC17a is a high-gain differential amplifier used without negative feedback. It is therefore subject to instability when the input voltages are close. This is minimized by the filter formed by C30 and R158. However, there is a better way of achieving stability with a comparator and this can be demonstrated on the 1750. If S13 is closed the inputs must now differ by a predictable threshold before the circuit will switch state.

Suppose that both inputs are around 0V and the comparator output has gone to +12V. By the potential divider formed by R158 and R159 there will be about +2V on the non-inverting input. The inverting input will now have to be taken above 2V before the output flips to -12V. When this happens the non-inverting input voltage will fall to around -2V and the inverting input will now have to go below this before the circuit changes state again. There is said to be about 4V **hysteresis** in this circuit.

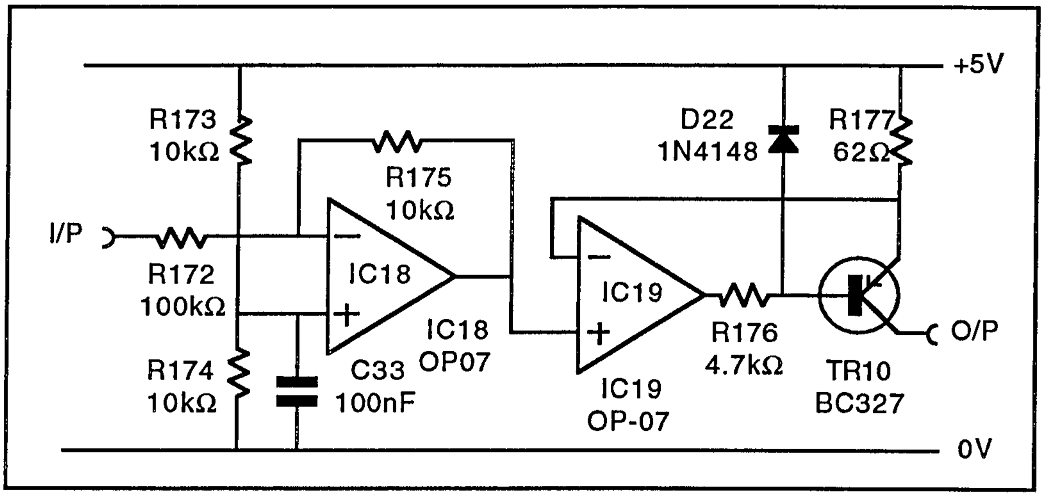
CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage range		-12V	-12V..10.5V	+12V
Input offset voltage				9mV
Output voltage	no load	-11.8V		+12V
Hysteresis	S13 'on'		4.2V	

SECTION 18 : CONVERTERS

18.1 VOLTAGE TO CURRENT CONVERTER

CIRCUIT DETAILS



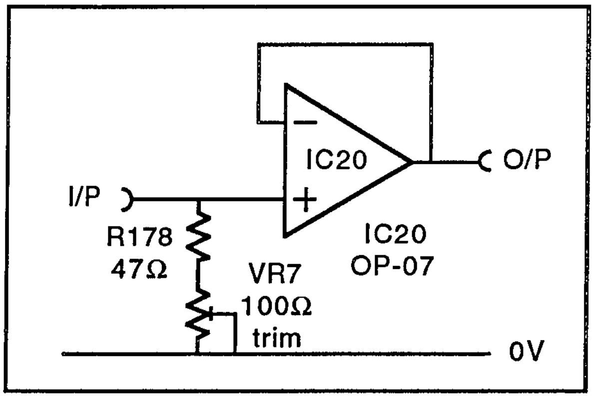
This circuit is designed to handle voltages in the range 0V to +1.5V and convert them into currents in the range 0-24mA.IC18 is an inverter with the non-inverting input biased at +2.5V. It s output is 5V minus the input voltage so that 1V on the input becomes 4V on the output.. This is fed to IC19 which drives TR10 via R178. D22 protects TR10 from reverse base bias. Taking our example, with 4V on the non-inverting input IC19 will try to drive TR10 so that 4V also appears on the inverting input. This is only possible if TR10 drives a suitable load such as the **I/V converter** detailed next.. However, if it does succeed it will maintain a constant 1V across R177 and therefore a constant 16mA through it. This current also flows in TR10's collector load irrespective (within limits) of the load resistance.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage range		-12V	0V..+1.5V	+12V
Output current range		0		24mA
Transfer ratio			16mA/V	

18.2 CURRENT TO VOLTAGE CONVERTER

CIRCUIT DETAILS



This circuit is basically just a buffered resistor. The input current **I** develops a voltage **IR** across R178 and VR7. The voltage is buffered by IC20.

CHARACTERISTICS

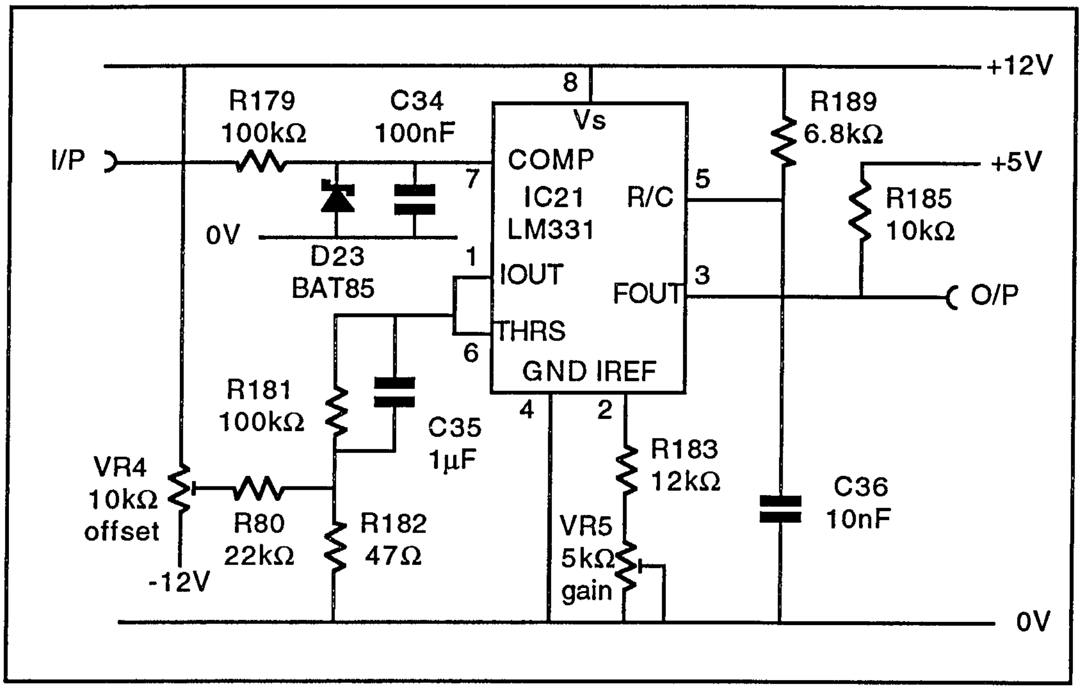
PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage range		-6V	0V...+1.5V	+6V
Input current range		-100mA	0...24mA	100mA
Transfer ratio			62.5mV/mA	

SETUP PROCEDURE

Connect the **V/I converter O/P** to the **I/V converter I/P**. Apply +1V to the **V/I I/P** and monitor the **I/V O/P**. Adjust VR7 until the **V/I I/P** and **I/V O/P** voltages are identical.

18.3 VOLTAGE TO FREQUENCY CONVERTER

CIRCUIT DETAILS



This circuit generates a stream of constant-width pulses when an input voltage is applied. The LM331 compares the voltage on pin 7 with that on pin 6. If greater, a monostable multivibrator is triggered and a pulse of charge is dumped on C35 which raises the voltage on pin 6 above pin 7. C35 then discharges through R181 and the voltage on pin 6 falls until the monostable triggers again. The monostable output drives pin 3 The higher the voltage on pin 7, the less the time taken for the voltage on pin 6 to fall below it and the faster the stream of pulses on pin 3. The design of the 331 provides a highly-linear voltage/frequency characteristic.

D23 clamps negative excursions at the input while R179 and C34 filter out noise. VR4 allows a small amount of offset to be added to pin 6. VR5 allows the gain to be trimmed to compensate for component tolerances. R189 and C36 set the monostable 'on' time.

Continued overleaf

CHARACTERISTICS

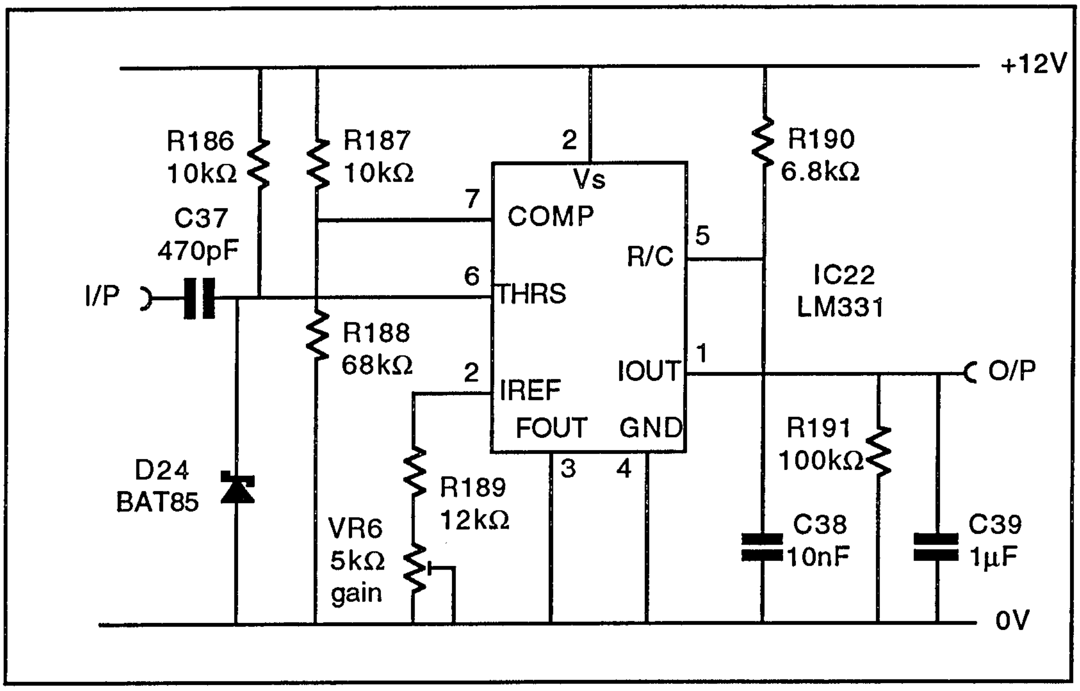
PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage range		-12V		+12V
Transfer ratio			1kHz/V	
Non-linearity	% of full scale	-0.14%	±0.024%	+0.14%
Full-scale frequency			10kHz	

SETUP PROCEDURE

Connect the input to 0V. Monitor the output with a scope and adjust VR4 until the output pulse train just stops. Connect the input to +5V and adjust VR5 until the output frequency is 5kHz (period 0.2ms).

18.4 FREQUENCY TO VOLTAGE CONVERTER

CIRCUIT DETAILS



In this application a pulse train applied to the input is differentiated by C37. Each negative-going edge causes the monostable multivibrator in the 331 to fire and a packet of charge is dumped on C39 thereby raising its voltage . The voltage falls until the next charge pulse is received and the average level is proportional to the input pulse frequency. With 1μF for C39 the response time is slow but the ripple is less than 10mV.

D24 clamps negative spikes att the input. The gain can be trimmed with VR6. C38 and R190 set the monostable pulse width.R191 and C39 are the output filter. Allowance must be made for the 100kΩ output impedance when making measurements.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Time constant			100ms	
Settling time			0.7s	
Accuracy		-0.1%		+0.1%
Output ripple				10mV
Output impedance			100kΩ	

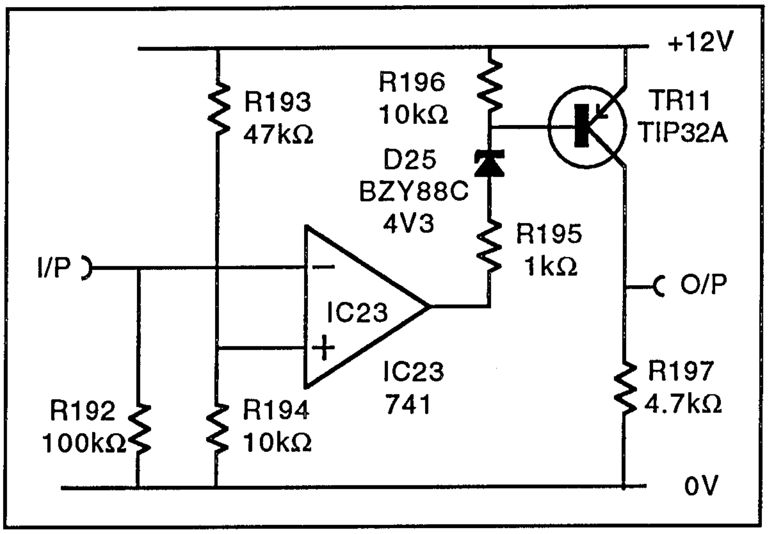
SETUP PROCEDURE

This method assumes that the **V/F converter** has already been set up.Connect the **V/F converter I/P** to +5V. Connect its O/P to the **F/V converter I/P.** Monitor the **F/V O/P** and adjust **VR6** until the **V/F I/P** and **F/V O/P** voltages are identical.

SECTION 19 : MISCELLANEOUS

19.1 ELECTRONIC SWITCH

CIRCUIT DETAILS



This is another comparator circuit. The output of IC23 is normally near the positive rail. Under this condition the transistor TR11 is cut off by R196. R195 limits the base current while D25 copes with the fact that IC23's output may be a couple of volts below +12V.If the voltage on **I/P** exceeds that on its non-nverting input (about 2V), IC23's output drops to near the negative rail and TR11 is turned on hard. Current can now be suppled to any load connected between TR11's collector and 0V. A nominal load is provided by R197.

CHARACTERISTICS

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Input voltage range		-12V	-9V...+9V	+12V
Trip voltage			+2.1V	
Output current				1A*

* The output current will be limited by two factors; the current gain of TR11 and the reserve capability of the 12V power supply. 1A is a typical upper limit.

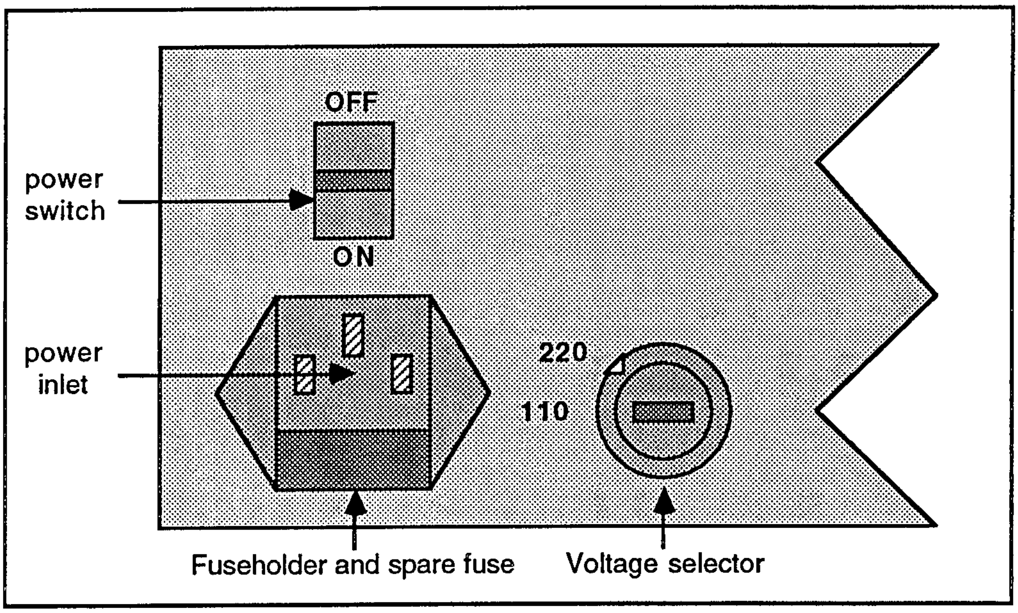
SECTION 20 : THE POWER SUPPLY UNIT

This chapter deals with the power supply in sections :

- The rear panel, voltage selector and fuse
- The transformer, pump, rectifier and smoothing capacitors
- The 5V and 12V regulated supplies
- The external ±5V supplies
- The baseplate and P.C.B. layout and wiring
- Specification

20.1 THE REAR PANEL

A diagram of the rear panel is shown below.



VOLTAGE SELECTOR

Do not switch on until you have read this section!

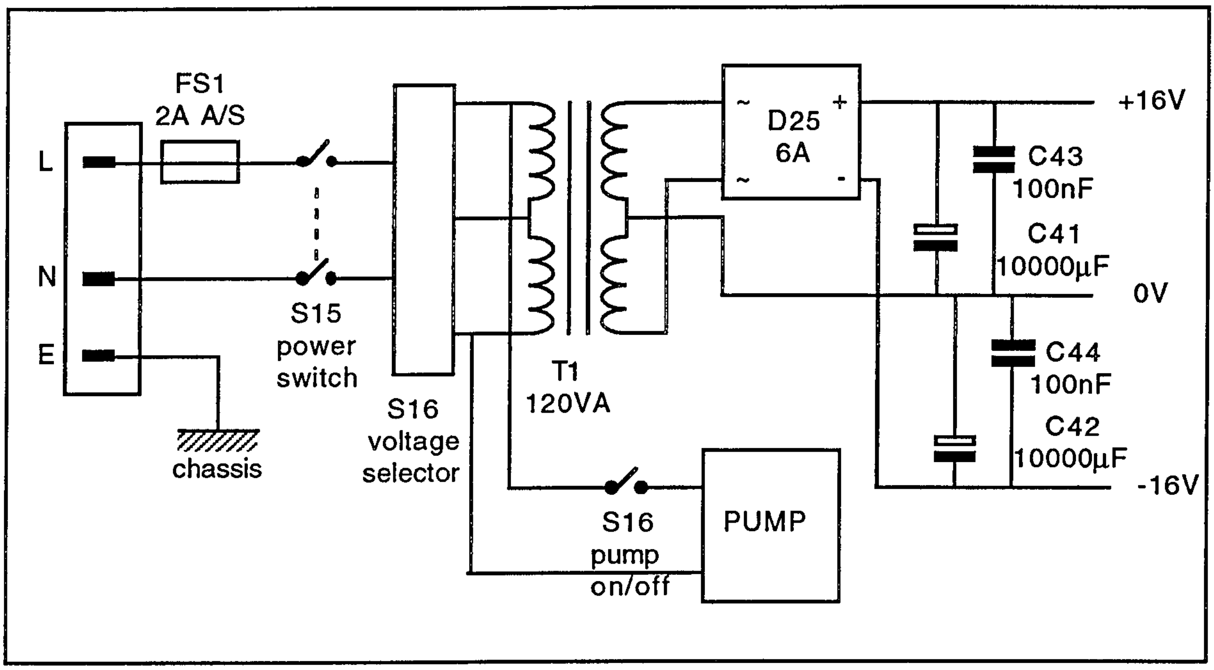
The 1750 comes complete with internal power supplies ready to connect to either **110-130V** or **220-240V, 50 / 60Hz A.C.** power. A voltage selector will be found on the rear panel. Using a small screwdriver, select the most appropriate voltage for your locality.

CHANGING THE FUSE

Should it ever become necessary to change the fuse, pull out the small drawer at the base of the power inlet .

The correct fuse rating is 2A, anti-surge, 20mm long.

20.2 TRANSFORMER, PUMP, RECTIFIER AND SMOOTHING CAPACITORS

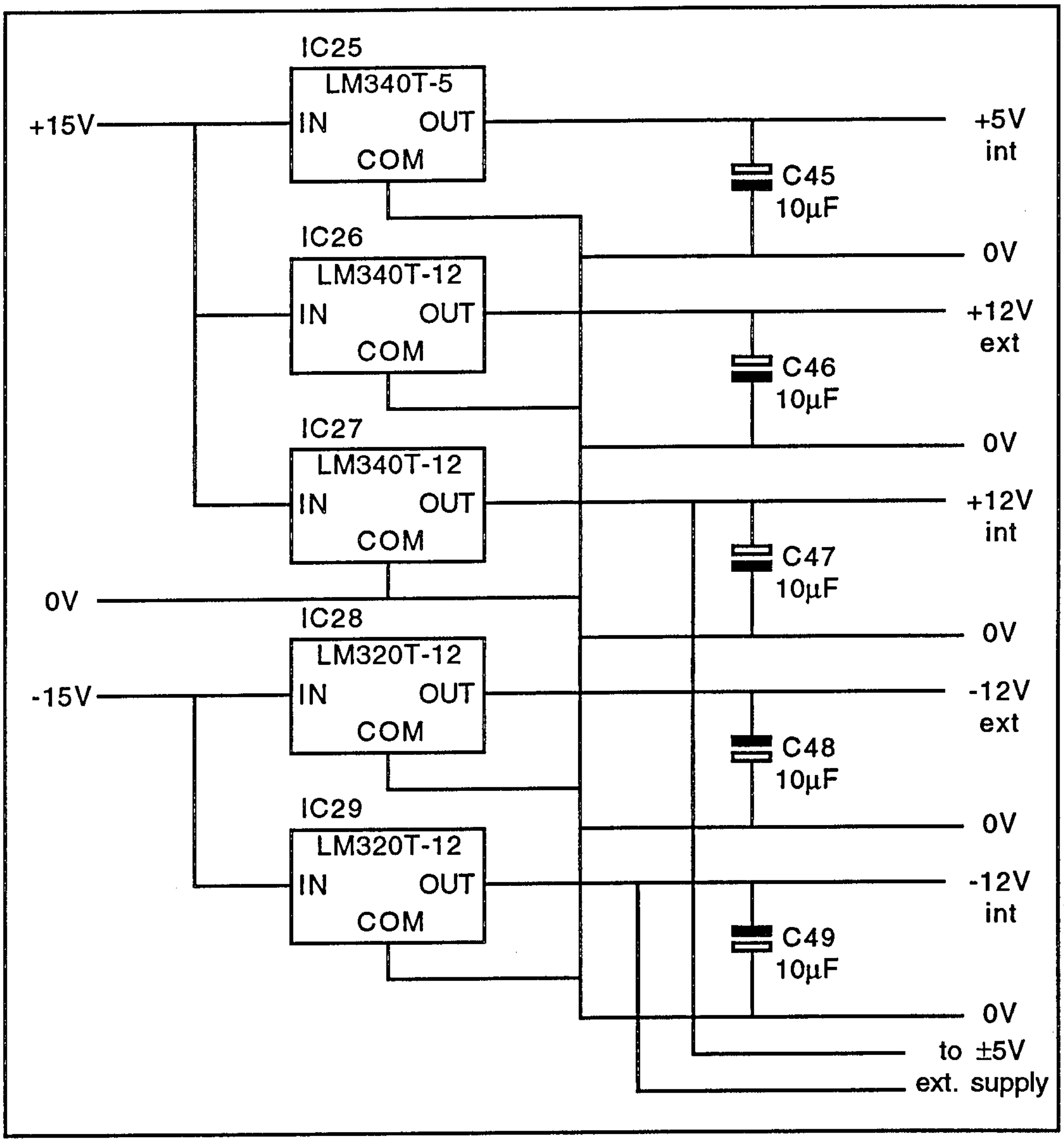


For low induced and radiated noise the 1750 uses linear-mode power supplies.

Power enters transformer T1 via the power inlet,fuse,switch and voltage selector. The pump is a 220/240V unit and is wired across the two primary windings. When the voltage selector is set to **220**, power is supplied to both windings in series. When set to **110** it is supplied to one winding only while the other acts as an autotransformer to supply 220V to the pump. Switch S16 allows the pump to be controlled from the motherboard. T1 is a toroidal transformer with less magnetic flux leakage than a standard type.

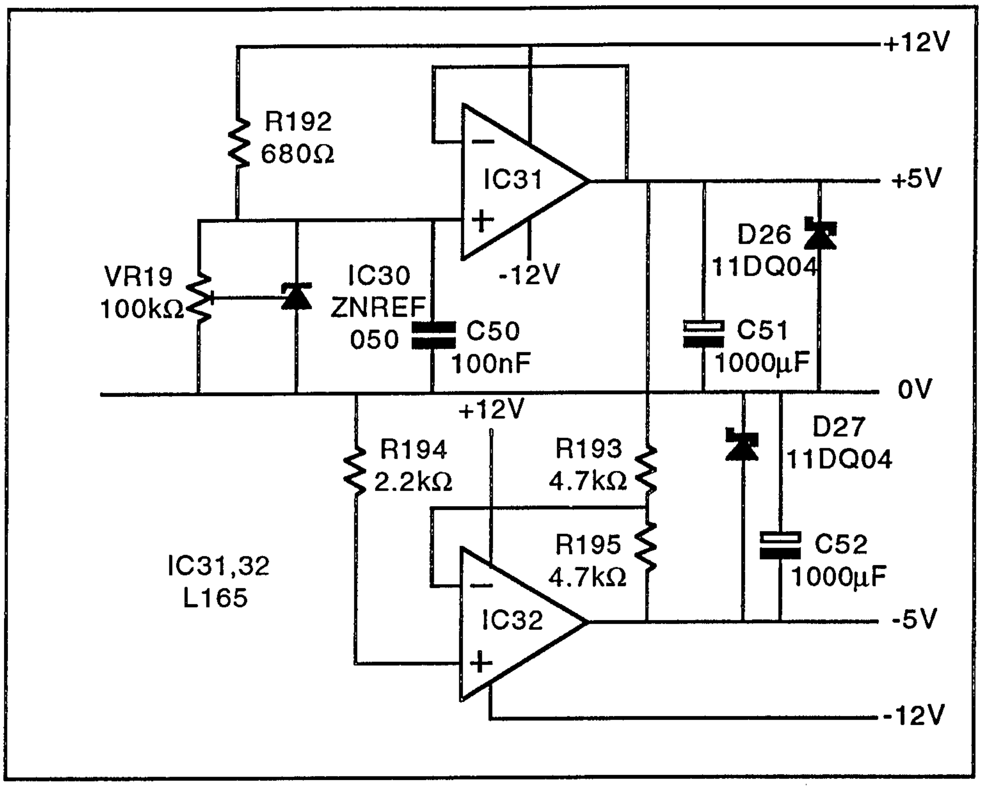
T1 has two 12V secondaries. Two terminals are commoned to form the 0V rail while the other pair feed the 6A bridge rectifier D25. The bridge outputs drive the smoothing capacitors C41 and C42 while C43 and C44 decouple high-frequency interference. The unregulated outputs are approximately 15V.

20.3 5V AND12V REGULATED SUPPLIES



These power rails all make use of three-terminal linear voltage regulators. The devices are mounted on a heatsink attached to the power supply PCB. C45-C49 are required for stability.

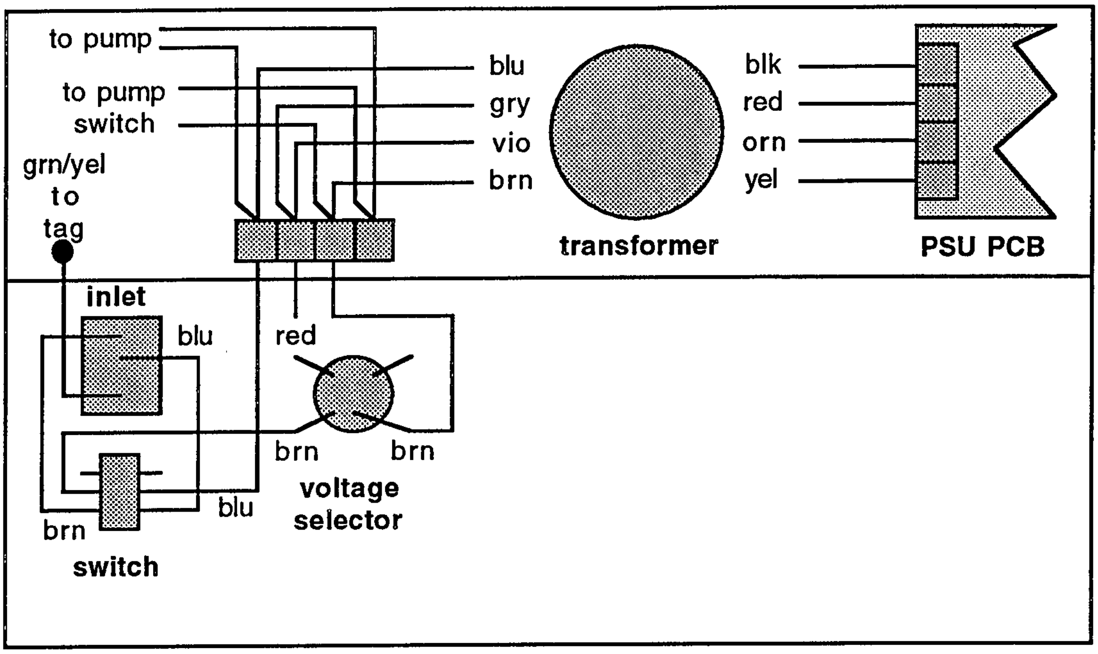
20.4 ±5V EXTERNAL SUPPLIES



This circuit uses a precision voltage reference and power operational amplifiers to provide an accurate ±5V supply. IC31 acts as a buffer for the voltage reference chip IC30. This device receives its operating current via R192 and voltage trimming is provided by VR19. C50 removes noise. The output of IC31 is decoupled by C51 while D26 prevents negative excursions.

The +5V supply obtained from IC31 is inverted by IC32 to provide -5V. R194 is included to balance the input currents. IC32's output is decoupled by C52 and positive excursions are clamped by D27.

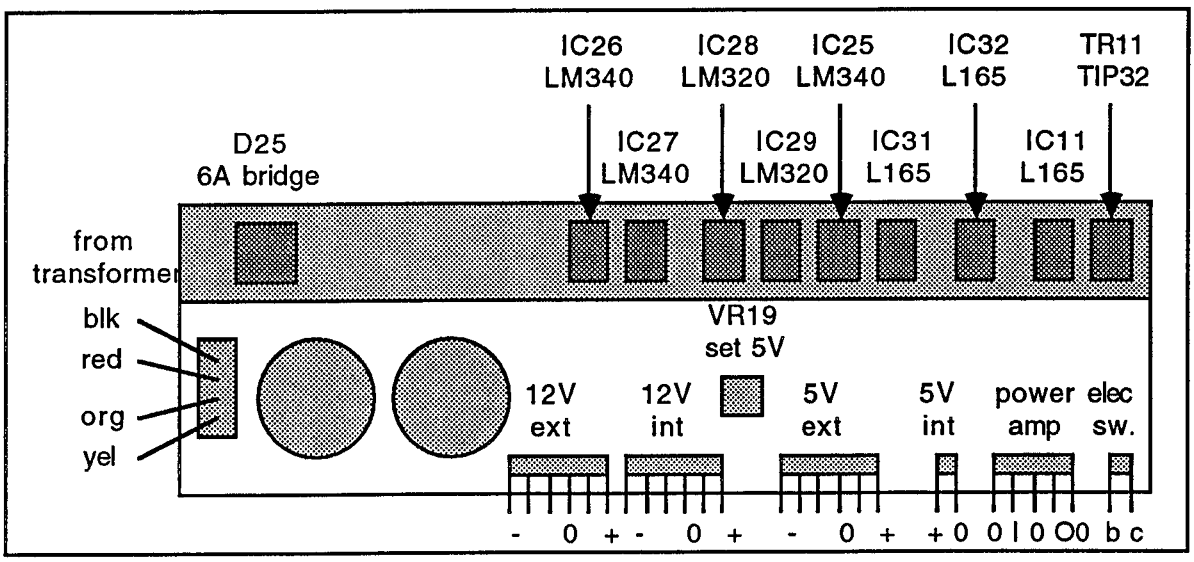
20.5 POWER SUPPLY LAYOUT AND WIRING



The wiring layout for the rear panel and baseplate is shown above.

Unplug the unit when gaining access to the power supply, and take care to reconnect correctly if the unit is dismantled.

POWER SUPPLY P.C.B. LAYOUT



The diagram above shows the external connections and identifies voltage regulators and integrated circuits.

20.6 POWER SUPPLY SPECIFICATION

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Fuse rating			2A A/S	2A A/S
Power requirements			17VA	120VA*
Current requirements	240V line		70mA	500mA*
Current requirement	120V line		140mA	1A*
Output noise, -5V			10mV	
Output noise, +5V			5mV	
Output noise, -12V			20mV	
Output noise, +12V			5mV	

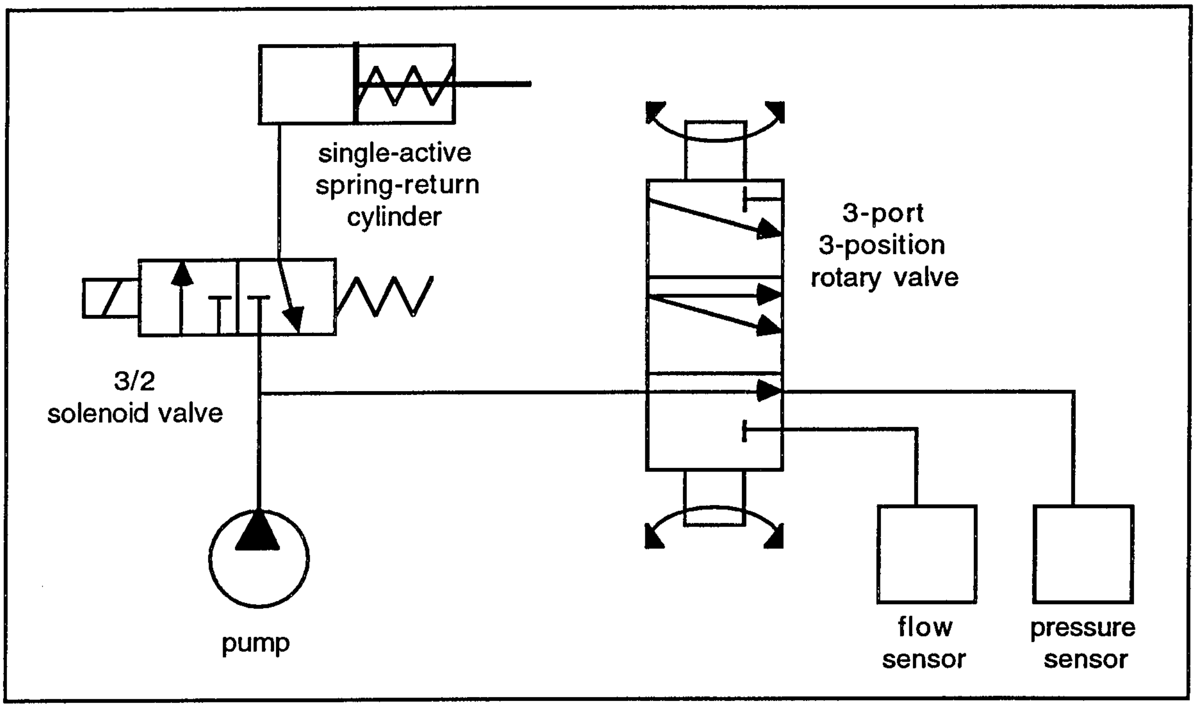
* External power supplies short-circuited. Prolonged testing of these parameters is not recommended.

PNEUMATIC CIRCUIT

The 1750 employs a small aquarium pump in a simple pneumatic circuit. This chapter contains the following information :

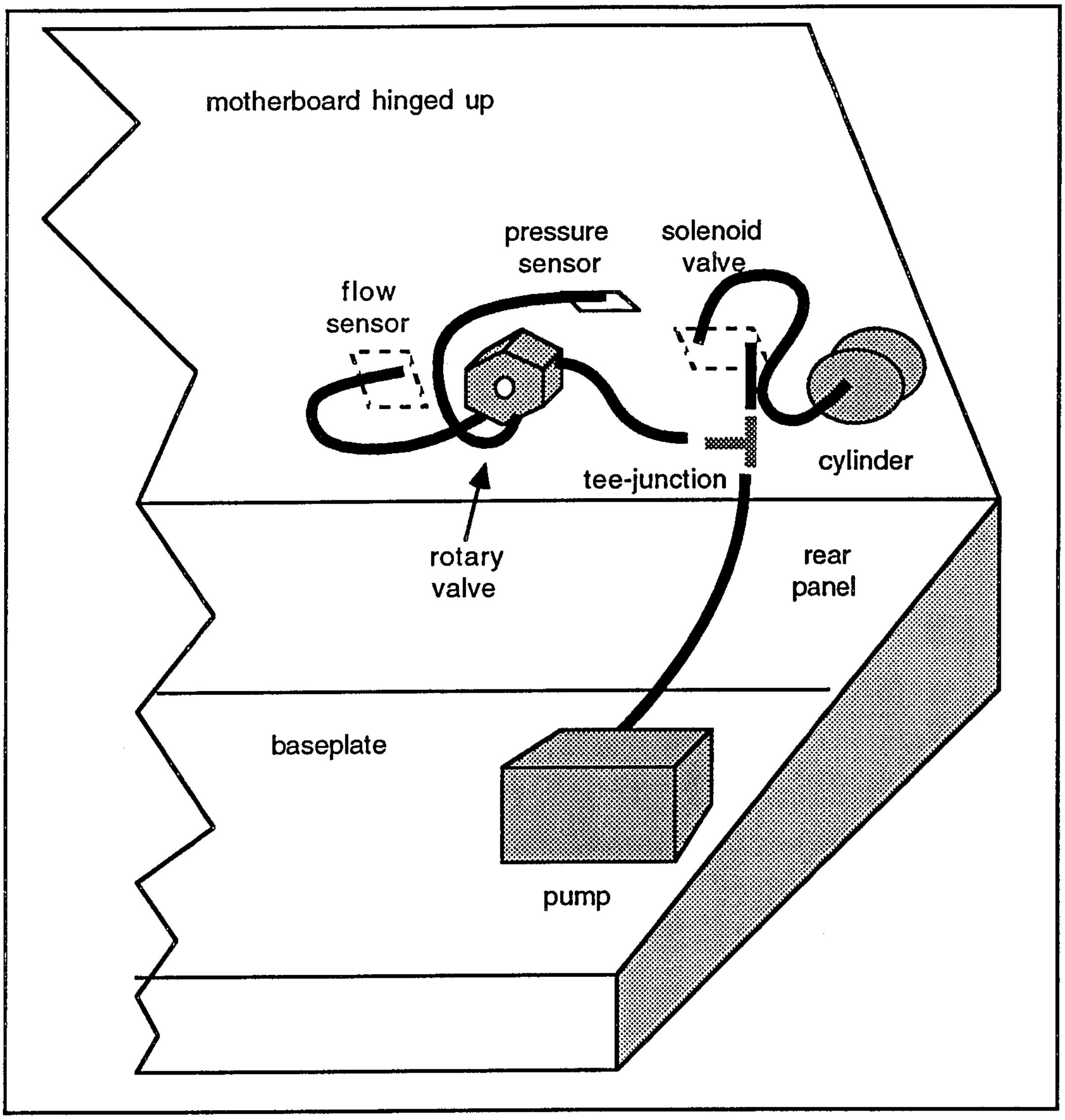
- Pneumatic circuit using standard symbols
- The pneumatic circuit in practice
- Specification

21.1 CIRCUIT USING STANDARD SYMBOLS



The diagram above is a schematic representation of the pneumatic circuit using standard symbols. The pump feeds a T-junction and the air branches two ways. One branch leads to the 12V solenoid valve. When the valve is turned on, air flows into the cylinder and operates an actuator rod. When the valve is switched off, air from the pump is prevented from entering the valve but air in the cylinder is vented, releasing the actuator. The second branch from the pump feeds the manual rotary valve. When fully counter-clockwise, air is diverted to the air flow sensor. When fully clockwise the pressure sensor is fed exclusively. In intermediate positions some air flows to each.

21.2 THE PNEUMATIC CIRCUIT IN PRACTICE



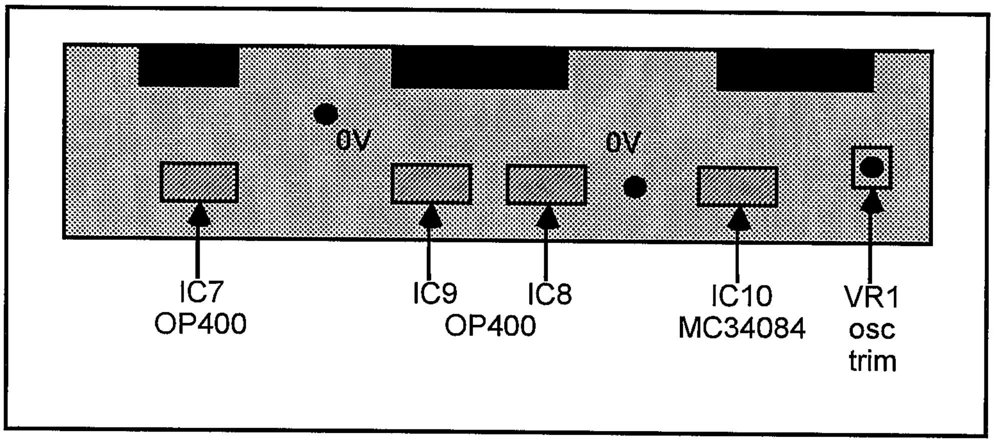
The diagram above shows the 'plumbing' of the 1750. Thick-walled plastic pipe of 6mm outside diameter and 3mm bore is used throughout.

21.3 SPECIFICATION

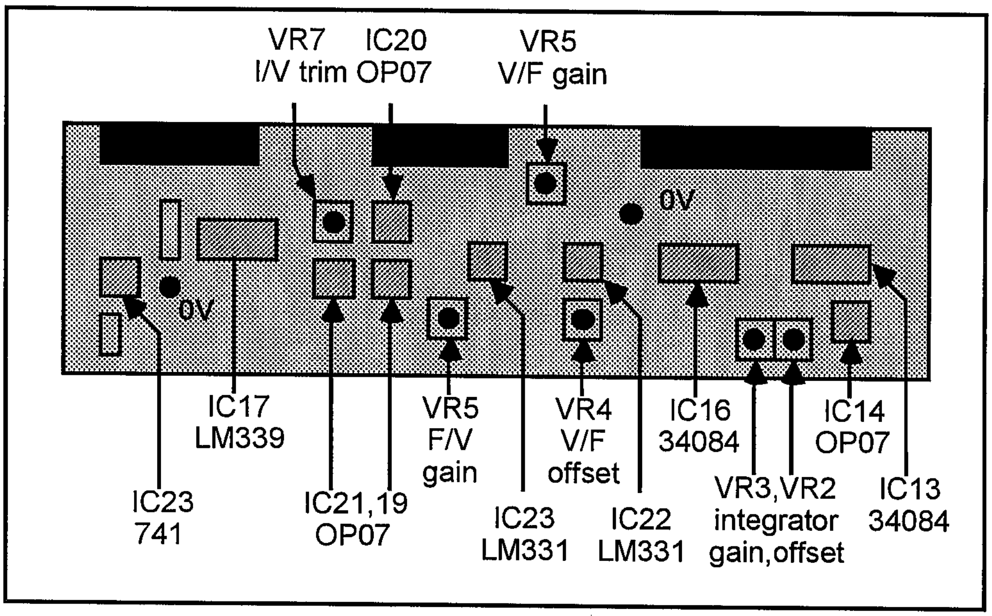
PARAMETER	CONDITIONS	MIN.	TYP.	MAX.
Pump power rating			3.8VA	4VA
Pump pressure			0.9 p.s.i.	
Pump flow rate			3 l/min	

DAUGHTERBOARD LAYOUT DIAGRAMS

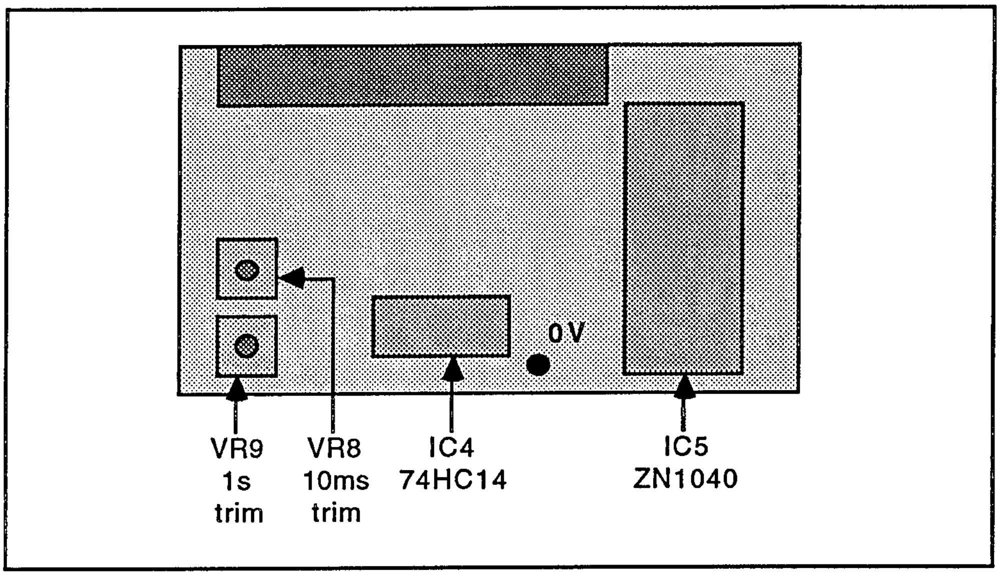
22.1 DAUGHTERBOARD 1750a



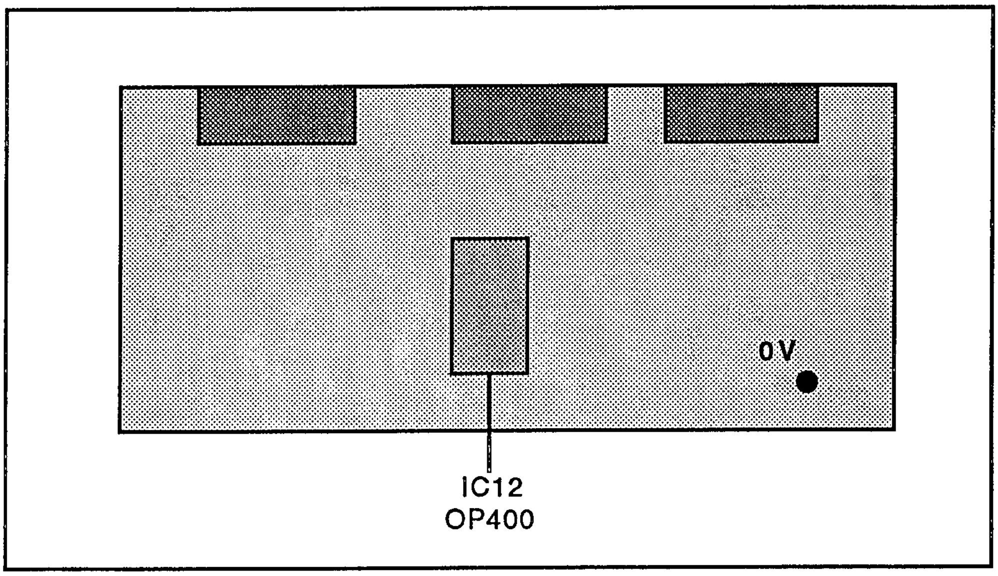
22.2 DAUGHTERBOARD 1750b



22.3 DAUGHTERBOARD 1750c



22.4 DAUGHTERBOARD 1750d

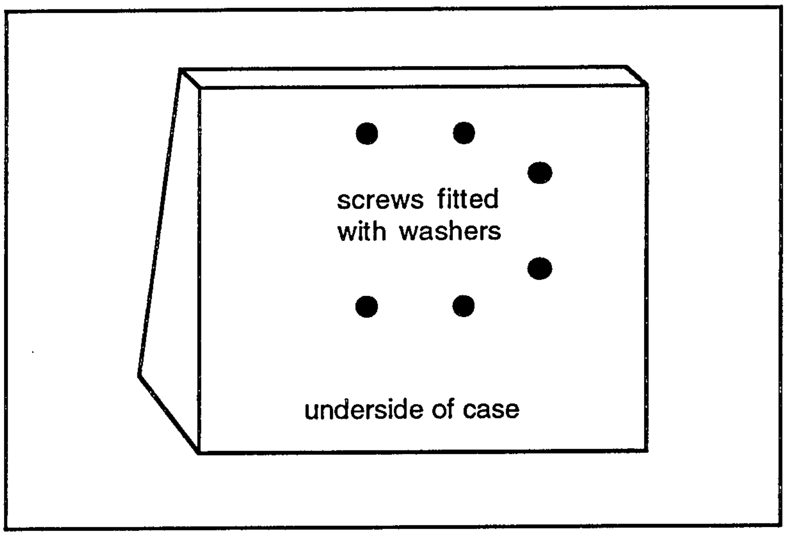


23.1 GAINING ACCESS TO THE CASE

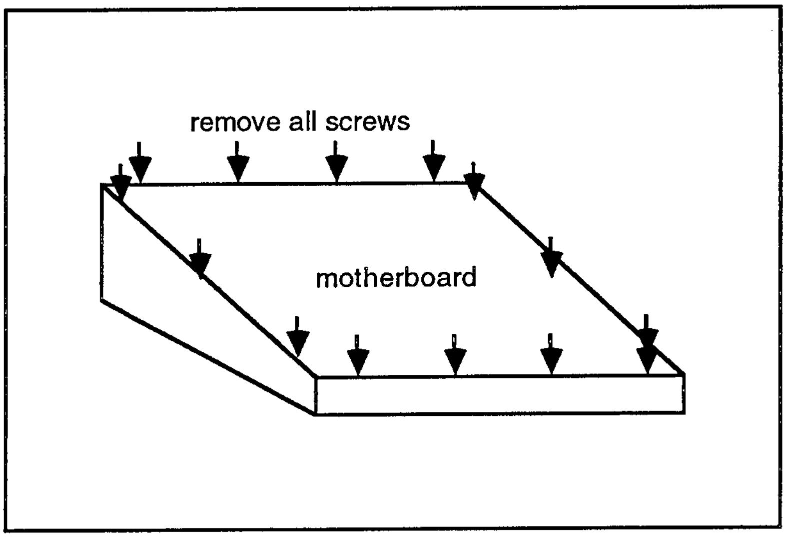
Ensure that power is disconnected before attempting to gain access!

- Remove the power plug and stand the unit on its back edge.
- Facing the underside of the unit, remove the six screws which are fitted with washers.

  Do not remove any other screws!

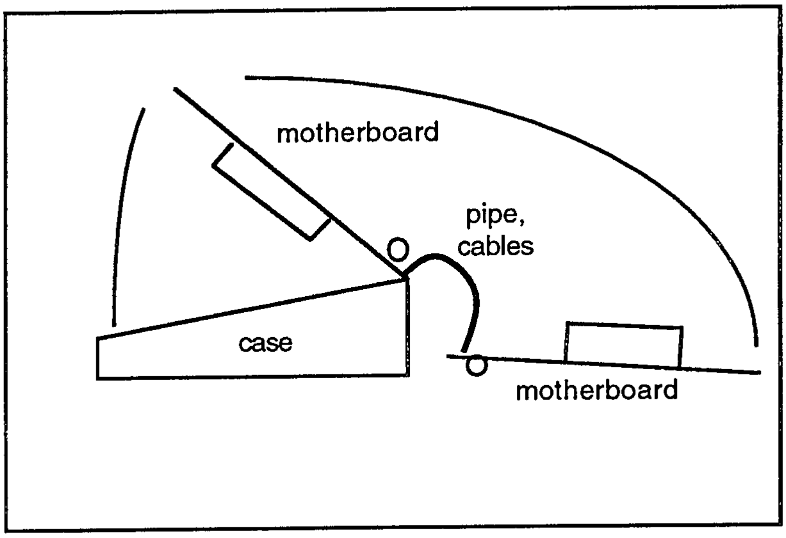


- Return the unit to its normal operating position.
- Remove **all** the self-tapping screws around the edge of the motherboard.



Continued overleaf

- The front edge of the motherboard may now be raised. If sufficient bench space is available the board may be inverted and carefully laid on the bench.



The interior of the case and the underside of the motherboard are now available for inspection. Power may now be reconnected if necessary.

Warning : high voltages are present beneath the insulating boots and around the 4-way screw terminal.

Technical Information

Equipment Name: **D1750 Trainer**

Part Number: **TD170**

Manufactured and supported by:

LJ Technical Systems Ltd
Francis Way
Bowthorpe Industrial Estate
Norwich
Norfolk NR4 9JA
United Kingdom

Tel: +44 1603 740421
Fax: +44 1603 746340
E-mail: support@ljgroup.com

LJ Technical Systems Inc
85, Corporate Drive
Holtsville
11742-2007
New York
USA

Tel: 1-800-237-3482
Fax: 1-631-758-1788
E-mail: lj@lj-tech.com

Technical specification

- Supply voltage - single phase either 110-120 V ac or 220-240 V ac 50-60 Hz at 46 VA. See equipment ratings label to determine which supply voltage applies to your product.
- A T2AL fuse is fitted to the trainer. Should a replacement fuse be required, use the same value and type.
- Weight - 7 Kg approx.
- Dims - 500 mm X 450 mm X 150 mm approx.
- For other technical information please refer to other documentation supplied.

Important Note: **This equipment must be grounded**. Ensure that the connection to the AC line socket has a ground (earth) connection.

Environmental conditions for which the equipment is designed

- The equipment is designed for indoor use only.
- Temperature between 5 °C and 40 °C
- Relative humidity up to 80% to 31 °C 50% at 40 °C
- No hoar frost, percolating water, rain, solar radiation etc.

Ventilation requirements

There are no specific ventilation requirements regarding safety, but ensure the unit is not covered by papers or other material.

Equipment installation

Please refer to the curriculum material supplied.

Equipment maintenance

There is no requirement for preventative maintenance other than occasionally cleaning. (See "Instructions for cleaning") There are no user serviceable parts inside the unit. Should a malfunction occur with the unit please contact the manufacturer or your agent who can provide further information.

Instructions for cleaning

Before cleaning ensure that the unit is unplugged from any power supply. Clean the equipment with a lightly damped cloth only. Ensure that no water can enter the equipment. Ensure the equipment is dry before any power is applied.

Maintenance of Product Integrity

LJ Technical Systems has taken great care to design and construct all products such as to ensure, so far as is reasonably practicable, safety during normal use, any maintenance and servicing.

The above care includes ensuring electrical integrity where live mains voltages are used to energise the equipment. Initial integrity is established by suitable tests and by inspection prior to despatch. It is considered that, because it is foreseeable that damage could occur due to misuse or accident, a regular inspection is carried out. If damage is suspected or deterioration could have occurred then basic tests for integrity should be carried out. These tests should be performed by a suitably qualified person using a portable appliance tester (PAT).

During PAT testing, when insulation resistance or dielectric withstanding voltage tests are involved, care must be taken to ensure that low voltage circuit components are not destroyed or degraded. Where damage due to the PAT testing *could* occur, or where the reading obtained by any discrete components, then explanatory and guidance notes are made in the appropriate sections of this manual.

Guidance Notes (Class I)

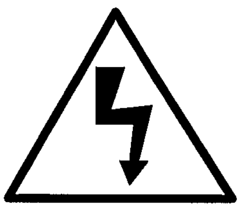
Insulation resistance	> 2 M Ω (500 V DC test voltage)
Leakage Current	< 0.25 mA. (Where discrete EMC components are present, a maximum 5.0 mA leakage current is allowed)
Earth Bonding impedance	< 0.1 Ω (6 V AC) (Case only!)

Warnings

(If the warnings below are not observed, harm to the individual or damage to the equipment may occur)

- Use the equipment for its intended use only
- Follow the advice of any warning/ prohibition labels on the equipment
- Keep hands, hair, clothing and alike away from any moving parts
- Ensure liquids i.e. tea and coffee are kept well clear of the equipment
- Do not attempt to repair or modify the equipment before contacting the manufacturer or agent for advice
- Do not attempt to dismantle the equipment

Warning/ Prohibition Labels



Warning High Voltage,
disconnect before gaining access.