FoodInfo Confidential Report No. 40

Operation and information handbook for Textron

- a multi-purpose, portable food testing machine

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CROP & FOOD RESEARCH

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1 SUMMARY

'The Textron' is a portable prototype instrument designed to test the mechanical properties of food. Early development of such an instrument began with the use of an Instron Universal Testing Machine to conduct and develop a stickiness test for bread dough. A need for a machine that was capable of conducting this stickiness test on site at various bakeries soon arose. Many testing machines were available on the market. However, they were not easily transported. The advantages of the Textron are its: portability, ease of operation, automatic data analysis through a computer, and low price.

The machine consists of a probe that moves vertically, applying vertical forces onto a test specimen. The specimen is held on a platform above a loadcell, which measures forces on the specimen. The instrument has been designed to connect to a computer so that data can be collected and probe movements controlled.

The Textron has been designed for various compressive tests and tensile tests to a limit of 20 N load. The standard set up of the instrument is with a 20 N loadcell and a stepper linear actuator capable of applying 125 N. It is possible to substitute the loadcell and actuator with a 200 N loadcell for larger loads and/or a 4 N linear actuator so that the probe is capable of faster movements. These substitutions will require the partial disassembly of the instrument.

Software is currently set up to conduct stickiness tests. However, this software is easily adapted to conduct other rheological tests.

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2 INTRODUCTION

Between November 1992 and March 1993 work was done on developing a portable instrument to test food on site, at various locations. In addition to being portable, the instrument had to be accurately controlled by a PC or laptop to conduct tests automatically.

This report contains the construction details of this prototype, multi purpose food testing machine. Information about the setting up and operation of the instrument is also included.

3 DESCRIPTION OF THE INSTRUMENT

The basic components of the Textron are as follows (see Fig. 2 for further details).

1. Stepping linear actuator

Mounted on top of the chassis. This component produces vertical motion by moving a lead screw. The standard unit has a maximum rated load of 125 N, maximum speed is 525 mm/min. A smaller unit can be substituted that is capable of 4 N force, and a maximum speed of 2000 mm/min.

2. Lead screw guide

Situated below the top of the chassis, this plastic guide holds the lead screw steady, preventing sideways movement. A small brass key is mounted on the guide. The key slides in a groove in the lead screw to prevent lead screw rotation.

3. Over-travel switch

This switch is located in the lead screw guide and prevents the linear actuator from moving the probe head beyond the designed vertical range. The effect of the switch is to change motor direction to downward travel.

4. Chassis

The instrument chassis, machined from a solid plate of 7079 grade aluminium, is rectangular in shape and forms the frame on which all the parts of the instrument are mounted.

5. Probe head

This is attached to the bottom end of the linear actuator lead screw. Probe heads are interchangeable for different tests. Attachment to the lead screw is by a M4 thread.

6. Stepper drive board

This board, behind the chassis but closest to the chassis, receives control signals from the computer. It produces electrical pulses to drive the stepper linear actuator. An on-board oscillator has been installed on this board so that it can generate its own control signals for manual control.

7. Loadcell

The loadcell is situated at the bottom of the chassis and is firmly held in place by two M6 capscrews. The standard loadcell is rated to loads of 20 N. A 200 N loadcell is available. On installation, the capscrews should be tightened to a torque of 7 Nm.

The test platform is connected through an aluminium block to the loadcell. The platform consists of two sheets of perspex plastic, and is designed to support test specimens. Note that if the loadcell is substituted, a different aluminium connecting block must be used.

8. Nine pin 'D' connector

This connector is mounted on the left side of the instrument to interface with a computer.

9. Power supply

This electrical board is located inside the cover at the front left of the chassis. The board supplies a maximum of 40 W. The power supply accepts voltages between 90 VAC and 260 VAC with frequencies between 47 and 63 Hz. Output from the power supply is set at -15 V, +5 V and +15 V.

10. Manual switches (Fig. 1)

Mounted on the front right column of the chassis, three switches allow manual control over the linear actuator. The bottom switch (SW1) selects between manual and automatic computer control. The middle switch (SW2), when in manual mode, controls the direction of the linear drive. The top switch (SW3) similarly controls the speed (fast/slow) of linear drive.

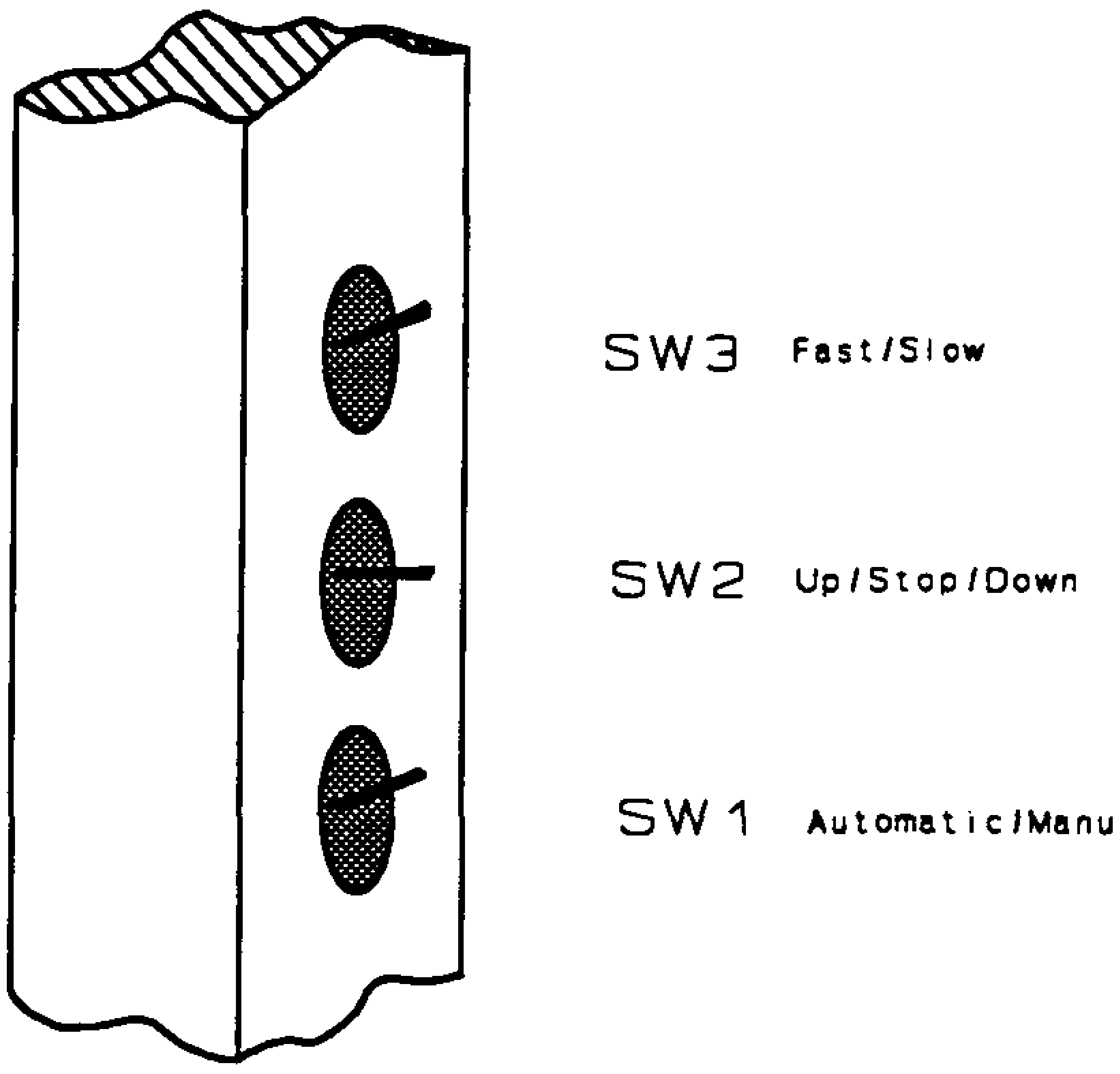

Figure 1: Layout of the manual control switches.

11. Interface and control board

This board is mounted on the stepper drive board and interfaces all the respective boards and switches. An overload circuit also reverses the linear actuator if there is too much force on the loadcell. The point of triggering the overload can be set by a variable resistor. Two other variable resistors set the manual control motor speeds.

12. Aluminium-housed resistor

This resistor, mounted on the right front of the chassis, steps down the voltage from the power supply from 15 V to 12 V by dumping excess energy as heat.

13. Strain gauge amplifier

This electronic board is located at the front of the chassis to the right of the power board. It is covered by an aluminium case to shield it from electronic noise. This board amplifies signals from the loadcell to voltages large enough for the computer to read. The amount of amplification and voltage offset can be set by turning two variable resistors on the board.

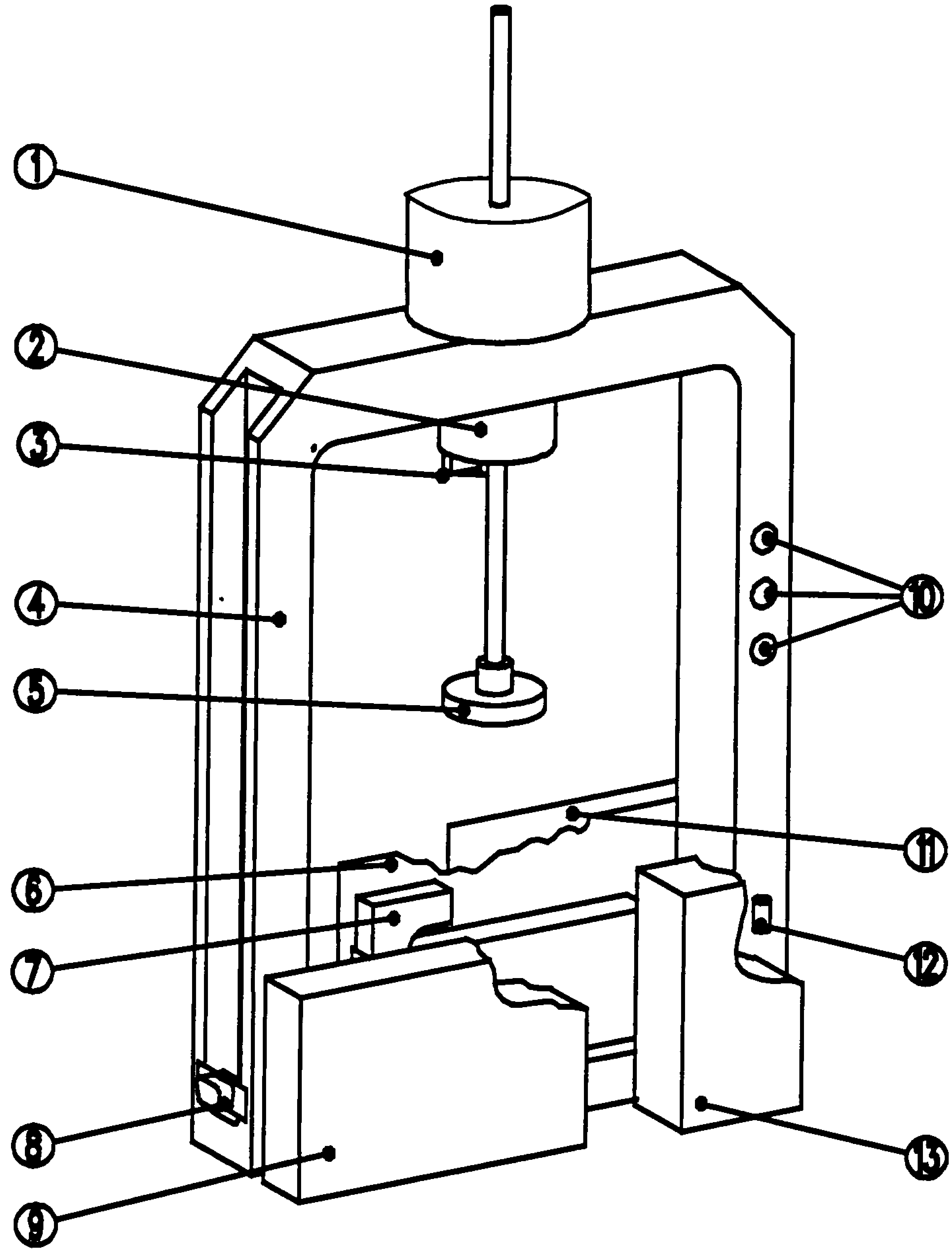

Figure 2: Layout of instrument.

4 SETTING UP THE INSTRUMENT

The Textron is very simple and quick to set up. The instrument should be placed on a level, flat surface and away from any sources of vibrations if possible.

The loadcell is very sensitive to background noise in the form of vibrations. If the sources of vibration cannot be isolated, post-acquisition software filtering procedures may be used.

Ensure the centre switch (SW2) is in the central position so that the linear actuator will not move when the power is turned on.

Plug in the power lead. The Textron can accept a large range of AC power supplies. The voltage range is between 90 and 260 VAC with frequencies between 47 and 63 Hz.

Turn on the power at the wall. There should be a click sound from within the instrument. This sound is from the overload relay, which reverses the velocity of the linear actuator in the case of an overload. (This response to power can be tested by pressing down on the platform and checking for an audible click when overload weight is reached.)

The linear actuator should now be controllable by the switches (SW2 direction and SW3 speed) after the bottom switch is set to manual (Section 5).

The computer's data acquisition can now be connected to the Textron. The instrument was designed for operation with an IBM-compatible PC, equipped with a data acquisition board. Two cables are supplied. One is compatible with the Metrabyte DAS8 data acquisition board. The other cable can be linked onto the previous cable and is compatible with a PCL-718 data acquisition card. Pin connections are shown in Appendix III.

Always allow five minutes for the loadcell amplifier to warm up. The instrument should now be ready for testing. Refer to the software instructions for further directions (Section 6).

5 MANUAL OPERATION

To accommodate different tests, various probe heads can be installed onto the linear actuator leadscrew. These are mounted by an M4 thread on the end of the leadscrew.

At any time it is possible to control the position of the probe using the manual switches. The probe can be controlled manually by setting the bottom switch (SW1) to manual control (downward position). The direction of movement is controlled by the middle switch (SW2). Switching upwards will move the probe up and similarly switching downwards will move the probe down; the middle position will stop the probe movement. The actuator can move at two speeds in manual control, the speed selection is made by the top switch (SW3) - upwards position will correspond to a slow speed and the downwards position corresponds to a fast speed. These speeds can be calibrated (Appendix IV).

A signal on pin 5 of the nine-pin connector represents the force on the loadcell (Appendix III). This is a bipolar signal proportional to the load on the loadcell; the signal gain can be adjusted (Appendix IV).

When conducting a test, a computer with appropriate software is usually employed for data acquisition and linear actuator control. It is possible to conduct a test manually without a computer by using the switches to control probe movement (the two motor speeds can be calibrated to appropriate velocities if necessary). Data output can be recorded by other means such as a chart recorder. This is usually tedious and inaccurate, however.

6 SOFTWARE OPERATION

The software provided with the Textron is intended for use when conducting stickiness tests only. However, the routines provided with this software can easily be adapted to conduct other tests. These routines are discussed in detail in the second part of this section. Finally, the third part of this section contains some guidelines about controlling and reading back data from the instrument, in case software is to be written 'from scratch'.

6.1 'Mr Sticky' stickiness test program

This program is written using a stack-based language and application called ASYST. There is a compiled executable programmed called 'mrsticky.exe'. Typing this filename at the DOS prompt starts up the program.

To start up the software while inside the ASYST application, load the program by typing 'load mrsticky.txt' and then start it up by typing 'go'. The ASYST application should be configured with the following overlays: Menu Tools, Data Files, 123 File Interface, Waveform Operations, Waveform Operations II, Data Acq Master, Ext DAS Driver Support, Counter Timer Support. These overlays correspond to the following files (which should be in the current directory along with 'mrsticky'): WAVEOPS.SOV, WAVEOPS2.SOV, ACQMET16.SOV, ACQUIS.SOV, 123IO.SOV, DATAFILE.SOV, ACQCOUNT.SOV, MENU.SOV.

Once the program has started, the probe head will move down to touch the platform so that the computer can find a reference point for its positioning. If, at any stage, manual control is used, the program will lose its reference point and the 'Find Zero' option in the program must then be used to relocate the reference point.

The program is completely menu-driven and is quite simple to operate. Usually, the first thing to do before a test, is to calibrate the loadcell. It is not vital to do this because the computer remembers its last calibration at start up, but it is recommended to do it at the start of each series of tests to provide more accurate results. To do a calibration, go to the 'Calibration' menu and select 'Do a Calibration' and follow instructions. You will need a 500 g test weight to conduct the calibration. It is possible to see all of the previous calibrations by selecting 'View Calibrations' in the 'Calibration' menu.

The parameters of the sticky test can be changed within the program by selecting 'Test Parameters' in the 'Calibration' menu. The initial parameters are set for a standard test of bread dough stickiness but these can be changed when necessary. The parameters that can be varied are the motor speeds at any stage of the test, the maximum compression force during the test, and the force at which relaxation is stopped.

To start a test, enter the 'Start Test' menu, and then follow instructions. Once the test has finished, the data can be analysed in the 'Analysis' menu.

The data from the test can also be saved in the 'Files' menu under 'Save Data'. There is an option to save the data as a 'data file', which is quick and economical on disk space (this saves the file with an extension of '*.stk'). The other option is saving as a 'Lotus 123 worksheet' file. This approach allows the data to be loaded into Lotus 123 for further analysis, manipulation and graphing (this saves the file with an extension of *.wk1).

All test data can be loaded back at any time for viewing and analysis. This is done through the 'Load Data' option in the 'Files' menu, selected by 'Enter' and 'ESC'.

A directory of the data files on record can be seen by selecting 'Directory' in the 'Files' menu. These files can be deleted by using the 'Delete File' option in the 'Files' menu. Once selected, a list of all current data files on record are listed, and to delete any particular file, the user must tag that file using the arrow keys and [Enter] (an arrow appears next to the file name once tagged). Once all the files that are to be deleted have been tagged, press [Esc] to start the deleting process. If a file has been tagged by accident it can be untagged by hitting [Enter] again.

To exit the program, select 'Quit' at the main menu, this will return the computer to DOS.

6.2 'Mr Sticky' program description

The following is a description of all the major routines in 'Mr Sticky' that are important for controlling the instrument and reading back data. It should provide useful information when modifying the software to suit different tests.

There are four basic routines that control the linear actuator movement:

1.	*motor.speed*	sets the linear actuator speed to a given speed in mm/min. e.g. *500 motor.speed* sets the linear actuator speed to 500 mm/min.
2.	*motor.up*	moves the probe upwards at a given speed e.g. *300 motor.up* will move the probe upwards at a speed of 300 mm/min. Note: this routine calls *motor.speed* to set the speed.

3.	*motor.down*	moves the probe downwards at a given speed e.g. *300 motor.down* will move the probe downwards at a speed of 300 mm/min. Note: this routine calls *motor.speed* to set the speed.
4.	*motor.stop*	will stop any probe movement.

The last three routines described above update a counter that keeps track of pulses being sent out, hence it is possible to keep track of the probe position. To get the probe position, the routine *get.probe.position* must be called. This routine places the position of the probe on the stack at a distance in millimetres from the initial platform position with no weight on it (note that the platform will deflect a small distance under load).

It is possible to move the probe to a given position at a given speed using *motor.move.to* e.g. *500 20 motor.move.to* will move the probe at a speed of 500 mm/min. from the current position to 20 mm above the platform. Unlike the above control commands, this routine will only exit when the probe has reached the required position, hence it is not possible to perform other tasks while this routine controls the probe movement.

Three routines are provided for data acquisition from the loadcell:

1.	*A/D.IN*	This is a redefinition of the ASYST system command, and essentially performs the same function. It reads a value (0-4095) in from analogue channel 0 (which is connected to the loadcell) and places it onto the stack. The difference with this redefinition is that there is no need to define a template for the channel because it always reads from channel 0. The other more important difference is that it does not require a DAS counter, and hence the spare counter can be used to track the probe position. (Note that to convert a sample into a reading in grams you must divide by the calibration value 'grams/volt' and then subtract from this the weight of the zero reference.)
2.	*get.steady.sample*	This routine takes 250 averaged samples (at a frequency dependent on the computer speed) using *A/D.IN* and returns this value. It is useful for finding a new reference zero weight value when a new sample has been placed on the loadcell.
3.	*get.quick.reading*	This routine takes an average of several samples (at a frequency dependent on the computer speed), converts

this value to a weight in grams and then places it on the stack.

When modifying the software for a new test. It is recommended that the entire 'Mr Sticky' program is retained for use as the core of the new program. The *analysis* routine must, of course, be completely rewritten. Also, for the new test, the *do.test* routine must be modified. The *start.sticky.test* may be renamed to avoid confusion, but would probably not need changing since it simply sets up the screen, the motor and sets the loadcell to zero for the start of a test.

When changing the *do.test* routine the following information may be useful:

- the data collected in the form of loadcell readings are stored in a token array called 'force'. The end of the data stored in 'force' should be marked by a scalar integer variable called 'termination_index', the value in this variable should correspond to the index number holding the last item of data in the force array. At the end of the test the force array should be trimmed (using *SUB[]*) to the size indicated by 'termination_index' to eliminate saving unnecessary data, and

- any important data that are to be stored in addition to force, such as certain test parameters, should be placed in a real array called 'misc_test_data', which has a size of 6. On saving and loading files, the information that is transferred will be the data held in the 'force' and 'misc_test_data' arrays. All other information about that test is lost, so it is important to store any important data in these arrays.

6.3 Basic software control

If software is to be written from scratch, without the aid of the routines described previously, the following is a guide to controlling the linear actuator and obtaining feedback.

6.3.1 Actuator movement

Three lines control the linear actuator. The ON/OFF lead must always be set high to enable the actuator. The direction is controlled by the DIR lead, which is set high to move the probe up and low to move it down. The speed of the actuator is controlled by the CLK lead. To produce movement, a square wave pulse train must be sent. Each pulse cycle corresponds to a single step of the linear actuator, which is 0.025 mm. At speeds above 500 mm/min. or 333 Hz the actuator is prone to stalling on sudden acceleration. It is best to ramp up the speed gradually when exceeding 500 mm/min. Do not send pulse trains faster than 400 Hz in frequency

(600 mm/min.) as the linear actuator will stall. Probe position can only be tracked if the number of pulses sent is counted, which may be useful for a number of tests.

6.3.2 Data acquisition

Loadcell data are in analogue form so a analogue to digital conversion must be made before entering the computer. Many data acquisition boards are available on the market for this purpose. The AN OUT line is connected to the loadcell and varies in voltage in proportion to the loadcell reading. This voltage is bipolar and can be calibrated to your needs by two variable resistors on the loadcell amplifier (Appendix IV). They control the amplification and voltage offset of the signal output.

7 RECOMMENDED DEVELOPMENTS

The Textron instrument described in this report is a prototype. This design is can be improved upon for future 'production' models. This section describes some improvements that can be made to the current design to increase performance and reduce costs.

The geometric layout of the instrument can be improved using a square 'C' frame chassis rather than the current rectangular frame. This would give better accessibility to the sample platform, and possibly allow a lighter chassis to be built.

The linear actuator in the current model produces rough stepping motions when the probe movement is slow. Using a standard DC motor with a built-in position encoder makes it possible to produce smooth movements at any speed. The encoder would give the added bonus of enhancing the positional accuracy at which the probe can be moved. This set up with a DC motor does not use power when there is no probe movement (unlike the stepping linear actuator currently in use). Thus, the energy requirements of the instrument are reduced making powering the instrument from batteries feasible.

The loadcell ideally should be placed at the probe tip. This relocation would reduce the amount of mechanical histeresis in the system. The current loadcell and platform set up deflects up to 1 mm under compression or tension and oscillates under excitations from background vibrations or forces applied from the probe.

Major improvements can be made in the design of the electronics that control the linear actuator and return the loadcell signal. The current setup is very expensive, requiring a dedicated data acquisition board to communicate between the Textron and the computer. It is recommended that inbuilt electronics, controlled by a dedicated microprocessor, should be incorporated. Motor control commands can then be sent via an RS-232 interface and, conversely, the loadcell signals should be returned along this line to the computer. This arrangement would allow the instrument to communicate to a large variety of computers - any computer with an RS-232 interface and enough processing power would be sufficient. By selecting a small, hand-held computer (such as a PSION Organiser) the instrument can be made highly portable and cheap, requiring no additional equipment.

8 SPECIFICATIONS

8.1 Linear actuator

Linear actuator supplier: Radio Spares, Part #318-711

Actuator load/speed:
Maximum rated speed: 525 m/min.
Maximum rated load: 125 N

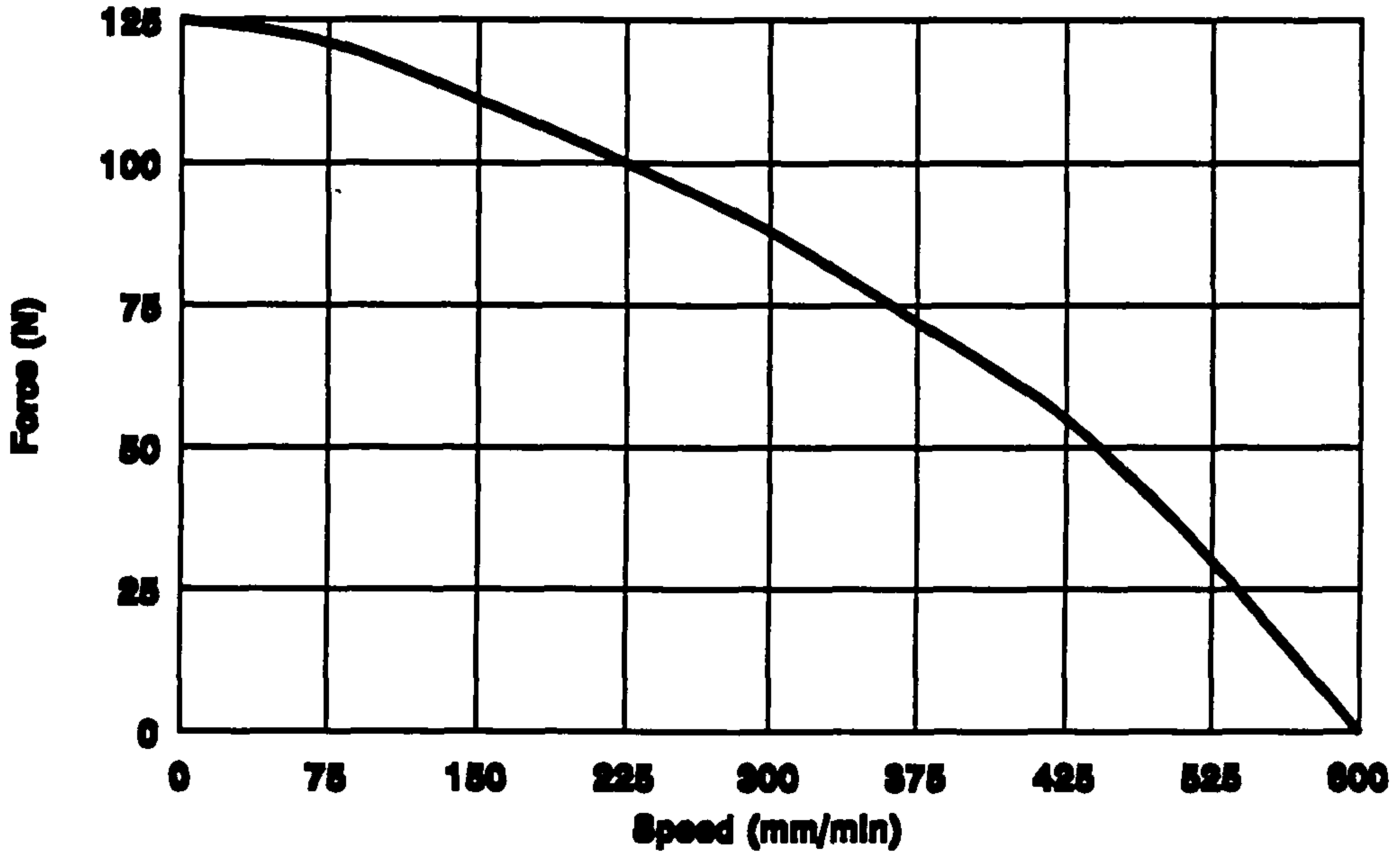

Figure 3: Actuator characteristics.

Linear actuator accuracy:
Step size: 0.025 mm
Step accuracy: ± 0.005 mm
Repetition accuracy: ± 0.01 mm

Linear actuator travel:
Approx 102 mm vertical travel (dependent on probe head height)

Linear actuator control:
Separate switch controls for:
Fast, slow speed.
Up, down, stop.
Manual, automatic control.

8.2 Loadcell

Loadcell supplier: Radio Spares, Part#632-736

Strain gauge amplifier supplier: Radio Spares, Part #308-815
#435-692

Warm-up time: 5 minutes

Load ranges:
0-20 N with unipolar data acquisition.
-20 N-20 N with bipolar data acquisition.
200 N range possible with interchangeable loadcells

Load accuracy:
± (0.018N + 0.4% of load), at 95% confidence
(One standard deviation = 0.009N + 0.2% of load[1])
Higher accuracy is easily obtained filtering to smooth the data signal and hence remove any noise.

Installation: torque loadcell mounting screws to 7 Nm.

8.3 Power supply

Power board supplier: Radio Spares, Part #595-889

Input range: 90-260 VAC

Frequency: 47-63 Hz

Maximum wattage: 40 W

Fusing: 2A 20 mm quick blow

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[1] The load relative to an empty platform.

8.4 Chassis

Machined 7079-grade aluminium.

8.5 Dimensions

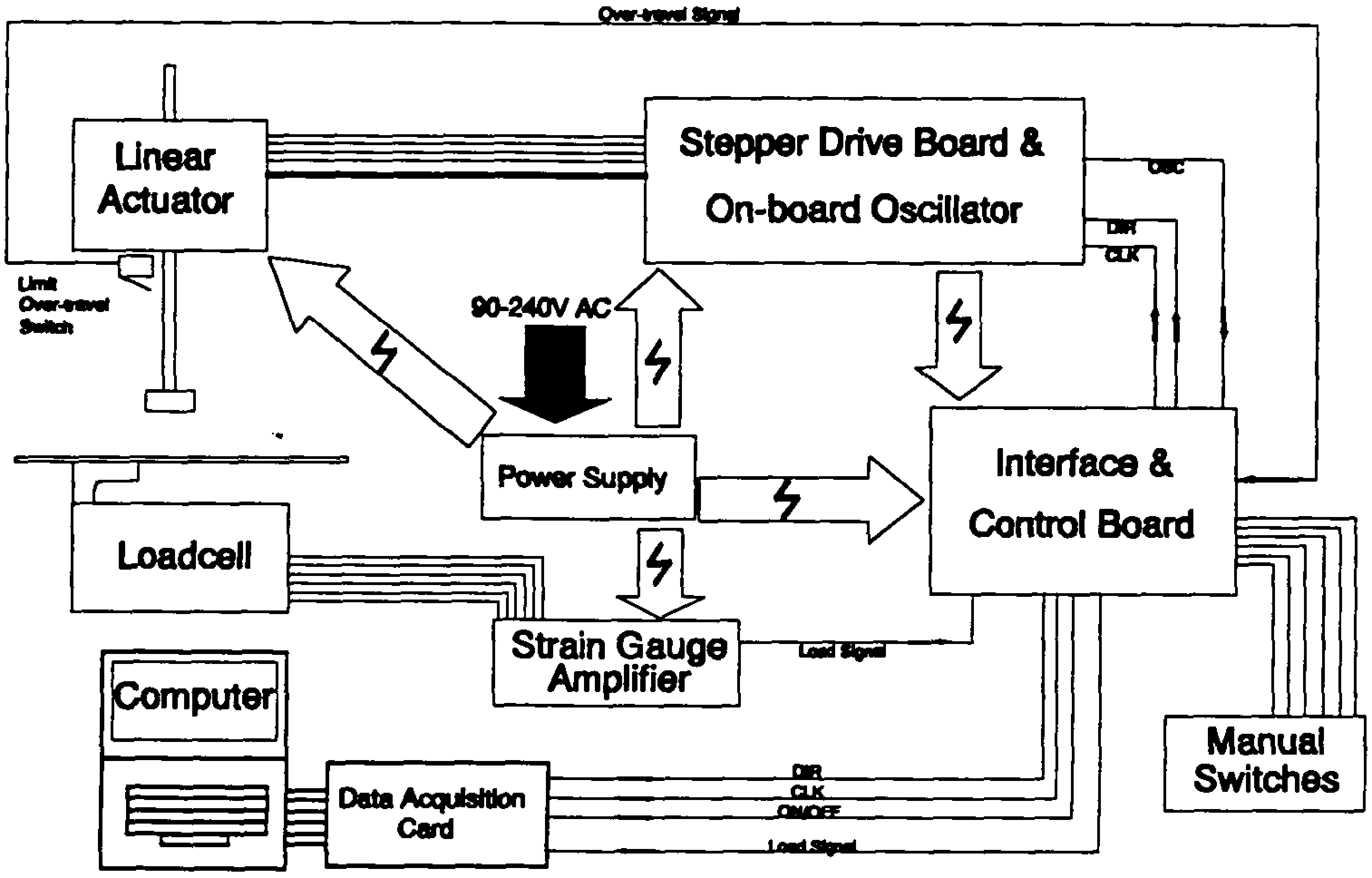
337 mm high x 228 mm wide x 132 mm deep
- excluding lead screw

8.6 Weight

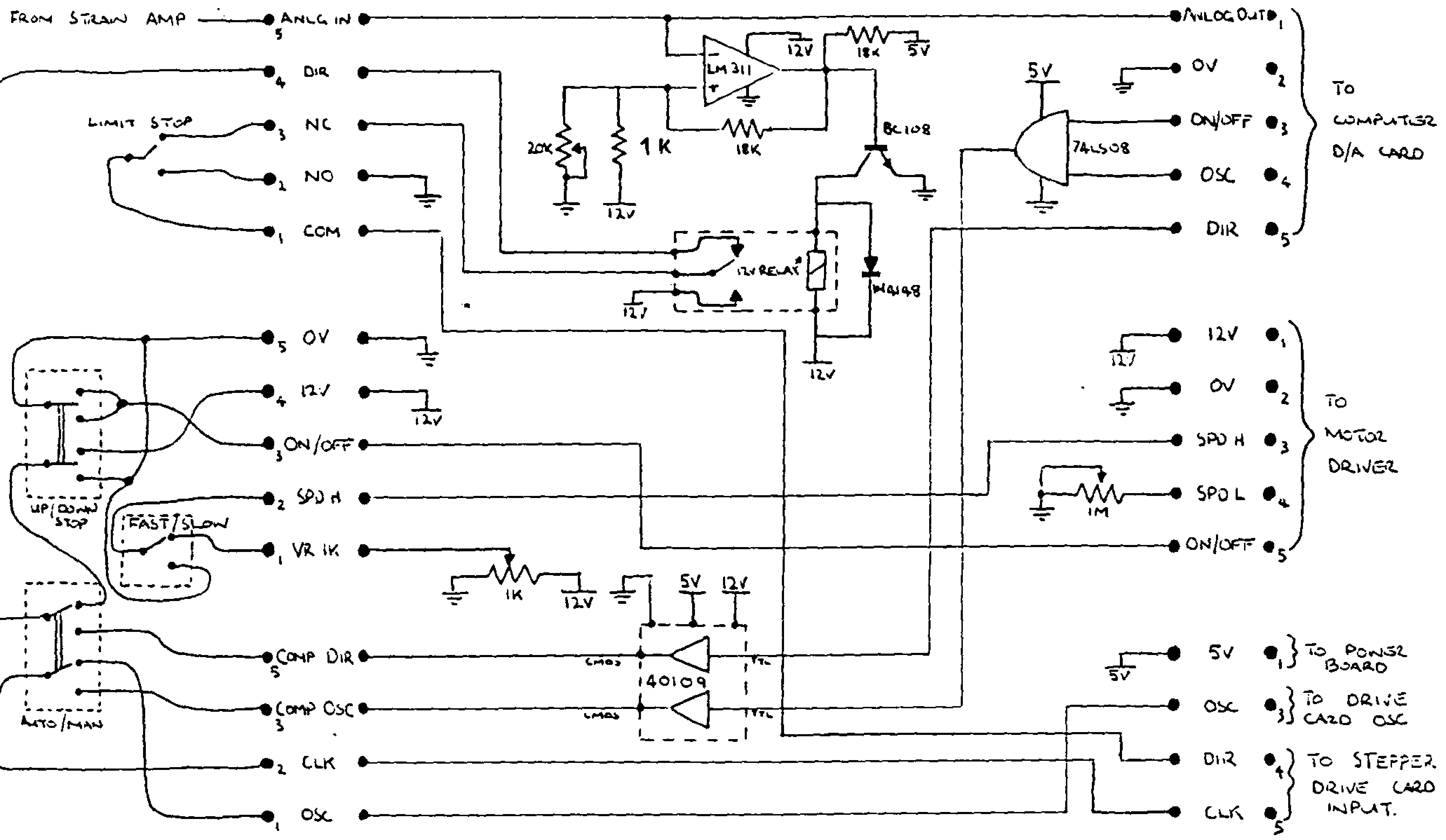
4.120 kg
- excluding computer cable

9 APPENDICES

Appendix I System block diagram



Appendix II Interface and control board



* RS PART NO. 345-038
ULTRAMINIATURE SPCO RELAY

Appendix III External connections

The nine-pin 'D' connector located on the left side of the instrument is the only means through which automatic control and data acquisition can be made. The connections for this plug are:

PIN1 - DIR	linear actuator direction - set high to move up - set low to move down
PIN2 - CLK	linear actuator speed - square wave train to the frequency of stepping motion
PIN3 - ON/OFF	actuator on/off control - set high to allow actuator movement
PIN4 - 0V	common signal
PIN5 - AN OUT	analogue loadcell signal output - bipolar output - variable voltage range (Appendix IV)
PIN6 - No Connection	
PIN7 - No Connection	
PIN8 - No Connection	
PIN9 - No Connection	

The connections for the nine-pin to 37-pin DAS8 connector lead is:

NINE PIN Connector		**37 PIN Connector**
		PIN 2 CTR0 CLK IN
		PIN 4 CTR1 CLK IN
PIN2 CLK	(green)	PIN 5 CTR1 OUT
		PIN 6 CTR2 OUT
PIN1 DIR	(blue)	PIN 7 OUT1
PIN3 ON/OFF	(yellow)	PIN 8 OUT2
PIN4 0V	(black)	PIN 28 COM
PIN5 AN OUT	(red)	PIN 36 ANLG IN (+) 1
No Connection	(Shield)	Connector Casing

The connections for the 37-pin to 2x20-pin connector for the PCL-718 are:

2x20 PIN Connector **37 PIN Connector**
CN1 PIN1 A/D H0 ——(red) ————PIN 37 ANLG IN (+) 0
CN1 PIN3 A/D H1 ——(blue/black) ——PIN 36 ANLG IN (+) 1
CN1 PIN19 A.GND —— (green/black) —— PIN 28 COM ————
PIN 18 ANLG IN (-) 1 ——
PIN 19 ANLG IN (-) 0 ——
CN2 PIN8 CTR0 CLK
CN2 PIN10 CTR0 OUT
CN2 PIN12 CTR0 GATE
CN2 PIN14 CTR2 OUT —(green) ———— PIN 5 COUNTER1
CN2 PIN16 D/O 4
CN2 PIN18 D/O 2 ———(yellow) ——— PIN 8 OUT2
CN2 PIN20 D/O 0 ———(blue) ———— PIN 7 OUT1

Pins CN2 PIN8 to CN2 PIN20 usually have no connection. These lines have been rerouted from their standard locations inside the PCL-718 to CN2 for external access in the following way:

CN3 PIN1 D/O 0 ———————— CN2 PIN20
CN3 PIN3 D/O 2 ———————— CN2 PIN18
CN3 PIN5 D/O 4 ———————— CN2 PIN14
CN5 PIN8 CTR0 CLK —————— CN2 PIN8
CN5 PIN10 CTR0 OUT —————— CN2 PIN10
CN5 PIN12 CTR0 GATE ————— CN2 PIN12
CN5 PIN14 CTR2 OUT —————— CN2 PIN14

Appendix IV Internal adjustments

The following is a description of the adjustments that can be made. Locations are illustrated in Appendix II and below. All adjustments are via blue, multi-turn variable resistors.

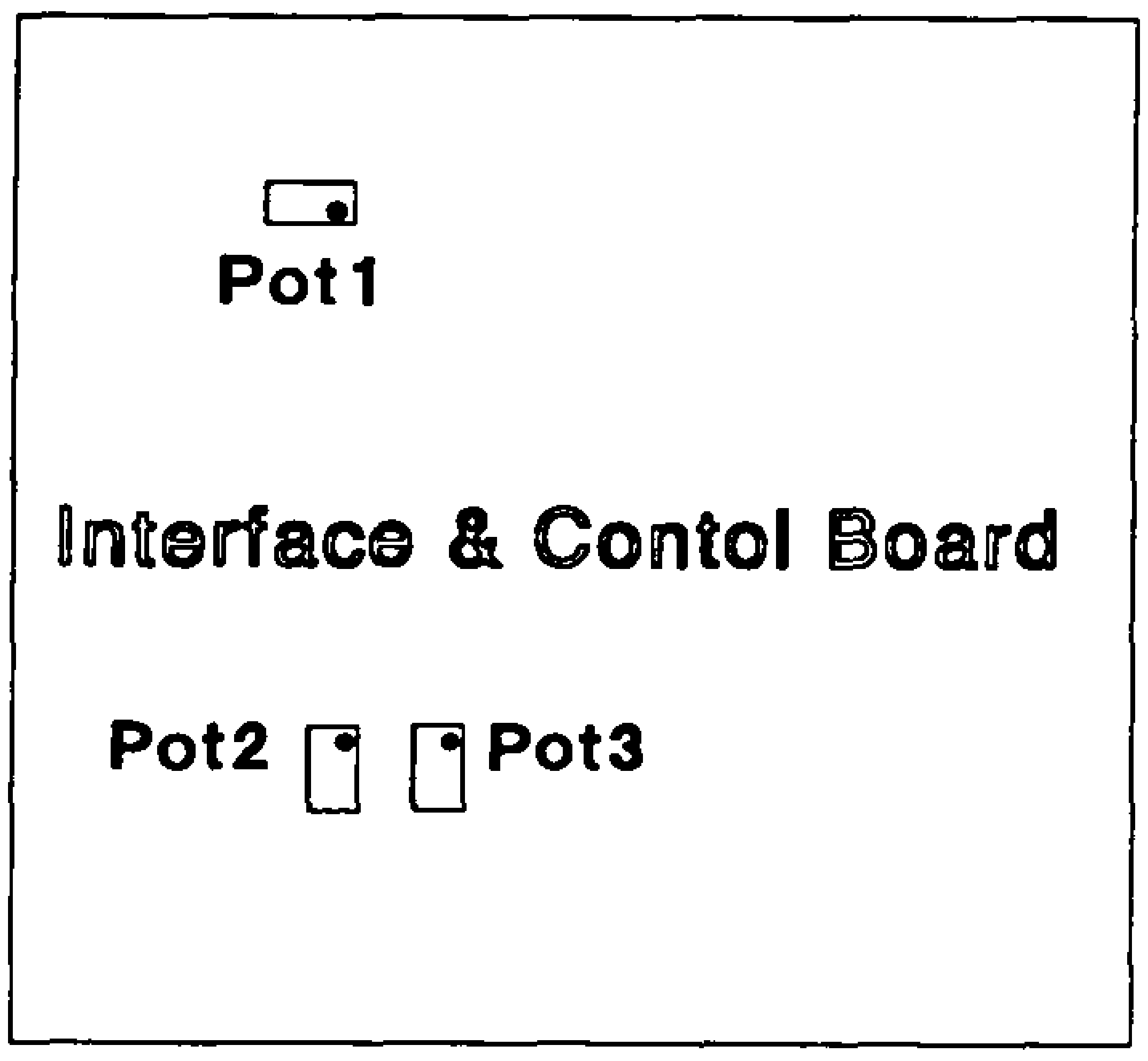
Pot1 Sets the load limit triggering point at which the linear actuator will automatically move upwards to prevent overloading the loadcell.

Pot2 Controls the on-board oscillator high frequency output i.e. the fast speed setting on manual control. Note that this speed is relative to the low speed setting.

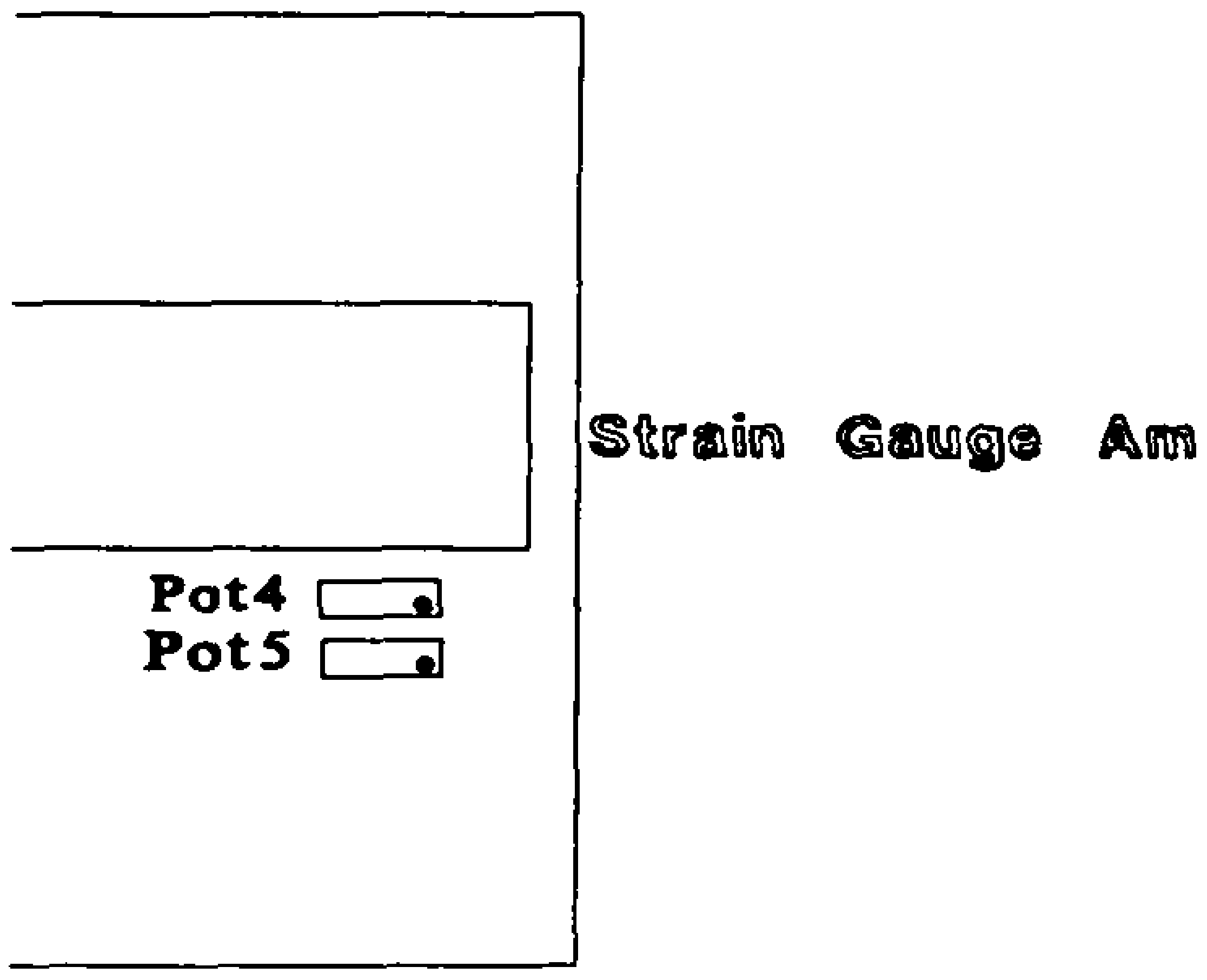
Pot3 Controls the on-board oscillator low frequency output i.e. the slow speed setting on manual control.

Pot4 Shifts the zero volts position of the analogue loadcell signal.

Pot5 Sets the voltage amplification on the loadcell signal.



Tuning pot locations on the interface and control board



Locations of tuning pots on the Strain Gauge Amplifier.
See Appendix VI for circuit diagram.

Appendix V Software printout

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==================================================
\       MR STICKY - Dough Stickiness Testing Program.
\
==================================================
\
\       Written by William Lau (C) Feb 1993
\               Crop & Food Research
\               Lincoln
\

MENU main.menu
   MENU files.menu
      MENU load.menu
      MENU save.menu
      MENU delete.menu
      MENU dir.menu
      MENU get.filename.menu
   MENU analysis.menu
      MENU show.parameters.menu
   MENU calibrate.menu
      MENU loadcell.calibration.menu
      MENU view.calibration.menu
      MENU test.parameters.menu


VUPORT bottom_vuport
   bottom_vuport
   0 .035 VUPORT.ORIG
   1 .865 VUPORT.SIZE
VUPORT calib_vuport
   calib_vuport
   .07 .55 VUPORT.ORIG
   .87 .25 VUPORT.SIZE

29  0 29 79  WINDOW bottomline_window
 6 16 22 65  WINDOW middle_window
14  5 23 74  WINDOW wide_window


TOKEN count                 EXP.MEM> count
TOKEN force                 EXP.MEM> force
TOKEN filtered_force        EXP.MEM> filtered_force
TOKEN derived_force         EXP.MEM> derived_force
TOKEN calibrations          EXP.MEM> calibrations
TOKEN calibration_time/date EXP.MEM> calibration_time/date
TOKEN misc_test_data        EXP.MEM> misc_test_data
REAL DIM[ 6 ] ARRAY.BECOMES> misc_test_data  \ [ 1 ] dough height
                                             \ [ 2 ] dough compression
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```
                                        \ [ 3 ] test compression speed
                                        \ [ 4 ] test pulling speed
                                        \ [ 5 ] test relaxation trigger
                                        \ [ 6 ] test tension trigger

INTEGER SCALAR array_size         2500 array_size :=
        SCALAR sample_rate          10 sample_rate :=
        SCALAR compression_speed    10 compression_speed :=
        SCALAR pulling_speed       500 pulling_speed :=
        SCALAR relaxation_trigger  150 relaxation_trigger :=
        SCALAR tension_trigger      75 tension_trigger :=


INTEGER SCALAR calib_datasize           \ size of the calibration array in file
        SCALAR termination_index        \ size of collected data
        SCALAR end_of_compression       \ position index for end of compression
        SCALAR end_of_relaxation        \   "      "    "  end of relaxation
        SCALAR end_of_tension           \                  end of tension
        SCALAR tension_period           \ size of tension period
        SCALAR peak_tension_index       \ position index for peak tesion
        SCALAR motor_status             \ motor status flag; 0=stop 1=up -1=down
        SCALAR probe_count
        SCALAR reading                  \ temporary storage for sample

REAL    SCALAR dough_height
        SCALAR dough_deformation
        SCALAR peak_compression
        SCALAR compression_energy
        SCALAR peak_tension
        SCALAR tension_energy
        SCALAR last_value
        SCALAR peak_compression_time
        SCALAR peak_tension_time
        SCALAR start_tension_time
        SCALAR relaxation_time
        SCALAR weight_0g                \ voltage with no weight
        SCALAR weight_500g              \ voltage with 500g weight
        SCALAR grams/volt               \ calibration value
        SCALAR zero_value               \ voltage at no weight
        SCALAR probe_position           \ position of probe in mm

INTEGER DIM[ 1 ]     ARRAY 2byte_array
        DIM[ 8 , 1 ] ARRAY time/date    \ temporary storage for time & date
REAL    DIM[ 1 ]     ARRAY calibration  \ temporary storage for calibrations


12  STRING  filename                    \ filename of file
18  STRING  time/date_string            \ time/date at calibration

DAS8
```

```
PULSE.TEMPLATE motor_clock              \ set-up counter 2 for pulses
   2 PULSE.CHANNEL
   .5 PULSE.DUTY.CYCLE
   10000 PULSE.PERIOD
PULSE.INIT

COUNT.TEMPLATE step_counter             \ set-up counter 0 to count pulses
   0 COUNT.CHANNEL
COUNT.INIT

0 1 EXT.DIGITAL.TEMPLATE dir_latch      \ set up digital outputs
DIGITAL.INIT

: A/D.IN
   00H 302H PORT.OUT               \ specify channel 0
   00H 300H PORT.OUT               \ trigger an input
   300H PORT.IN 16 / #>MASK           \ read low byte  , shift 4 bits right
   301H PORT.IN 16 * #>MASK           \ read high byte , shift 4 bits right
   OR MASK>#                      \ combine bytes & convert into integer
;

\ DAS Stepper Motor Driver Commands ________________________________________
: reset.count
   COUNT.INIT
   COUNT.START
;
: get.probe.position
   COUNT>STACK                       \ get count
   40 /                          \ convert to mm
   motor_status *                   \ give count direction polarity
   probe_position +                   \ add to last position
;

\ Motor Speed. \\\\\\\\\\\\\\\\\\\\\\\\\\
\ - [ speed - ]
\ - sets the motor speed in mm/min
: motor.speed
   15000 SWAP /                   \ calculate pulse period for given speed
   motor_clock
   PULSE.PERIOD                     \ set pulse period
   PULSE.INIT
   PULSE.START
;

\ Motor Up/Down/Stop \\\\\\\\\\\\\\\
\ - [ - ]
\ - direct motor control commands;
\ - writes to digital outputs 1 & 2 to control direction and on/off latches
: motor.up
   get.probe.position probe_position := \ update probe position
   reset.count
```

```
  1 motor_status :=                  \ set motor status flag
  5, WRITE.BITS                        \ digital output to control dir
  motor.speed                      \ start motor at given speed
;
: motor.down
  get.probe.position probe_position := \ update probe position
  reset.count
  -1 motor_status :=                 \ set motor status flag
  4, WRITE.BITS                        \ digital output to control dir
  motor.speed                      \ start motor at given speed
;
: motor.stop
  PULSE.STOP                         \ stop motor
  get.probe.position probe_position := \ update probe position
  0 motor_status :=                  \ set motor status flag
\   PULSE.STOP                         \ stop motor
;
\ Motor Accelerate. \\\\\\\\\\\\\\\\\\\\\\\\
: motor.accel.up
  11 7 DO
    DUP I LOG * motor.up
  LOOP
  DROP
;

\ Motor Move to. \\\\\\\\\\\\\\\\\\\\\\\\\
\ - [ speed , position - ]
: motor.move.to
  DUP
  get.probe.position >
  IF
    SWAP motor.up
    BEGIN
      DUP get.probe.position <=
    UNTIL
  ELSE
    SWAP motor.down
    BEGIN
      DUP get.probe.position >=
    UNTIL
  THEN
  DROP
  motor.stop
;

\ Find Zero. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\ - finds the zero motor position (platform level)
: find.zero
  CR ." Please wait while I touch the platform..."
  500 motor.down
  BEGIN
```

```
      A/D.IN
      A/D.IN 80 -
      <
   UNTIL
   A/D.IN 20 - reading :=
   motor.stop
   CR CR ." Oooohhhh.. I just found it."
   0 probe_position :=
   200 1.5 motor.move.to
   20 motor.down
   BEGIN
      A/D.IN
      reading >=
   UNTIL
   motor.stop
   0 probe_position :=
   CR CR CR ." Okay."
   CR CR ." I'm ready."
   500 40 motor.move.to
;

\ ____________________________________________________________

\ Key Wait. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\ - Pauses until a key is pressed
: key.wait
   BEGIN
      ?KEY
   UNTIL
   KEY DROP
;


\ Get Steady Sample \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
: get.steady.sample
   0
   250 0 DO
      A/D.IN
      +
   LOOP
   250 /
;

\ Get Quick Reading. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\ - take a quick averaged reading in grams
: get.quick.reading
   0
   5 0 DO
      A/D.IN
      +
   LOOP
```

```
   5.0 /
   409.6 / grams/volt * zero_value -
;

\ ---------------------------plot calibration---------------------------
   REAL DIM[ 60 ] ARRAY x
   REAL DIM[ 60 ] ARRAY y
: plot.cal
   find.zero 500 10 motor.move.to
   get.steady.sample 409.6 / grams/volt * zero_value :=
   250 .5 motor.move.to
   VERTICAL 0 3000 WORLD.SET
   HORIZONTAL -.50 2.5 WORLD.SET
   XY.AXIS.PLOT
   WORLD.COORDS

   1.5 motor.down
   1000 SYNC.PERIOD
   61 2 DO
      SYNCHRONIZE
      get.probe.position -1 * x [ I ] :=
      a/d.in       y [ I ] :=
      x SUB[ I 1 - , 2 ] y SUB[ I 1 - , 2 ] XY.DATA.PLOT
   LOOP
;

\ Overwrite \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\ tests for file existence, ask for overwrite
: overwrite
   filename DEFER> FILE.SIZES
   0.5 > IF
      bottomline_window
      CR BELL
      ."        "
      filename "TYPE
      ." already exists. Overwrite file? (Y/N)"
      KEY DUP
      CR
      89 =          \ 'Y' ?
      121 =         \ 'y' ?
      OR
   ELSE
      TRUE
   THEN
   DROP             \ file size from file.sizes
;

\ Get Filename \\\\\\\\\\\\\\\\\\\\\\\\\\\\
: get.filename
   4 1 GOTO.XY
   ." >"
```

```
   "INPUT
   MENU.ESCAPE
;


\ Load Data File. \\\\\\\\\\\\\\\\\\\\\\
: load.data.file
   filename DEFER>  FILE.OPEN
      1 SUBFILE FILE>UNNAMED.ARRAY BECOMES> force
      force []SIZE termination_index := DROP
      termination_index RAMP BECOMES> count
      2 SUBFILE FILE>UNNAMED.ARRAY BECOMES> misc_test_data
   FILE.CLOSE
;

\ Load Worksheet. \\\\\\\\\\\\\\\\\\\\\\
: load.worksheet
   filename DEFER>  123FILE.OPEN
      4 3 1 1 123READ.RANGE 123FILE>UNNAMED.ARRAY
      [ 1 ] termination_index :=
      termination_index RAMP BECOMES> count
      5 3 6 1 123READ.RANGE misc_test_data 123FILE>ARRAY
      REAL DIM[ termination_index ] ARRAY.BECOMES> force
      12 2 termination_index 1 123READ.RANGE force 123FILE>ARRAY
   123FILE.CLOSE
;

\ Load File. \\\\\\\\\\\\\\\\\\\\\\\\\\
: load.file
   load.menu MENU.EXECUTE              \ choose file & put on stack
   0 <>
   IF
      12 "LEFT -TRAILING filename ":=
      filename 4 "RIGHT
      " .STK" "=
      IF                          \ determine file type
         load.data.file            \ load data file
      ELSE
         load.worksheet             \ load spreadsheet file
      THEN
      bottom_vuport
      count force XY.AUTO.PLOT          \ display file
      OUTLINE
      MENU.STACK.CLEAR
      main.menu MENU.EXECUTE
   THEN
;


\ Save File. \\\\\\\\\\\\\\\\\\\\\\\\\\
: save.data.file
```

```
   termination_index 0 < >
   IF
      REGULAR.DATAFILE
      FILE.TEMPLATE
         force          []FORM.SUBFILE
         misc_test_data []FORM.SUBFILE
      END
      BEGIN
         get.filename.menu MENU.EXECUTE
         8 "LEFT  " .stk"  "CAT  filename  ":=
         overwrite
      UNTIL
      filename DEFER> FILE.CREATE
      filename DEFER> FILE.OPEN
         1 SUBFILE force          ARRAY>FILE
         2 SUBFILE misc_test_data ARRAY>FILE
      FILE.CLOSE
      count force XY.AUTO.PLOT
   THEN
;


\ Save Worksheet. \\\\\\\\\\\\\\\\\\\\\\\\
: save.worksheet
   termination_index 0 < >
   IF
      get.filename.menu MENU.EXECUTE
      8 "LEFT  " .wk1"  "CAT  filename  ":=
      filename DEFER> 123FILE.CREATE
      filename DEFER> 123FILE.OPEN
         " Mr Sticky Datasheet"      1 1 123WRITE.ACROSS ">123FILE
         " Date:"                    1 3 123WRITE.ACROSS ">123FILE
         "DATE                       1 4 123WRITE.ACROSS ">123FILE
         " Time:"                    2 3 123WRITE.ACROSS ">123FILE
         "TIME                       2 4 123WRITE.ACROSS ">123FILE
         " Data Array Size:        " 4 1 123WRITE.ACROSS ">123FILE
         " Initial Dough Height    " 5 1 123WRITE.ACROSS ">123FILE
         " Dough Deformation       " 6 1 123WRITE.ACROSS ">123FILE
         " Test Compression Speed  " 7 1 123WRITE.ACROSS ">123FILE
         " Test Pulling Speed      " 8 1 123WRITE.ACROSS ">123FILE
         " Test Compression Target"  9 1 123WRITE.ACROSS ">123FILE
         " Test Relaxation Target " 10 1 123WRITE.ACROSS ">123FILE
         termination_index          4 3 123WRITE.ACROSS ARRAY>123FILE
         misc_test_data             5 3 123WRITE.DOWN   ARRAY>123FILE
         force                     12 2 123WRITE.DOWN   ARRAY>123FILE
      123FILE.CLOSE
   THEN
   MENU.ESCAPE
;
```

```
\ Delete File. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
: delete.file
   delete.menu MENU.EXECUTE
   DUP 0 =
   IF
      DROP
   ELSE
      middle_window
      0 16 GOTO.XY CR
      0 DO
         12 "LEFT  -TRAILING
         "DUP
         CR ." Deleting " "TYPE ." ..."
         DEFER> DELETE
         500 msec.delay
      LOOP
   THEN
;

\ Directory. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
: directory
   DIR.BRIEF *.stk
   DIR.BRIEF *.wk1
;


\ Get Directory. \\\\\\\\\\\\\\\\\\\\\\\\\\\
: get.directory
   directory
   key.wait
   MENU.ESCAPE
;



\ Do Test. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
: do.test
   500 18 motor.move.to               \ bring motor down to start height
   60 motor.down                      \ slow down motor
   1000 sample_rate / SYNC.PERIOD         \ set sample rate
   0
   BEGIN
      DROP
      get.quick.reading
      DUP 5.0 > =                     \ wait until probe touches dough
   UNTIL
   SYNCHRONIZE
   force [ 1 ] :=
   compression_speed motor.down
   get.probe.position dough_height :=    \ record dough height
   CR ." Compressing ..."
```

```
array_size 1 + 2 DO              \ compression loop
   SYNCHRONIZE
   get.quick.reading DUP force [ I ] :=
   count SUB[ I 1 - , 2 ]
   force SUB[ I 1 - , 2 ]
   XY.DATA.PLOT
   relaxation_trigger > = IF
      I 1 +
      LEAVE
   THEN
LOOP
motor.stop                       \ stop motor
dough_height get.probe.position
- dough_deformation :=           \ record dough deformation
CR ." Relaxing ..."
array_size 1 + SWAP DO           \ relaxation loop
   SYNCHRONIZE
   get.quick.reading DUP force [ I ] :=
   count SUB[ I 1 - , 2 ]
   force SUB[ I 1 - , 2 ]
   XY.DATA.PLOT
   tension_trigger < = IF
      I 1 +
      LEAVE
   THEN
LOOP
pulling_speed motor.up
CR ." Pulling away ..."
array_size 1 + SWAP DO           \ tension loop
   SYNCHRONIZE
   get.quick.reading
   force [ I ] :=
   count SUB[ I 1 - , 2 ]
   force SUB[ I 1 - , 2 ]
   XY.DATA.PLOT
   get.probe.position
   60 >
   IF
      I
      LEAVE
   THEN
LOOP
termination_index :=             \ record data into variables
motor.stop

force SUB[ 1 , termination_index ] BECOMES> force
count SUB[ 1 , termination_index ] BECOMES> count
1000 msec.delay CR
dough_height       misc_test_data [ 1 ] :=
dough_deformation  misc_test_data [ 2 ] :=
compression_speed  misc_test_data [ 3 ] :=
```

```
   pulling_speed      misc_test_data [ 4 ] :=
   relaxation_trigger misc_test_data [ 5 ] :=
   tension_trigger    misc_test_data [ 6 ] :=
;


\ Start Sticky Test. \\\\\\\\\\\\\\\\\\\\\\
: start.sticky.test
   grams/volt 0.0 =
   IF                          \ check calibration has been loaded
      NOP
   ELSE
      bottom_vuport
      VUPORT.CLEAR
      bottomline_window
      500 40 motor.move.to          \ move motor down to a closer point
      HORIZONTAL 0 array_size WORLD.SET
      VERTICAL  -600 200 WORLD.SET
      INTEGER array_size RAMP          \ clear arrays for recording
      BECOMES> count
      REAL DIM[ array_size ]
      ARRAY.BECOMES> force
      XY.AXIS.PLOT                  \ draw graph
      CR
      ." Place a sample on platform & hit any key twice to start test ..."
      key.wait
      CR ." Test in progress ..."
      get.steady.sample
      409.6 / grams/volt * zero_value := \ record zero weight reference
      do.test
      RESET.KEYBOARD.BUFFER
      CR ." Hit [Space] to save"
      KEY 32 =
      CR
      IF
         save.data.file
      ELSE
         count force XY.AUTO.PLOT
      THEN
   THEN
;



: get.loadcell.calibration
   0 0 GOTO.XY
   ." Ensure 'Dr SQUEEZE' is level" CR
   ." Please clear the platform and then hit any key." CR
   key.wait
   HORIZONTAL 0 1000  WORLD.SET
```

```
  VERTICAL
  get.steady.sample DUP 10 -
            SWAP 10 + WORLD.SET    \ set vertical range  (at 0g)
  WORLD.COORDS
  0 A/D.IN POSITION
  0
  400 0 DO                        \ read in 400 values to average
    A/D.IN
    DUP I SWAP DRAW.TO                \ graph reading
    +
  LOOP
  409.6 / 400 / weight_0g :=           \ calculate voltage
  weight_0g . ." volts" CR
  ." Please place 500g weight on platform and then hit any key." CR
  key.wait
  VERTICAL
  get.steady.sample DUP 10
           - SWAP 10 + WORLD.SET    \ set new vertical range (at 500g)
  0
  400 0 DO                      .  \ read in 400 values to average
    A/D.IN
    DUP I 400 + SWAP DRAW.TO           \ graph reading
    +
  LOOP
  409.6 / 400 / weight_500g :=         \ calculate voltage
  weight_500g . ." volts" CR
  500 weight_500g weight_0g - /        \ calculate calibration value
  grams/volt :=
  CR
  ." The loadcell has been calibrated at "
  grams/volt . ." gm/V"
;

\ Reset Calibration Arrays. \\\\\\\\\\\\\\\\
: reset.calibration.arrays
    REAL DIM[ 1 ] UNNAMED.ARRAY BECOMES> calibrations
    INTEGER DIM[ 8 , 1 ] UNNAMED.ARRAY BECOMES> calibration_time/date
  1 calib_datasize :=
;

\ Load Calibration Arrays. \\\\\\\\\\\\\\\\\
: load.calibration.arrays
  FILE.OPEN calib.%%%
    1 SUBFILE FILE>UNNAMED.ARRAY
      []SIZE calib_datasize :=        \ find array size & store
      BECOMES> calibrations           \ store in calibrations token
    2 SUBFILE FILE>UNNAMED.ARRAY
      BECOMES> calibration_time/date
  FILE.CLOSE
  ONERR:
    ?ERROR#
```

```
    CASE
      560 OF reset.calibration.arrays ENDOF
    ENDCASE
;


\ Save Calibration Arrays. \\\\\\\\\\\\\\\\
: save.calibration.arrays
  REGULAR.DATAFILE
  FILE.TEMPLATE
    calibrations          []FORM.SUBFILE
    calibration_time/date []FORM.SUBFILE
  END
  FILE.CREATE calib.%%%
  FILE.OPEN calib.%%%
    1 SUBFILE calibrations          ARRAY>FILE
    2 SUBFILE calibration_time/date ARRAY>FILE
  FILE.CLOSE
;

\ Save Loadcell Calibration. \\\\\\\\\\\\\\\
: save.loadcell.calibration
  load.calibration.arrays
  grams/volt calibration [ 1 ] :=
  calibrations calibration CATENATE
    BECOMES> calibrations
  time/date
    "TIME  5 "LEFT  " "  "CAT  "DATE  "CAT
    " >ARRAY
  calibration_time/date time/date CATENATE
    BECOMES> calibration_time/date
  1 calib_datasize + calib_datasize :=
  save.calibration.arrays
;

\ Loadcell Calibration. \\\\\\\\\\\\\\\\\\\\\
: loadcell.calibration
  wide_window
  calib_vuport
  OUTLINE
  get.loadcell.calibration
  save.loadcell.calibration
;

\ Print Calibration Information. \\\\\\\\\\\\
: print.calibration.info
  calib_datasize 1 =
  IF
    ." No calibration values on record."
  ELSE
    2 calib_datasize DO
```

```
            calibrations [ I ] .
            ."  gm/V as at: "
            calibration_time/date
            SUB[ I , 1 ]
            DIM[ 8 ] RESHAPE
            time/date_string
            ARRAY > "
            time/date_string "TYPE CR
       -1 +LOOP
    THEN
;

\ View Calibrations. \\\\\\\\\\\\\\\\\\\\\\\\
: view.calibrations
    view.calibration.menu MENU.EXECUTE
    drop
;


\ Draw Left Arrow \\\\\\\\\\\\\\\\\\\\\\\\\\
: draw.left.arrow
    RELATIVE NORMAL.COORDS
    .025 .0125 DRAW.TO
    0 -.025 DRAW.TO
    -.025 .0125 DRAW.TO
    ABSOLUTE WORLD.COORDS
;

\ Draw Left Arrow. \\\\\\\\\\\\\\\\\\\\\\\\\
: draw.right.arrow
    RELATIVE NORMAL.COORDS
    -.025 .0125 DRAW.TO
    0 -.025 DRAW.TO
    .025 .0125 DRAW.TO
    ABSOLUTE WORLD.COORDS
;

\ Analysis \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
: analysis
    .5 SET.CUTOFF.FREQ                 \ filter out noise less than 2 pts wide
    force SMOOTH BECOMES >  filtered_force \ create filtered force array
    force []size termination_index :=
    REAL termination_index RAMP          \ create x axis array
    sample_rate /                 \ convert to seconds
    filtered_force
    VERTICAL   GRID.OFF                \ no grids on graph
    HORIZONTAL GRID.OFF
    bottom_vuport
    VUPORT.CLEAR                     \ clear bottom vuport
    xy.auto.plot                  \ plot graph
    OUTLINE                          \ frame graph
```

```
filtered_force []MAX                \ find peak compression value
peak_compression :=
termination_index 1 + 1 DO             \ find peak compression array index
   filtered_force [ I ]
   peak_compression =
   IF
      I
      LEAVE
   THEN
LOOP
end_of_compression :=                 \ mark peak compression position
force SUB[ 1 , end_of_compression ]
INTEGRATE.DATA                          \
[]MAX 9.81 *                        \ find area under compression curve
misc_test_data [ 3 ] 60000.0 /      \ compression speed in m/s
sample_rate
/ * compression_energy :=             \ calculate compression energy
end_of_compression 1 + 1 DO             \ shade in compression area
   I 1.0 * sample_rate /
   0
      POSITION
   I 1.0 * sample_rate /
   filtered_force [ I ]
      DRAW.TO
9 +LOOP

termination_index 1 +
end_of_compression
DO
   filtered_force [ I ]
   misc_test_data [ 6 ] <=            \ search tension trigger
   IF
      I 1 -
      LEAVE
   THEN
LOOP
end_of_relaxation :=                \ mark end of relaxation
filtered_force
1 SET.ORDER
5 SET.DEGREE
DIFFERENTIATE.DATA                        \ do 1st order derivative
BECOMES> derived_force
1 termination_index DO
   derived_force [ I ] 5 >          \ search for gradient > 5
   IF                           \ <=> of end of tension
      I 1 +
      LEAVE
   THEN
-1 +LOOP
end_of_tension :=                   \ mark end of tension
end_of_tension
```

```
   end_of_relaxation
   - tension_period :=                   \ calculate tension period
   filtered_force []MIN peak_tension :=  \ find peak tension value

   termination_index 1 +
   end_of_relaxation
   DO
      filtered_force [ I ]
      peak_tension =                     \ find position of peak tension
      IF
         I
         LEAVE
      THEN
   LOOP
   peak_tension_index :=                  \ mark peak tension position

   force
   SUB[ end_of_relaxation , tension_period ]
   INTEGRATE.DATA                             \ area under tension curve
   [ tension_period ] 9.81 *
   misc_test_data [ 4 ] 60000.0 /         \ pulling speed in m/s
   sample_rate /
   * tension_energy :=                    \ calculate tension energy
   end_of_tension end_of_relaxation DO
      I 1.0 * sample_rate /
      0
        POSITION
      I 1.0 * sample_rate /
      filtered_force [ I ]
        DRAW.TO                           \ shade in tension area
   4 +LOOP

   1.0 end_of_compression * sample_rate / peak_compression_time :=
   1.0 end_of_relaxation * sample_rate / start_tension_time :=
   1.0 peak_tension_index * sample_rate / peak_tension_time :=
   start_tension_time peak_compression_time - relaxation_time :=
\ print out data onto graph
   0 0 POSITION
   20 -5 CHARS.REL
   " compression energy"
   -1 2 FIX.FORMAT
   compression_energy "." -TRAILING "CAT " mJ" "CAT
   0 -1.5 CHARS.REL CENTERED.LABEL
   " tension energy "
   -1 1 FIX.FORMAT
   tension_energy "." -TRAILING "CAT " mJ" "CAT
   1 -.9 CHARS.REL LABEL

   peak_compression_time relaxation_time 2 / + 0 POSITION
   " relax"
   0 -1 CHARS.REL
```

```
    CENTERED.LABEL
    2 -1 CHARS.REL
    "  time"
    -1 1 FIX.FORMAT
    relaxation_time "." -TRAILING " s" "CAT "CAT
    CENTERED.LABEL
    start_tension_time 0 POSITION
    peak_compression_time 0 DRAW.TO
    draw.left.arrow
    start_tension_time 0 DRAW.TO
    draw.right.arrow

    peak_compression_time peak_compression POSITION
    " Compression Time:"
    -1 1 FIX.FORMAT peak_compression_time "." -TRAILING "CAT " s" "CAT
    3.5 -.75  CHARS.REL LABEL

    peak_tension_time peak_tension POSITION
    " Peak Tension: "
    -1 0 FIX.FORMAT peak_tension "." -TRAILING "CAT " g ," "CAT
    -1 1 FIX.FORMAT peak_tension_time "." -TRAILING "CAT " s" "CAT
    -32 .75 CHARS.REL LABEL

    AXMAX AYMAX POSITION
    " Dough Height"
    -1 1 FIX.FORMAT misc_test_data [ 1 ] "." "CAT " mm" "CAT
    -16 .25 CHARS.REL LABEL
    " Compressive Strain"
    -1 1 FIX.FORMAT
    misc_test_data [ 2 ] misc_test_data [ 1 ] / 100 *
    "." "CAT " %" "CAT
    -6 -.9 CHARS.REL LABEL

    AXMAX AYMIN POSITION
    -10 -2 CHARS.REL " Time (s)" LABEL
    AXMIN AYMAX POSITION
    -10 0 CHARS.REL " Force" LABEL
    1 -1  CHARS.REL " (g)" LABEL

    CURSOR.OFF
    VERTICAL GRID.ON
    HORIZONTAL GRID.ON
    analysis.menu MENU.EXECUTE
;

\ Print Parameters \\\\\\\\\\\\\\\\\\\\\\\\\
: print.parameters
    0 2 GOTO.XY
    ."              Number of samples taken:" termination_index . CR
    ."  Dough height at start of compression:" misc_test_data [ 1 ] . ." mm"
    CR
```

```
    ."    Dough height at end of compression:" misc_test_data [ 2 ] . ." mm"
    CR
    ." Percentage dough deformation (strain):"
    misc_test_data [ 2 ] misc_test_data [ 1 ] / 100 * . ." %" CR
    ."                    Compression speed:" misc_test_data [ 3 ] . ." mm/min"
    CR
    ."                      Pull-away speed:" misc_test_data [ 4 ] . ." mm/min"
    CR
    ."                   Compressive target:" misc_test_data [ 5 ] . ." g"
    CR
    ."                    Relaxation target:" misc_test_data [ 6 ] . ." g"
    CR
;
\ Set Test Parameters \\\\\\\\\\\\\\\\\\\\\\
: set.test.parameters
    3 0 FIX.FORMAT
    "  Compression Speed is " compression_speed "." " mm/min. Enter new value:"
    "CAT "CAT CR "TYPE #INPUT
    IF compression_speed := THEN
    "     Pulling Speed is " pulling_speed "." " mm/min. Enter new value:"
    "CAT "CAT CR "TYPE #INPUT
    IF pulling_speed := THEN
    " Test will compress to " relaxation_trigger "." " g.     Enter new value:"
    "CAT "CAT CR "TYPE #INPUT
    IF relaxation_trigger := THEN
    "   Test will relax to " tension_trigger "." " g.     Enter new value:"
    "CAT "CAT CR "TYPE #INPUT
    IF tension_trigger := THEN
    MENU.ESCAPE
;

\ Files Menu. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
files.menu
    MENU.PULL.DOWN
    4 1 10 18 MENU.SHAPE
    6 14 MENU.COLOR
    MENU.STORE.DISK
    1 3 " Load File "   MENU.ITEM{ load.file }
    3 3 " Delete File " MENU.ITEM{ delete.file }
    2 3 " Save File "   MENU.ITEM{ save.menu }
    4 3 " Directory "   MENU.ITEM{ dir.menu }
    5 3 " Quit Menu "   MENU.ITEM{ MENU.ESCAPE }
MENU.END


    \ Load Menu \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
    load.menu
        " Select File to Load & Press ESC" MENU.TITLE
        MENU.BLOW.UP
        6 16 25 65 MENU.SHAPE
        6 14 MENU.COLOR
```

```
      1 46 MENU.DISPLAY directory
  MENU.END


  \ Save Menu. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
  save.menu
      " Select File Format" MENU.TITLE
      MENU.PULL.DOWN
      7 16 10 40 MENU.SHAPE
      6 14 MENU.COLOR
      MENU.STORE.DISK
      1 3 " Data Array          " MENU.ITEM{ save.data.file }
      2 3 " Lotus 123 Worksheet" MENU.ITEM{ save.worksheet }
  MENU.END


  \ Delete Menu. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
  delete.menu
      " Tag Files to Delete & Press ESC" MENU.TITLE
      MENU.BLOW.UP
      6 16 23 65 MENU.SHAPE
      5 14 menu.color
      15 46 MENU.DISPLAY directory
  MENU.END



  \ Directory Menu. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
  dir.menu
      " Directory " MENU.TITLE
      MENU.BLOW.UP
      6 16 25 65 MENU.SHAPE
      5 14 menu.color
      MENU.STATUS get.directory
  MENU.END


  \ Get Filename Menu. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
  get.filename.menu
      " Enter filename ..." MENU.TITLE
      MENU.BLOW.UP
      11 26 13 62 MENU.SHAPE
      5 14 menu.color
      MENU.STORE.DISK
      MENU.STATUS get.filename
  MENU.END

\ Analysis Menu. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
analysis.menu
  " Analysis Menu" MENU.TITLE
  MENU.PULL.DOWN
```

```
   1 1 1 78 MENU.SHAPE
   5 14 menu.color
   MENU.STORE.DISK
   0  5 " Show Test Parameters "  MENU.ITEM{ show.parameters.menu }
   0 60 " Quit "                  MENU.ITEM{ MENU.ESCAPE }
MENU.END

   \ Show Parameters Menu. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
   show.parameters.menu
      " Test Parameters" MENU.TITLE
      MENU.BLOW.UP
      8 12 20 67 MENU.SHAPE
      5 14 menu.color
      MENU.STATUS print.parameters
   MENU.END

\ Calibrate Menu. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
calibrate.menu
   MENU.PULL.DOWN
   4 49 10 76 MENU.SHAPE  .
   5 14 menu.color
   MENU.STORE.DISK
   1 3 " Calibrate Loadcell "  MENU.ITEM{ loadcell.calibration.menu }
   2 3 " View Calibrations  "  MENU.ITEM{ view.calibrations }
   4 3 " Set Test Parameters"  MENU.ITEM{ test.parameters.menu }
   3 3 " Select Printer     "  MENU.ITEM{ nop }
   5 3 " Quit               "  MENU.ITEM{ MENU.ESCAPE }
MENU.END

   \ Calibration Menu. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
   loadcell.calibration.menu
      " Loadcell Calibration" MENU.TITLE
      MENU.BLOW.UP
      5 5 24 74 MENU.SHAPE
      5 14 menu.color
      MENU.STATUS loadcell.calibration
   MENU.END

   \ View Calibration Menu \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
   view.calibration.menu
      " Calibration Records" MENU.TITLE
      MENU.BLOW.UP
      8 10 24 69 MENU.SHAPE
      5 14 menu.color
      0 60 MENU.DISPLAY print.calibration.info
   MENU.END

   \ Test Parameters Menu. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
   test.parameters.menu
      " Set Test Parameters" MENU.TITLE
      MENU.BLOW.UP
```

```
        8 10 23 69 MENU.SHAPE
        5 14 menu.color
        MENU.STATUS set.test.parameters
     MENU.END


\ = = = = = = = = = = = \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\ Main Menu. \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\ = = = = = = = = = = = \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
main.menu
     " Mr Sticky" MENU.TITLE
     MENU.PULL.DOWN
     1 1 1 78 MENU.SHAPE
     6 14 MENU.COLOR
     MENU.STORE.MEMORY
     0 17 " Start Test "  MENU.ITEM{ start.sticky.test }
     0 65 " Find zero  "  MENU.ITEM{ find.zero }
     MENU.STORE.DISK
     0  1 " Files      "  MENU.ITEM{ files.menu }
     0 49 " Calibrate  "  MENU.ITEM{ calibrate.menu }
     0 33 " Analysis   "  MENU.ITEM{ analysis }
MENU.END


: go
     COUNT.INIT
     2500 msec.delay
     load.calibration.arrays
     calibrations [ calib_datasize ] grams/volt := \ find last calibration value
     A/D.IN 4080 < > IF
        NORMAL.DISPLAY
        find.zero                          \ find reference position
        500 40 motor.move.to                  \ move probe to start height
     THEN
     GRAPHICS.DISPLAY
     bottom_vuport
     OUTLINE
     VERTICAL   LABEL.SCALE.OFF
     HORIZONTAL LABEL.SCALE.OFF
     main.menu MENU.EXECUTE                        \ start program menu
     NORMAL.DISPLAY
;
```

Appendix VI Component datasheets

RS
Data Library

Strain gauges and load cells

Strain gauges

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

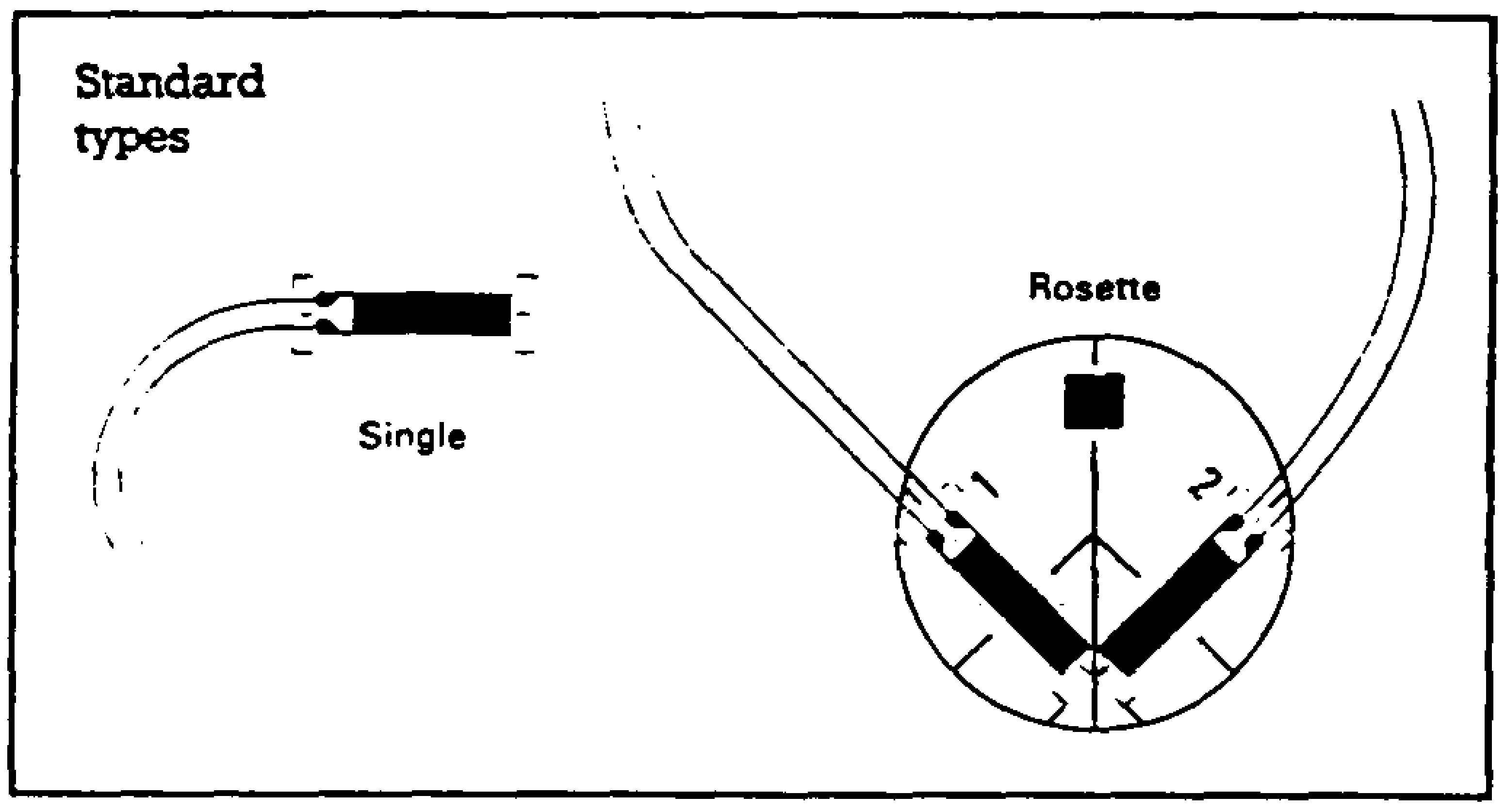
Miniature gauges can be used for precise point measurement or instrumentation of small components. The polyimide backing of the gauges can withstand temperatures up to 180°C making them ideal for higher temperature applications.

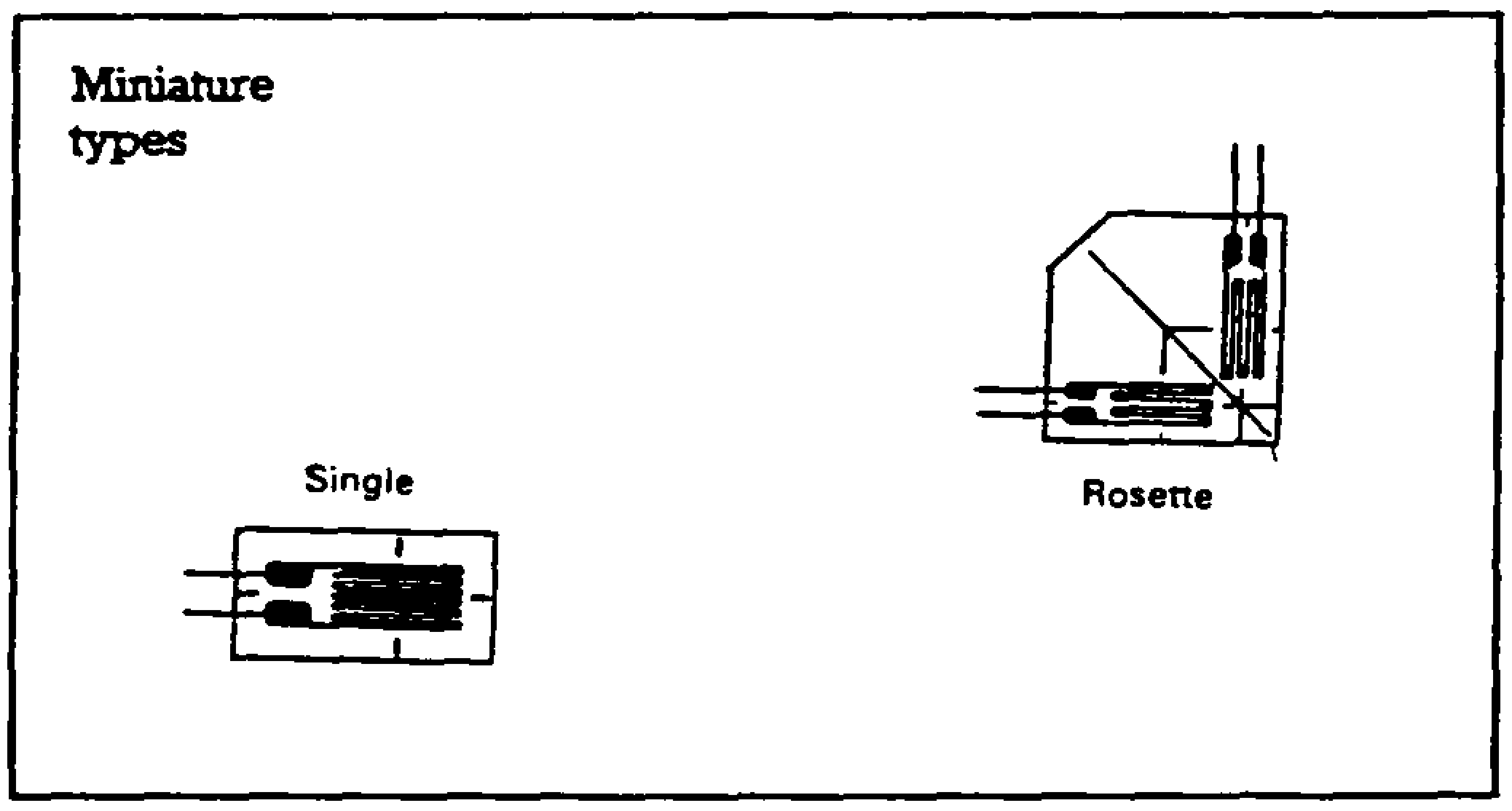
The larger size of the standard gauges will not only make these gauges suitable for larger components, but is useful to assess the average strain over the area covered by the gauge thus reducing the possibility of incorrect readings due to stress concentrations.

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

Gauges temperature compensated for mild steel match materials with a coefficient of thermal expansion of 10.8 x 10^{-6}/°C and are indicated by red colour coding of the backing material.

Single types are intended for uniaxial strain measurements only, while rosette types can be used for biaxial measurements having two gauges at right angles to each other in the same plane. Included in the backing material are gauge lines to enable accurate alignment of gauges along principal strain.





General specification (all types)

Measurable strain	2 to 4% maximum
Thermal output 20 to 160°C	±2 micro strain/°C*
160 to 180°C	±5 micro strain/°C*
Gauge factor change with temperature	±0.015%/°C max
Gauge resistance	120Ω
Gauge resistance tolerance	±0.5%
Fatigue life	>10^5 reversals @ 1000 micro strain*
Foil material	copper nickel alloy

Specification (Standard polyester backed types)

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

Specification (Miniature polyimide backed type)

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

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

Construction and principle of operation

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

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

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

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

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

where K is a constant known as a gauge factor,

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

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

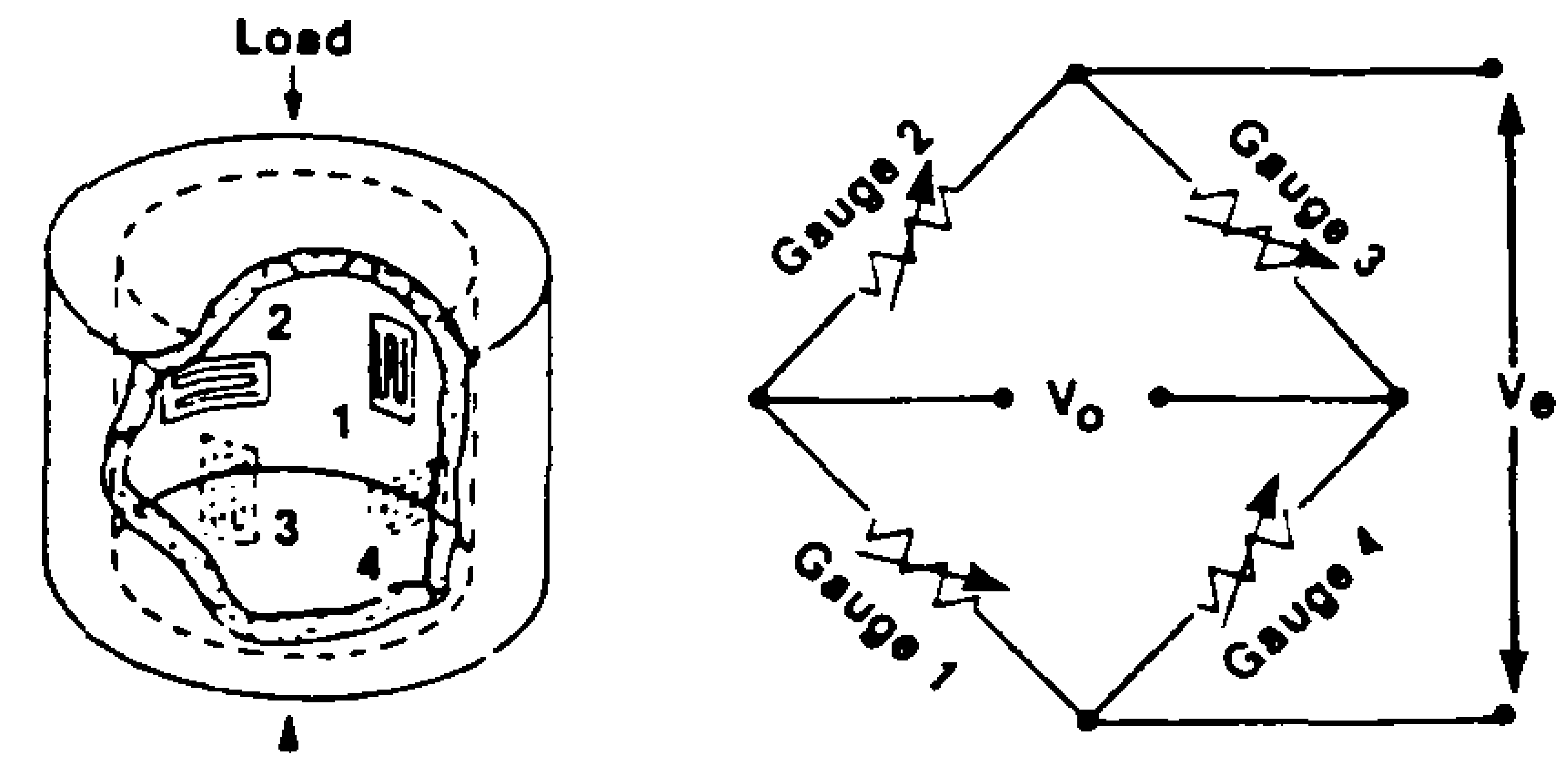
The change in resistance of the strain gauge can therefore be utilised to measure strain accurately when connected to an appropriate measuring and indicating circuit eg. RS strain gain amplifier 308-815 detailed on page 3 of this data sheet.

Application

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

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

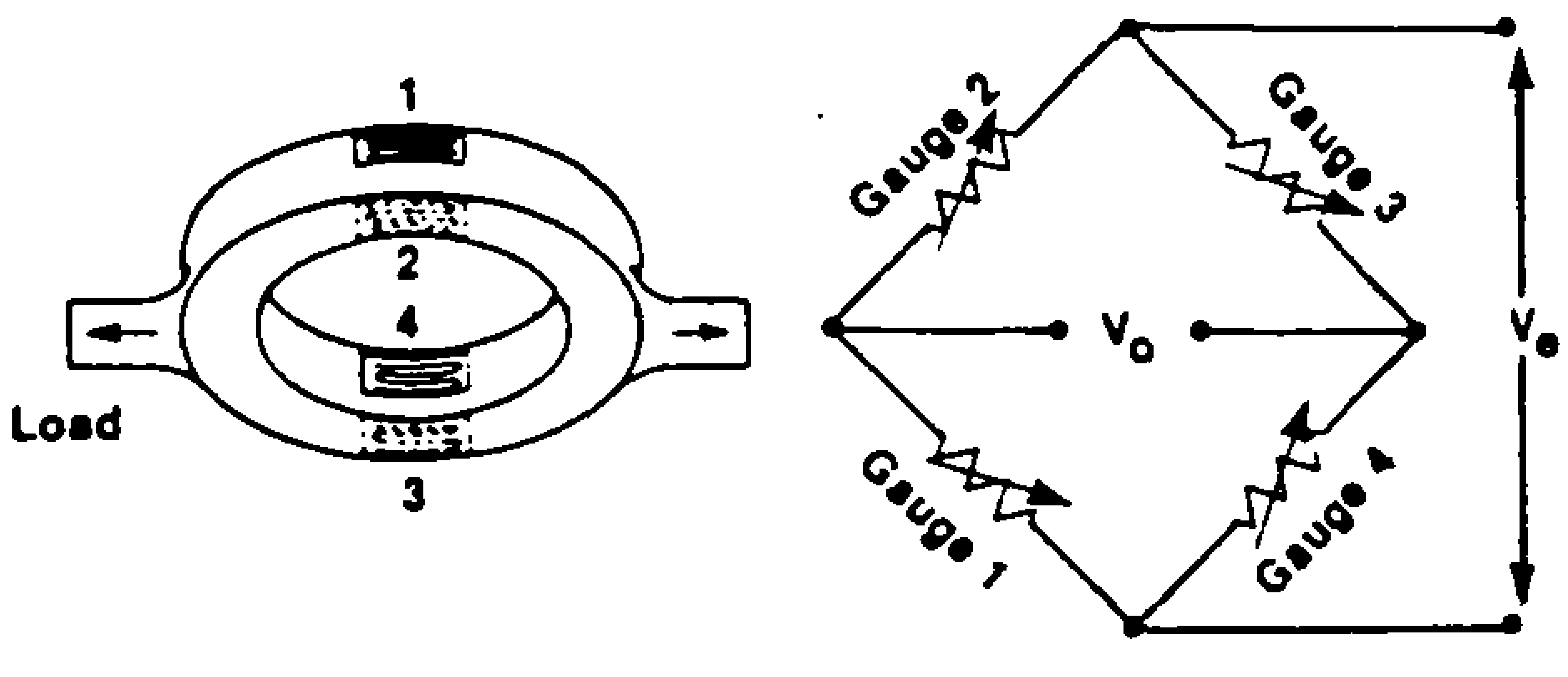
Figure 1 **Compressive load transducer**



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

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

Figure 2 **Tensile load transducer**



Instructions for mounting of strain gauges

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

1) Specimen surface preparation

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

The area should now be degreased with a solvent such as RS PCB Solvent Cleaner, stock no. 555-134, and finally neutralised with a weak detergent solution. Tissues or lint free cloth should be used for this operation, wetting the surface and wiping off with clean tissues or cloth until the final tissue used is stain free. Care must be taken not to wipe grease from a surrounding area onto the prepared area or to touch the surface with the fingers.

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

2) Strain gauge preparation

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

3) Adhesives and strain gauge installation

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

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

4) Wiring

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

Installation protection

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

Connecting to strain gauges

The following bridge circuits are shown with connections referring to the basic amplifier circuit, Figure 7. All resistors, precision wirewound 0.1% 5ppm. (For RS Precision Resistors see current catalogue.)

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

Figure 3 **Full bridge**

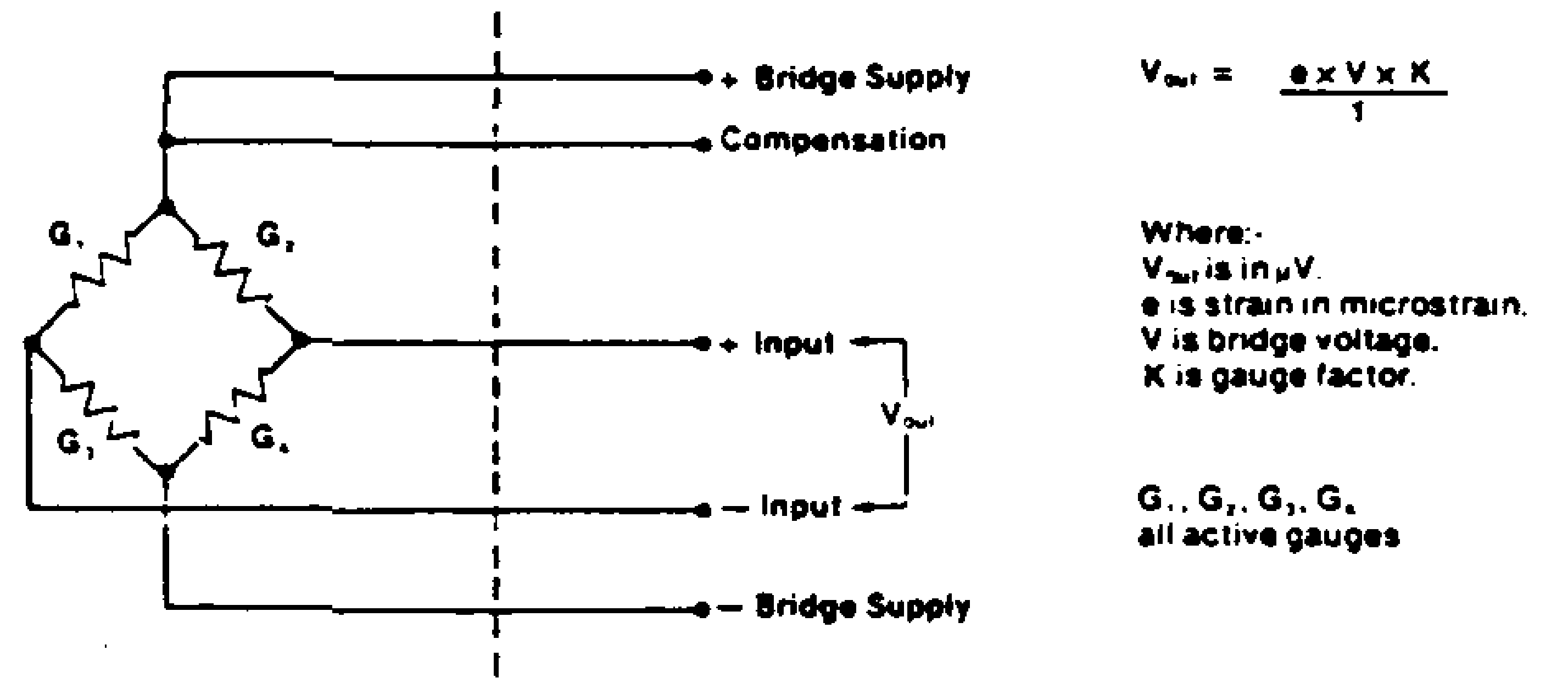


Figure 4 **Half bridge**

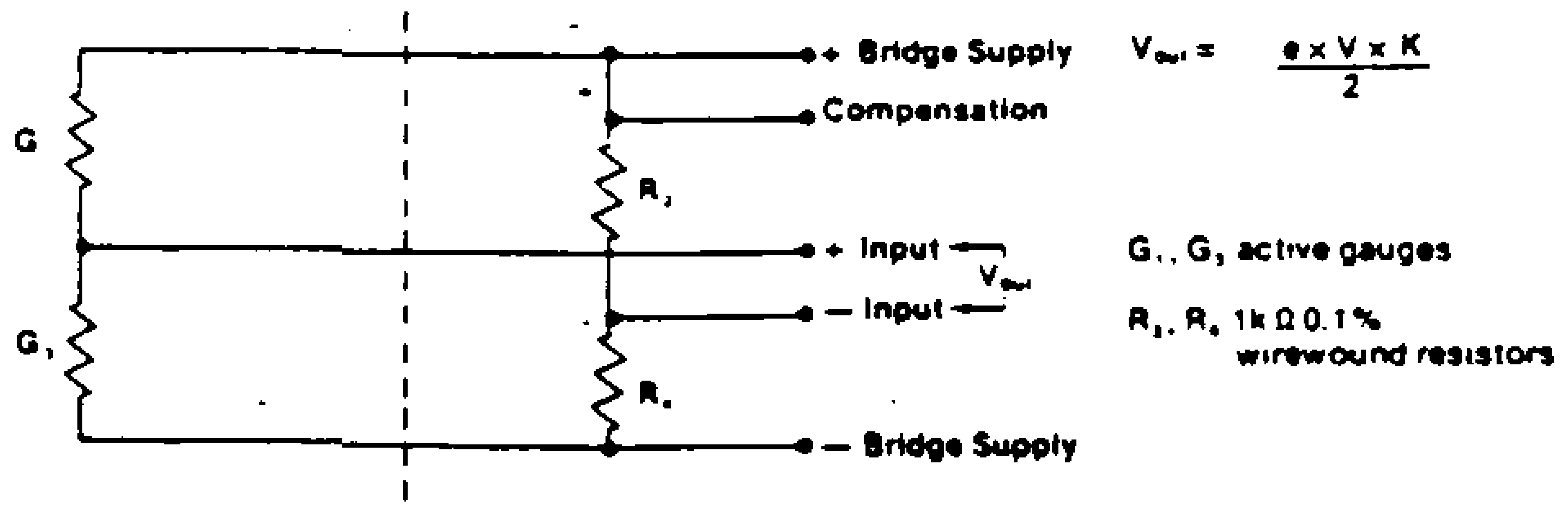
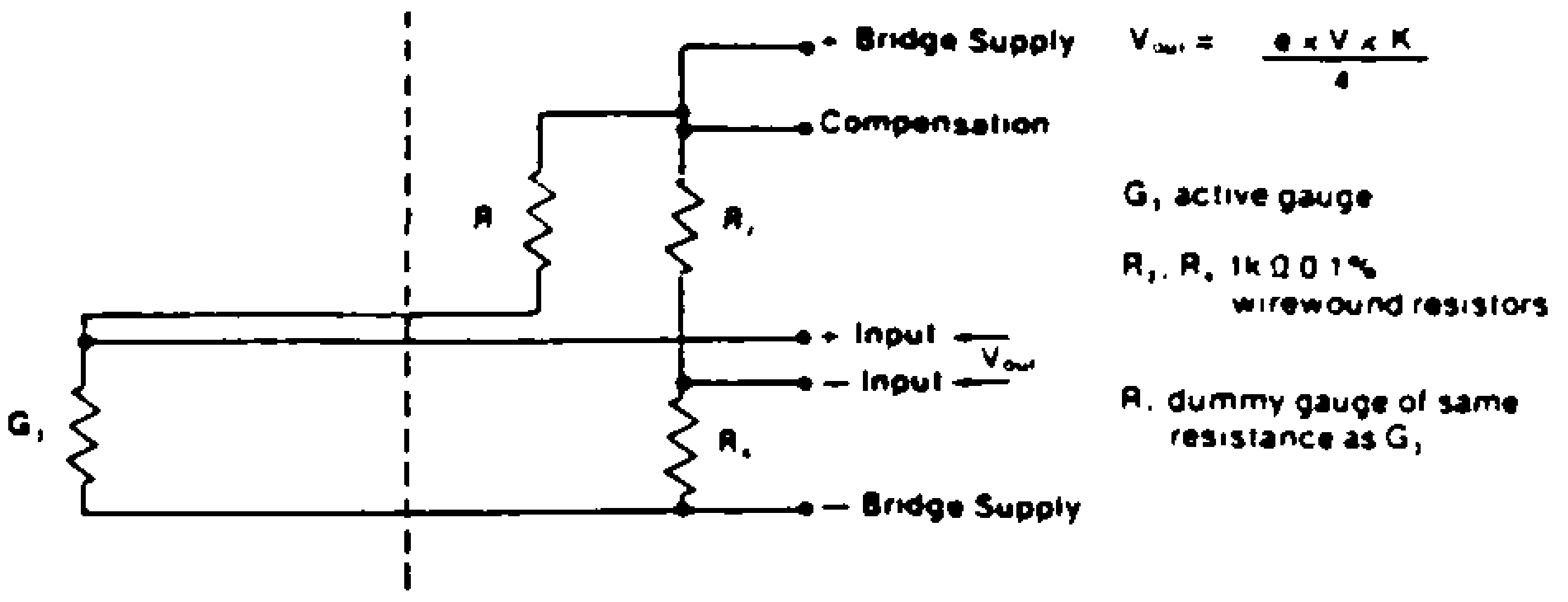


Figure 5 **Quarter bridge (3 wire)**



Strain gauge amplifier (308-815) and printed circuit board (435-692)

Description and operation

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

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

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

The advantages of such a system are:

1. No floating power supply needed.
2. Bridge supply easily varied with remote sense if necessary.
3. 5 wire remote sense system.
4. Freedom from common mode effects.
5. Very high stability dc amplifier enables numerous configurations to be assembled.
6. Low noise.
7. High speed (at low gains).

Figure 6 **Pin connections**

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

Top view

Specification

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

Supply voltage	±2 to ±20V dc
Input offset voltage	1mV max
Input offset voltage/temperature	1μV/°C max
Input offset voltage/supply	5μV/V max
Input offset voltage/time	1μV/month max
Input impedance	>2.5MΩ min
Input noise voltage	1μVp.p max
Band width (unity gain)	400kHz
Output current	5mA
Output voltage span	$\pm(V_s-3)$V
Closed loop gain (adjustable)	5 to 10,000
Open loop gain	>100dB
Common mode rejection ratio	>100dB
Bridge supply voltage/temperature	20μV/°C
Maximum bridge supply current	12mA
Power dissipation	0.5W
Warm up time	5mins
Operating temperature range	-25°C to +85°C

Figure 7 **Basic circuit for printed circuit board 435-692 (gain approx. 1000)**

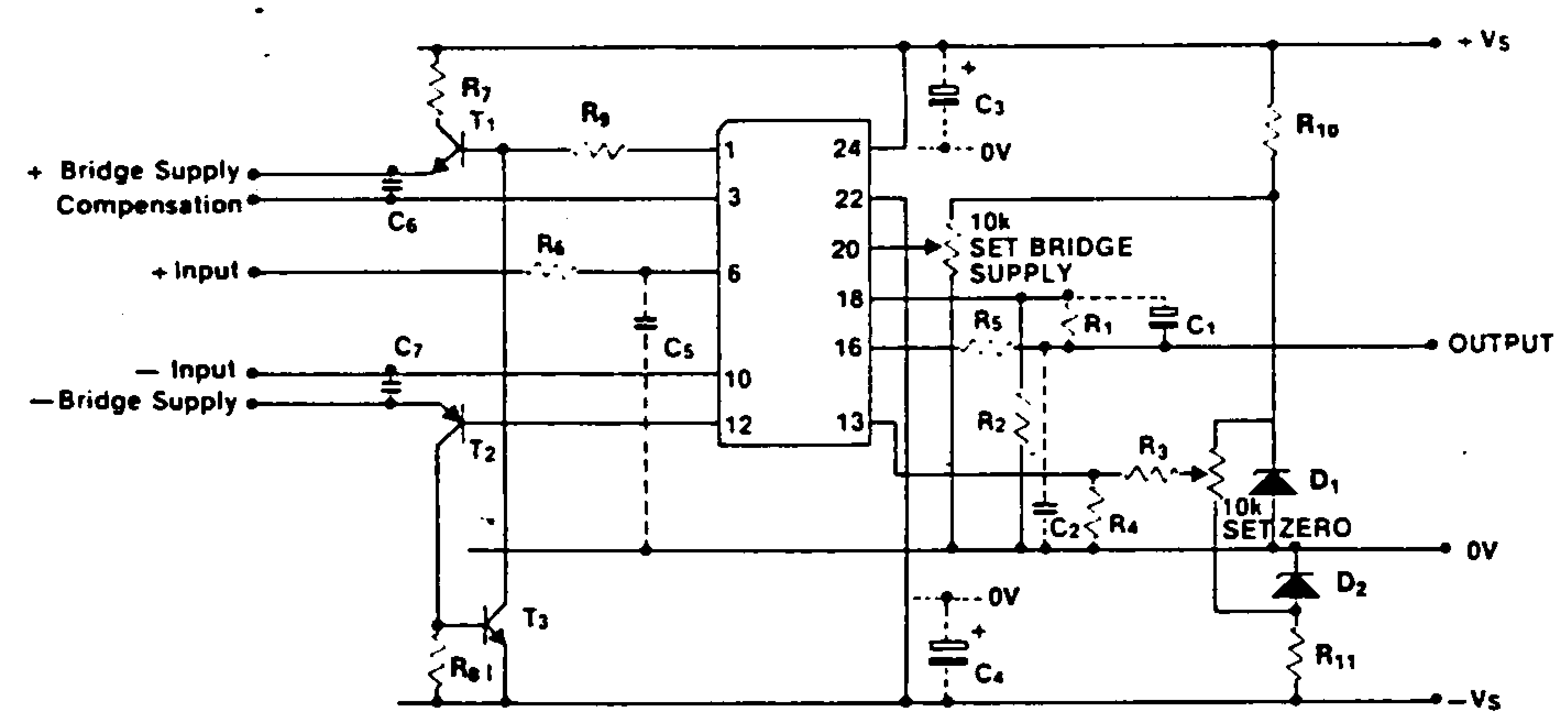
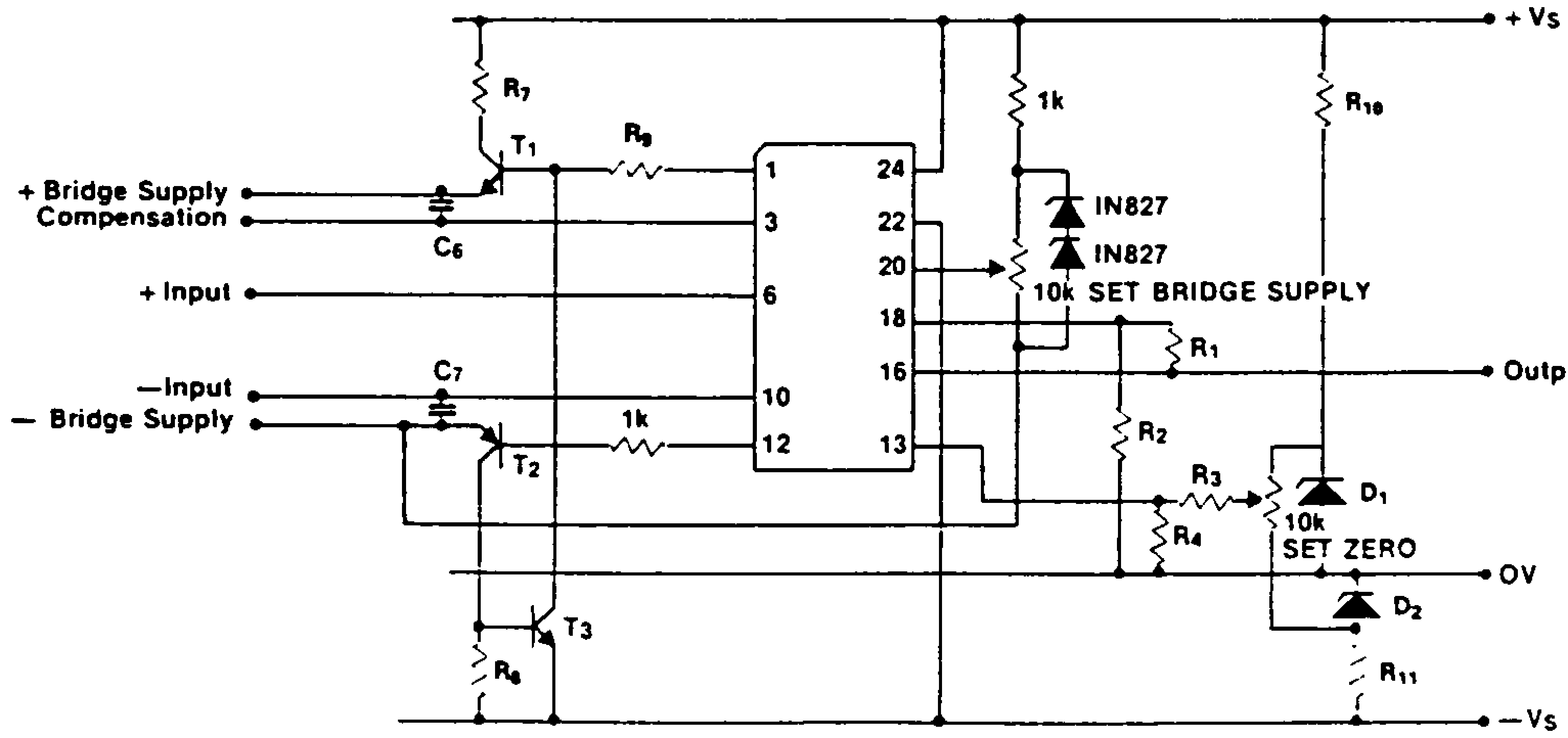


Figure 8 **Circuit for semiconductor gauges and transducers**



Component values (Figures 7 and 8)

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

A glass fibre printed circuit board, stock number 435-692, is available for the basic circuit as given in Figure 7.

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

Only typical values are given for certain components, as adjustment of these values may be necessary in specific applications to obtain optimum noise reduction (see Minimisation of Noise, page 5).

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

Notes:

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

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

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

C_5 may be omitted for input lead lengths of less than 10 metres.

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

T_3 and R_5 provide current limit of approx 60mA.

Where high stability power supplies are being used zero and bridge supply reference may be taken direct from the power rails.

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

Minimisation of noise

1. Inherent white/flicker noise in amplifier

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

2. Supply frequency (or harmonics) inference.

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

3. Power supply transient interference.

It is good practice to decouple the supply lines to the amplifier, by fitting C_3 and C_4, as close to it as possible. If a particular nuisance then fit a mains suppressor, eg. RS stock no. 238-407.

4. Electromagnetic interference

This may be picked up by input leads, output leads, supply leads or direct into the circuit. Minimisation involves a combination of screening, decoupling and reducing operating bandwidth. Screening. The shield should be connected to only one earth potential at the receiving monitoring equipment end. Try not to earth any of the dc power lines (eg. 0V). If the shield at the sensor end is earthed then earth the shield at the receiving end and if possible connect this earth potential to the strain gauge amplifier circuit shield. Decouple the power supply leads by fitting C_3 and C_4, decouple the input leads with R_6 and C_5 (note a similar action on the input is not possible). Remove any pickup from the output leads by fitting R_5 and C_2. Fit C_5 if input leads are more than 10m long and fit C_6 if remote sense is longer than 10m. Reduce the operating bandwidth by fitting C_1 and C_2.

Load cells

Introduction

Load cells are basically a beam or other shaped member arranged so that an applied load will cause a proportional strain at certain fixed points on the device. This strain can be detected in several ways, the most common being an arrangement of strain gauges. These gauges convert the strain into an electrical signal which can then be displayed, used as a control signal, etc.

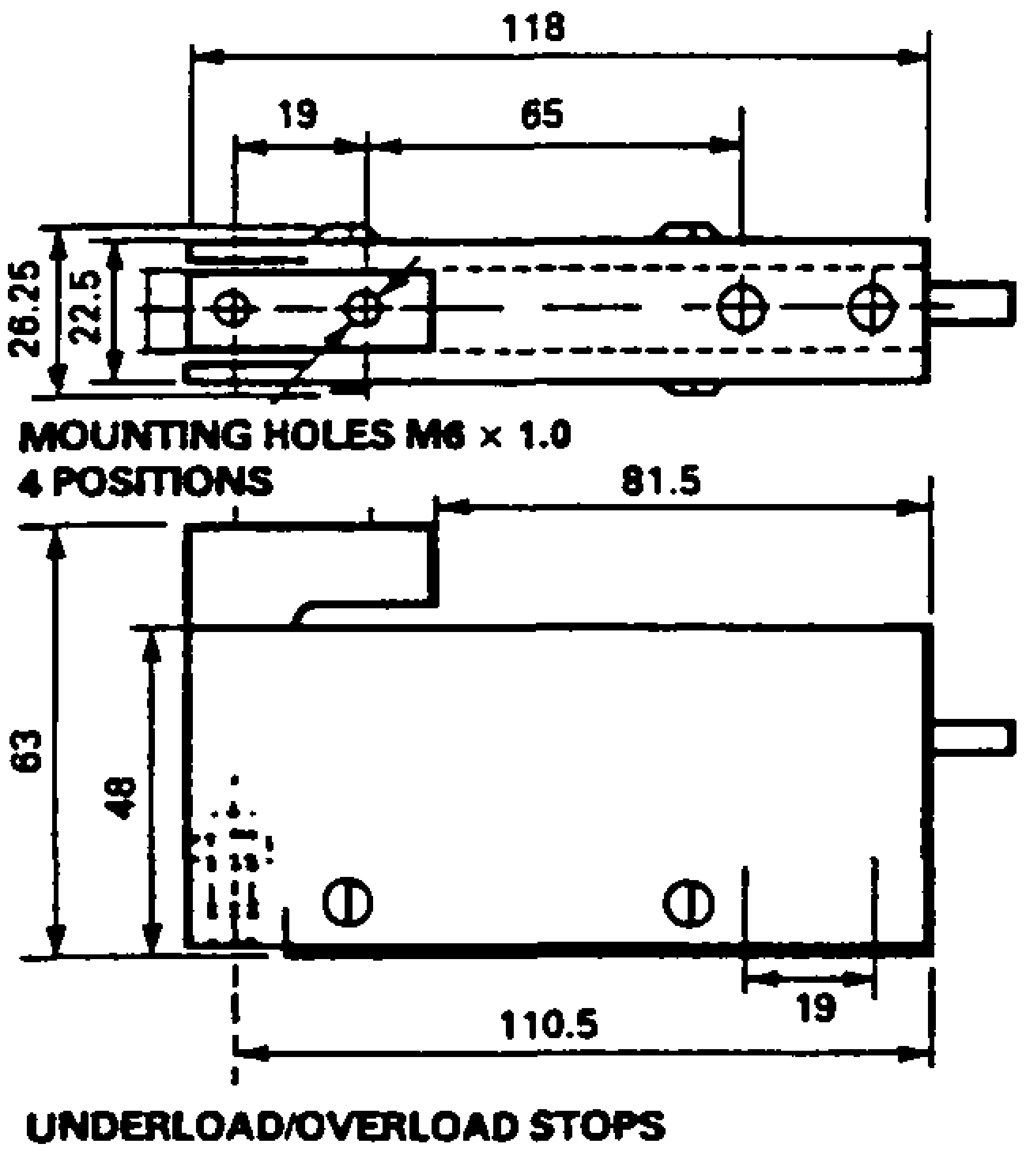
Centre point load cells

The RS range of load cells is of the centre point type in which a double beam is used. They are supplied complete with a full bridge of four strain gauges fitted and calibrated ready to connect to any suitable amplifier.

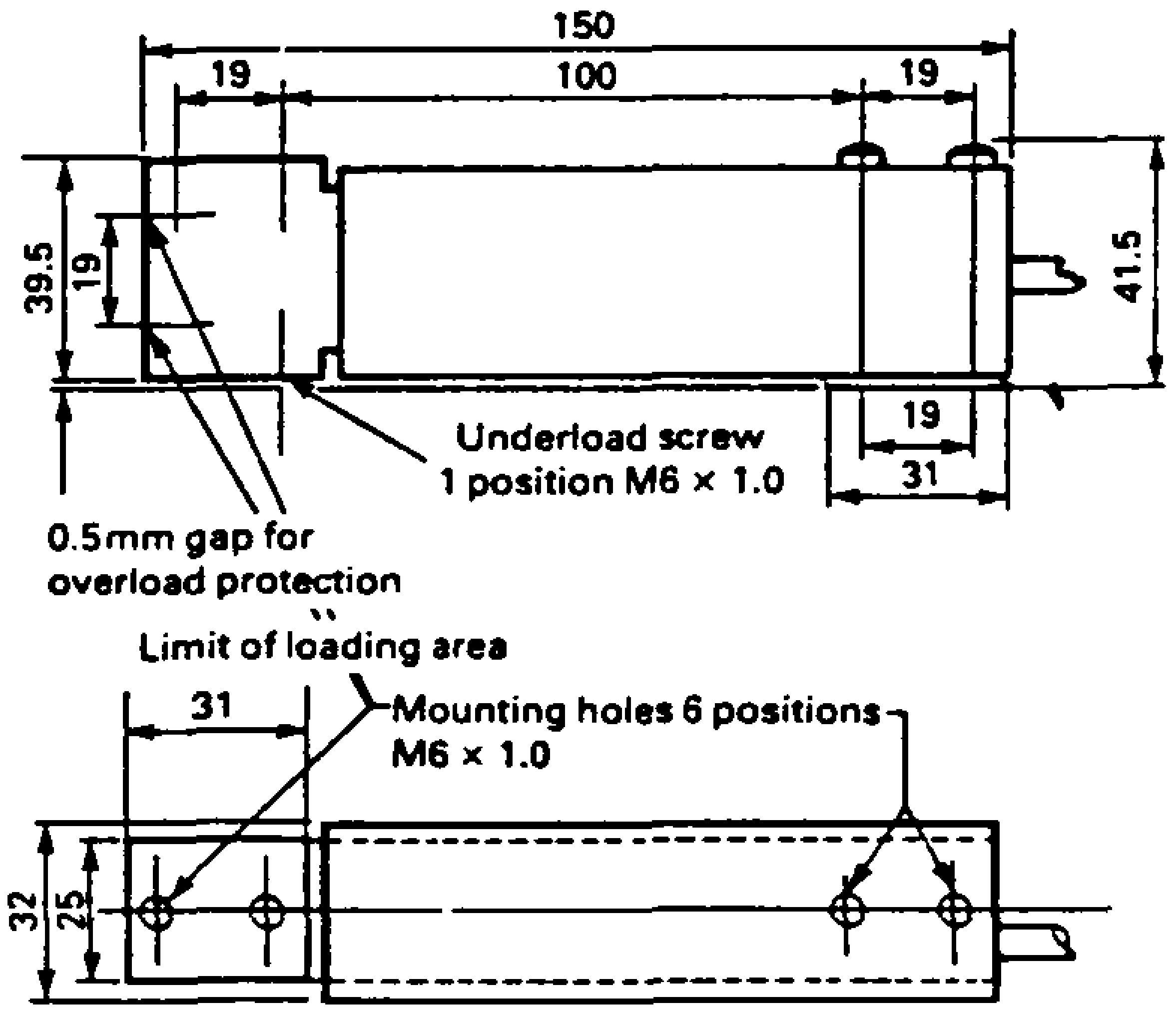
Three sizes are available for weighing up to 2kg, 20kg or 100kg and, although physically different all cells are the same in method of operation and construction.

Figure 9 **Dimensions**

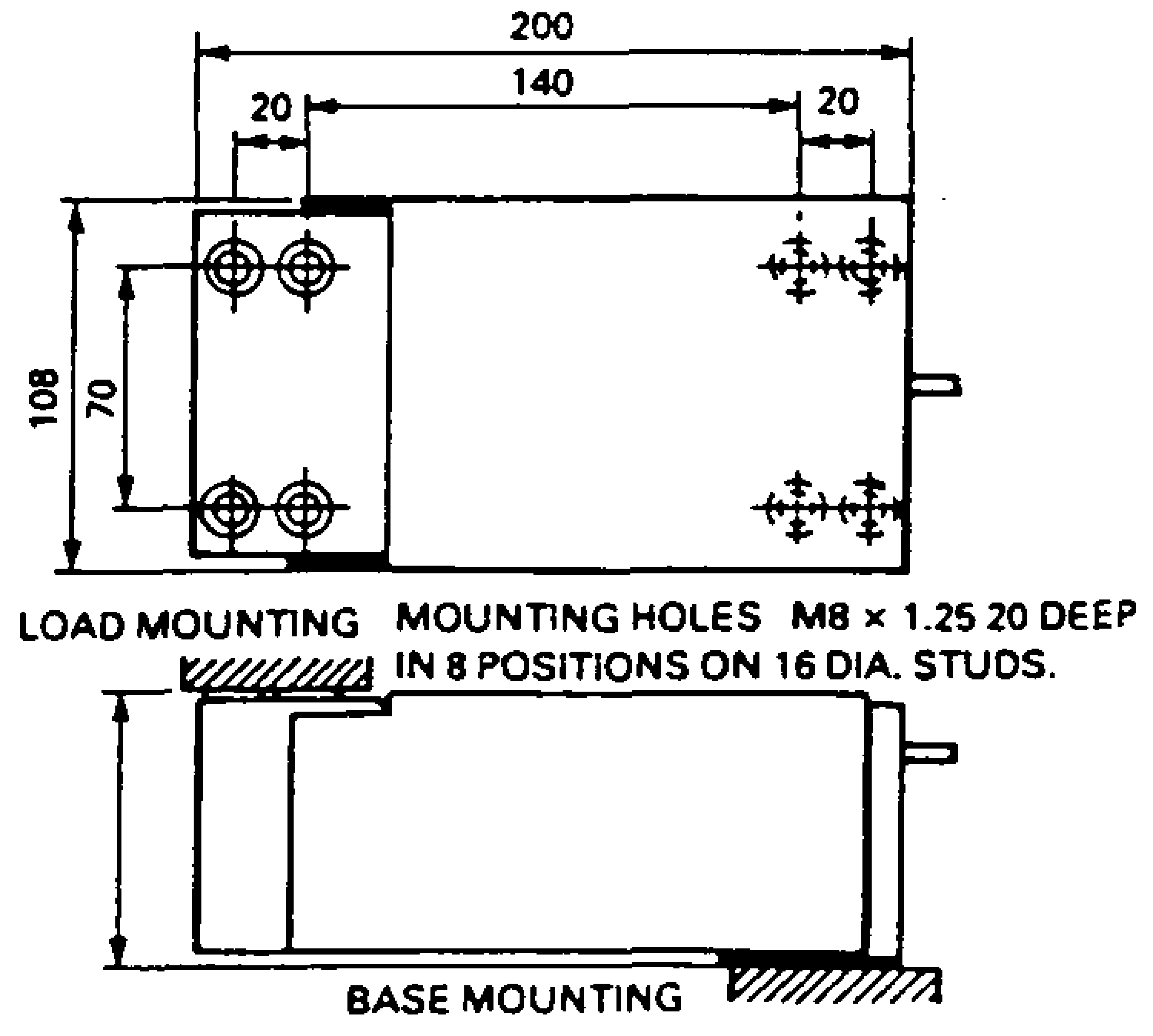
2kg load cell



20kg load cell



100kg load cell



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

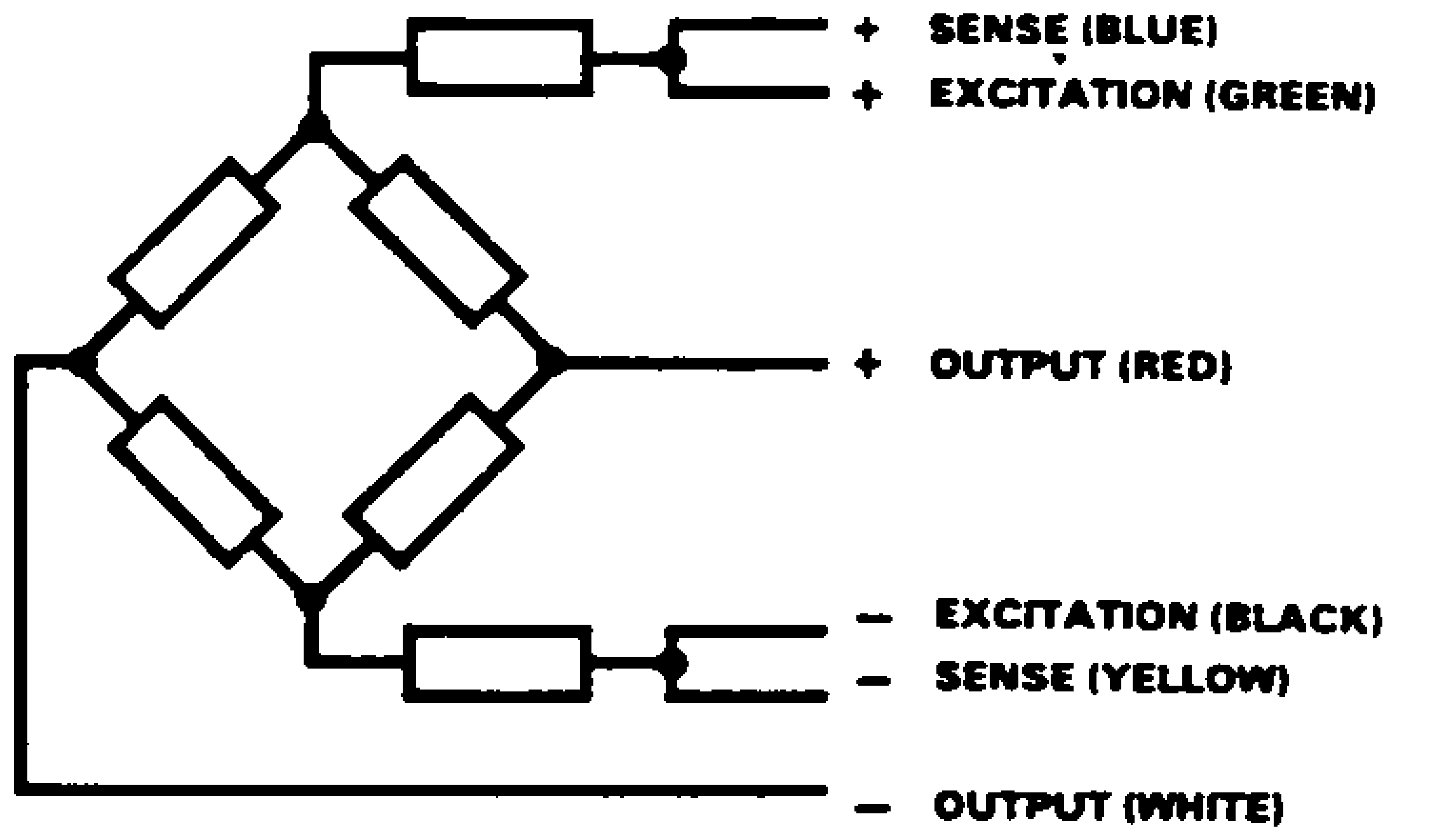
Electrical connections

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

The RS strain gauge amplifier stock number 308-815 can be used with these load cells. Use the circuit shown in Figure 7, connecting bridge supply to excitation and compensation to sense (Figure 10). In this circuit a five wire system is employed so that the – sense wire shown in Figure 10 is not used and should be connected to the – supply.

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

Figure 10 **Internal wiring all types**



Amplifiers such as the chopper stabilized amplifier 7650 and 7652. (stock nos. 303-854 and 630-667) and the precision instrumentation amplifier AD524 AD (stock no. 302-463) would be suitable for this application. Separate RS data sheets are available for these devices.

Mechanical fixings

Both cells are fixed by M6 x 1 set screws and the bodies of the cells are drilled and tapped to a depth of 10mm.

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

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

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

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

Overload stops

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

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

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

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

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

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

Tension/Compression load cell

A general purpose load cell for force measurement with loads up to 250kg (500lb or 2.5kN approx.). Mechanical connections are by M12 x 1.75 threads in the body of the device and electrical connections via a 3m 5-core screened cable.

This cell can be used for weighing but is ideally suited for the measurement of tensile, or compressive forces by using the cell to replace the structural member under investigation.

Other applications include, for example, determining the power output of a motor by replacing the mounting with the cell and measuring the torque reaction produced.

Figure 11 **250kg load cell dimensions**

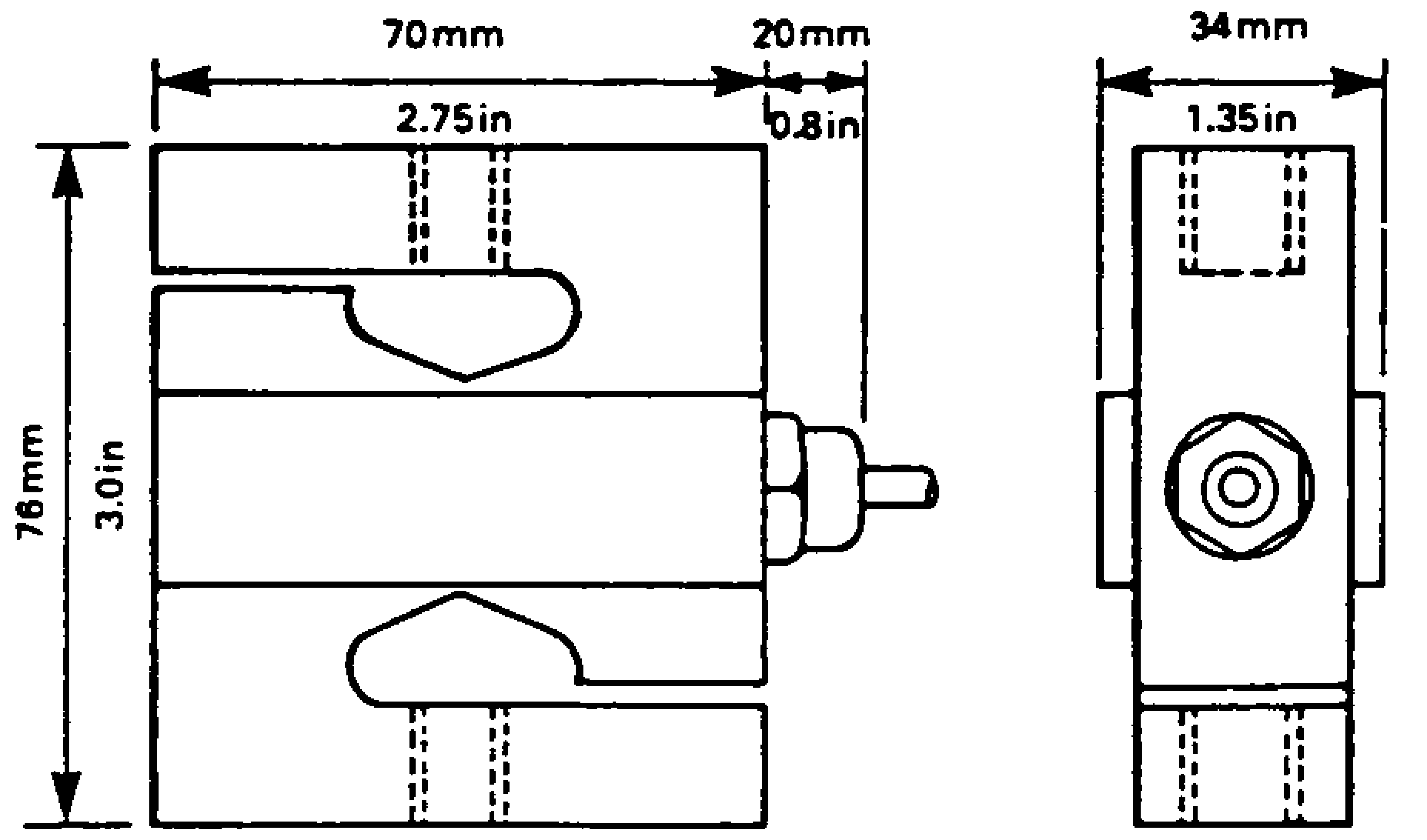
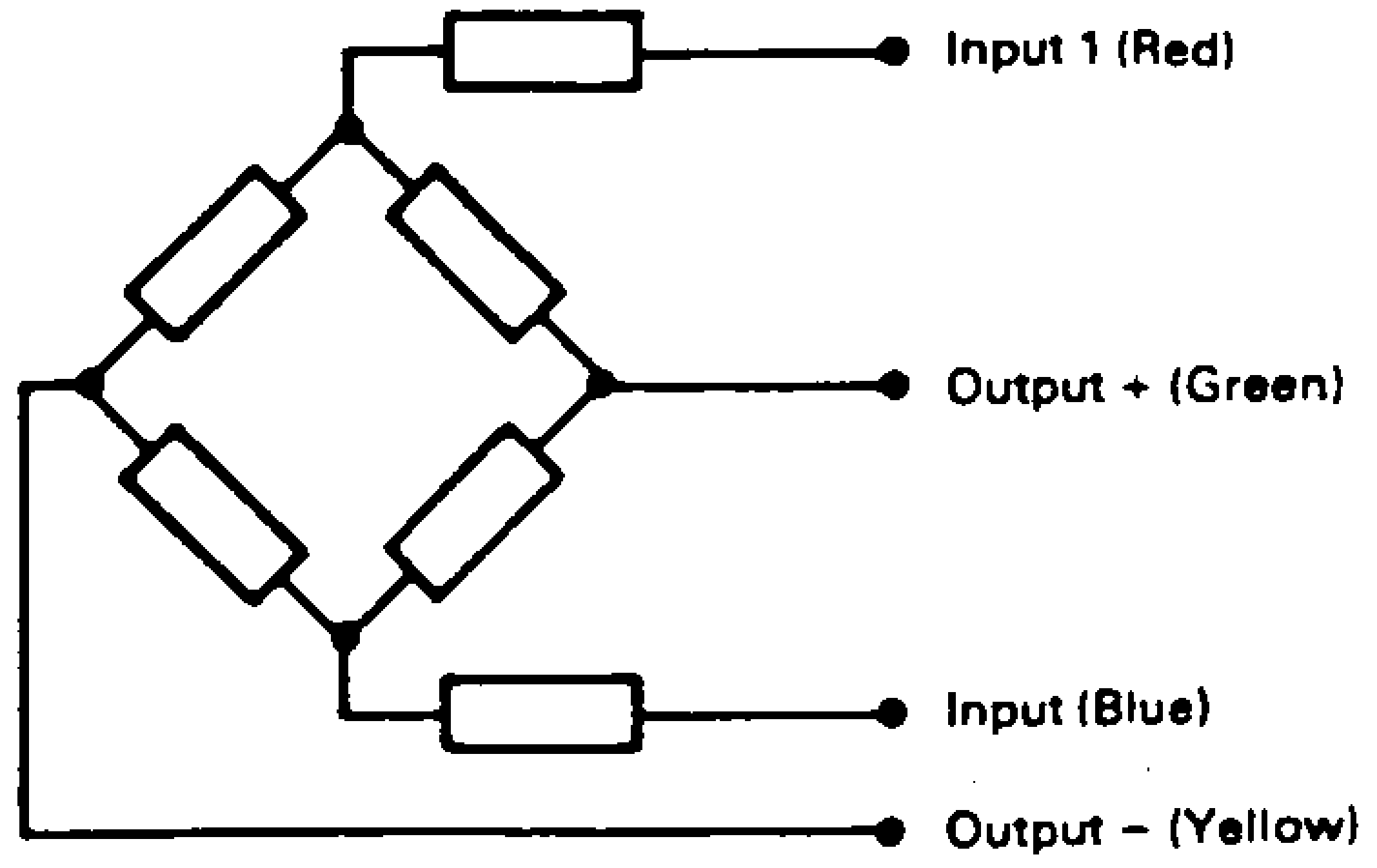


Figure 12 **Internal wiring**

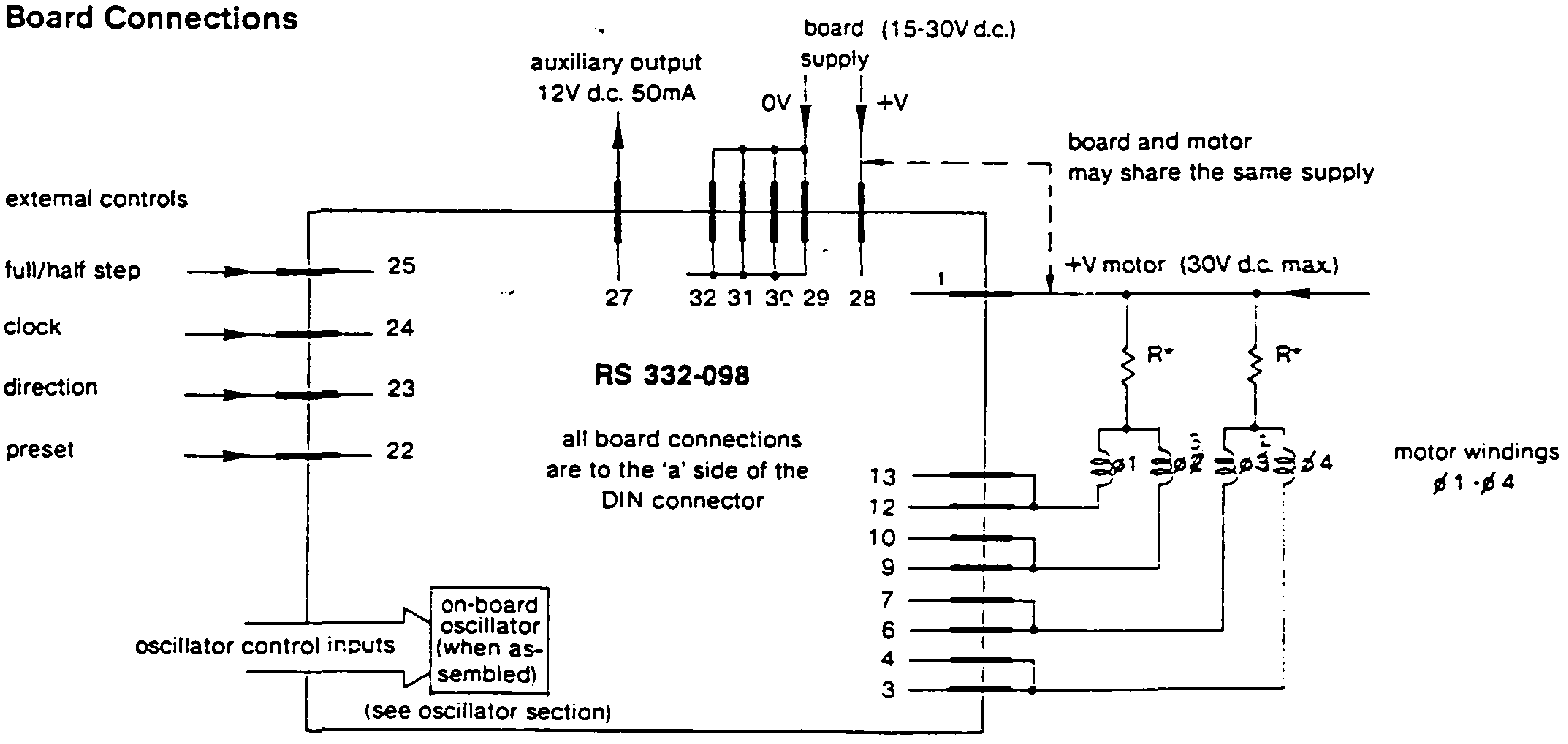


4-Phase Unipolar Stepper Motor Drive Board 332–098

Technical specification:

Size	standard Euro card 168 x 100 x 15
Mating edge connector	standard 32-way DIN 41612 socket e.g. RS 471-503 or 467—453
Supply (board and motor)	15-30V d.c. + 10% max. unregulated smoothed
Current consumption:	
a) board only	60mA
b) motor windings	dependent on motor used-up to 2A/phase max.
On-board auxiliary output	12V d.c. 50mA max. regulated
Switching logic control inputs	Level '0' 0V Level '1' 12V } CMOS and open collector T.T.L. compatible
a) full/half step	Level '1' full step Level '0' half step
b) direction	
c) clock	1Hz-25kHz, 10µs min. pulse width negative edge triggered
d) preset	Active Level '0' sets motor drive states to Q1, & Q3 OFF, Q2 & Q4 ON (full step mode) Q1, Q2 & Q3 OFF, Q4 ON (Half step mode) - see fig. 1. Automatic preset at switch-on

Board Connections



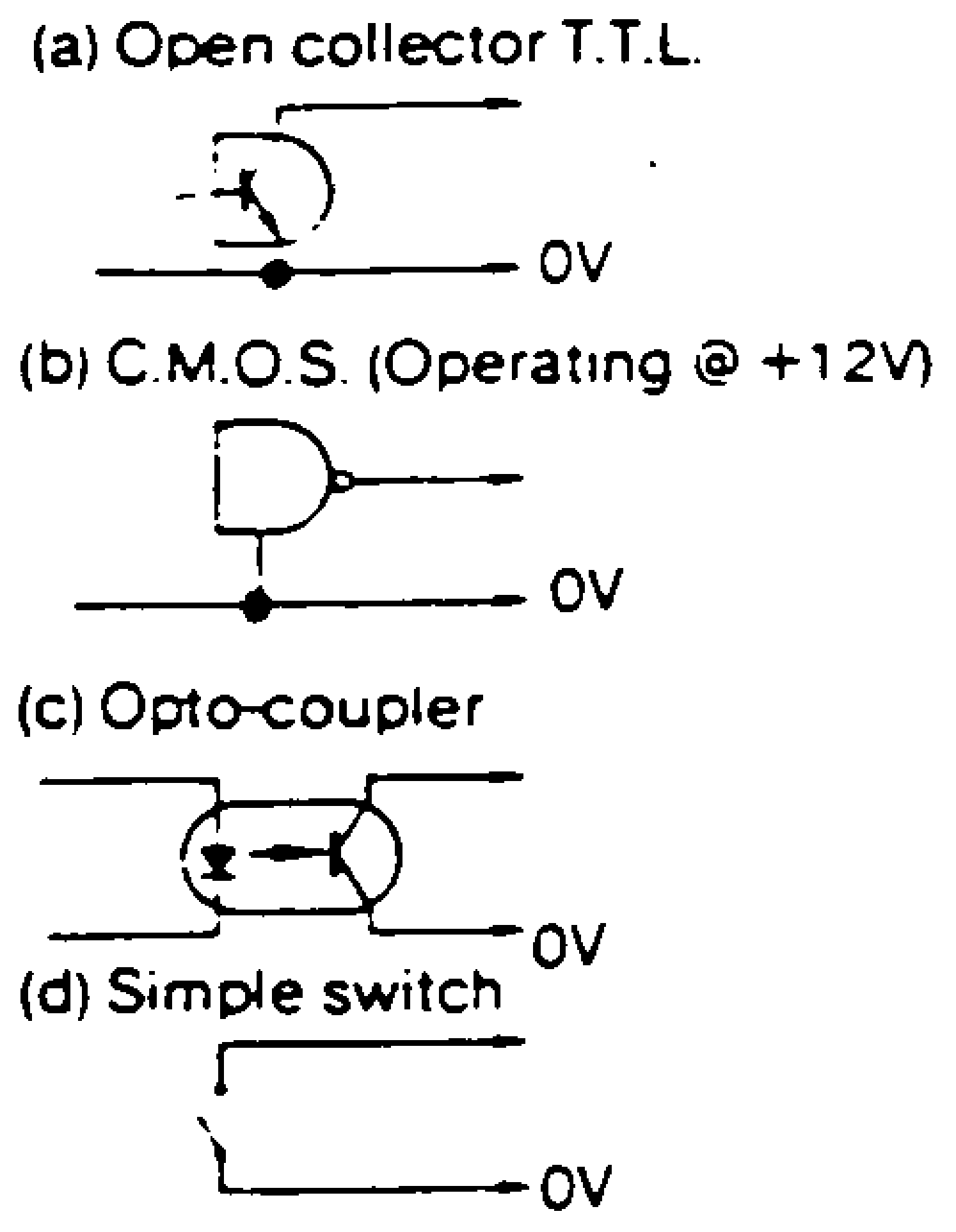
$$*R = \frac{+V\ \text{motor} - \text{rated winding voltage}}{\text{rated winding current}}$$

Fig. 1

Max. power dissipated through R = (rated motor current)^2 x R. If the power dissipation is high it is advisable to arrive at the required value of R by using a network of series or parallel resistors. (The use of higher wattage resistors and heat sinks may be required).

Max. current consumption (motor & board) = 2 x (current per phase) +60mA. Thus ensure power supply cables used are sufficiently rated.

External control signals e.g. full/half step, direction etc. as well as the oscillator (if fitted) stop/run signal can be applied to the circuit in any of the methods of fig. 2.


(a) Open collector T.T.L.

(b) C.M.O.S. (Operating @ +12V)

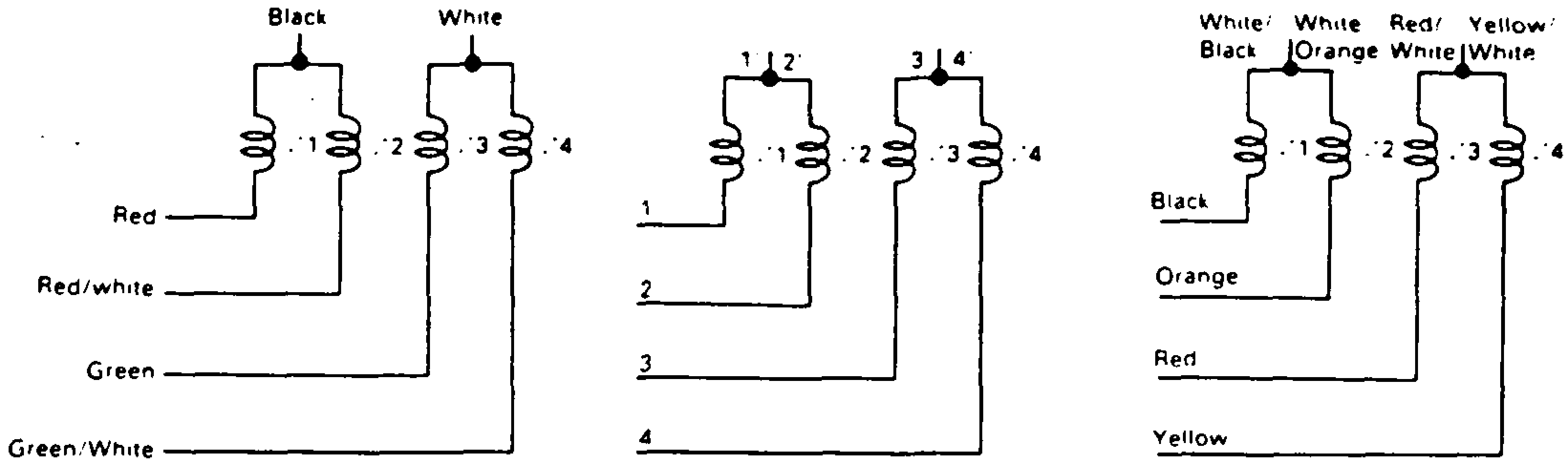
(c) Opto-coupler

(d) Simple switch

Fig. 2

Connection to RS stepper motors

When the windings of the RS Stepper Motors are assigned (Ø1 - Ø4) as shown in Fig. 3, they can be connected to the board according to Fig. 1.



1.8° Stepper motor 332-082

7.5 Stepper motors 332-947 332-953

1.8 Stepper motor 344-631

Fig. 3

If the supply voltage is set to 24V d.c. then R values for use with the RS motors are given in table 1 below:

motor	rated current (A)	rated winding votage (V)	R (Ω)	power dissipation through R (W)
332–947	0.1	12	120	1.2
332–953	0.24	12	47	3
332–082	1	5	19	19
344–631	1.7	3	12.3	36

Table 1

For other design details and motors performance refer to RS data sheet on stepper motors.

On-board oscillator assembly

If external clock source is not available, an on-board oscillator can be assembled simply by soldering into place the required RS Components listed below.
Note: the oscillator clock output must be externally wired to the clock, input-pin 24a).

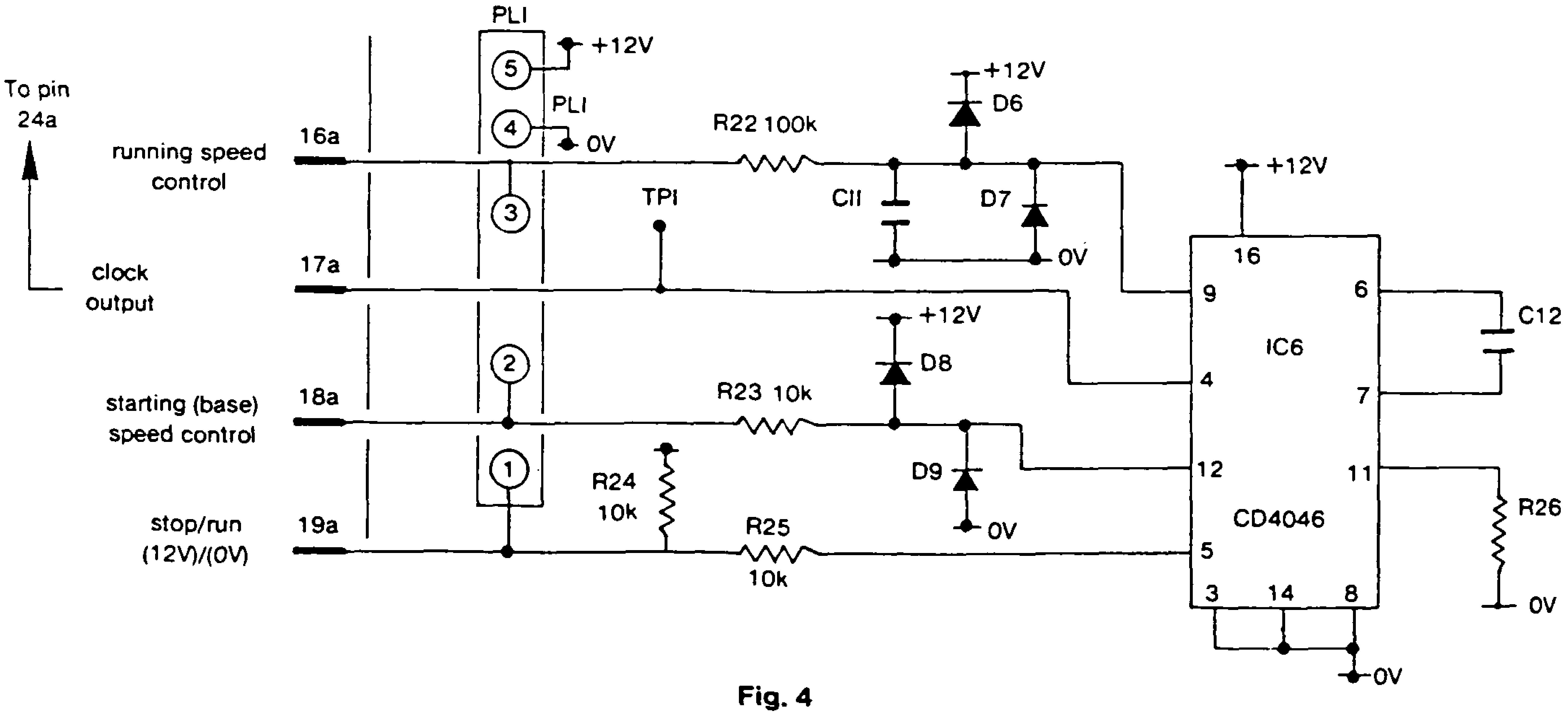


Fig. 4

R22	100KΩ resistor	RS 131—491	1 off
R23, 24, 25	10KΩ resistor	RS 131—378	3 off
D6, 7, 8, 9	signal diode	RS 271—606	4 off
IC6	CMOS I.C.	RS 306—645	1 off
R26, C11 & C12	(value depends on application)		1 off each

If oscillator remote controls are required (e.g. front panel controls) then plug PL1 (5-way RS inter-p.c.b. 467—576) can be added together with mating cable shell RS 467-627 and crimp terminals RS 467-598.

Starting (base) and running speed control

The on-board oscillator can be arranged to start at a fixed frequency (thus a fixed motor speed) and then ramp up to a final value (the running motor speed). This facility is available to start the motor within its pull-in performance region and then accelerate the motor through so that it can operate within the pull-out mode. On switch-off the motor decelerates automatically.
Three parameters need to be determined for any application:

a. The starting speed: this should be below the pull-in speed for the motor (with any additional load).
b. The running (final) speed: this should be within the pull-out capability of the motor (with any additional load).
c. The acceleration and deceleration rate between starting and running speeds: this is limited by the motor capability to accelerate through its own (plus any load) inertia.

Oscillator controls (external)

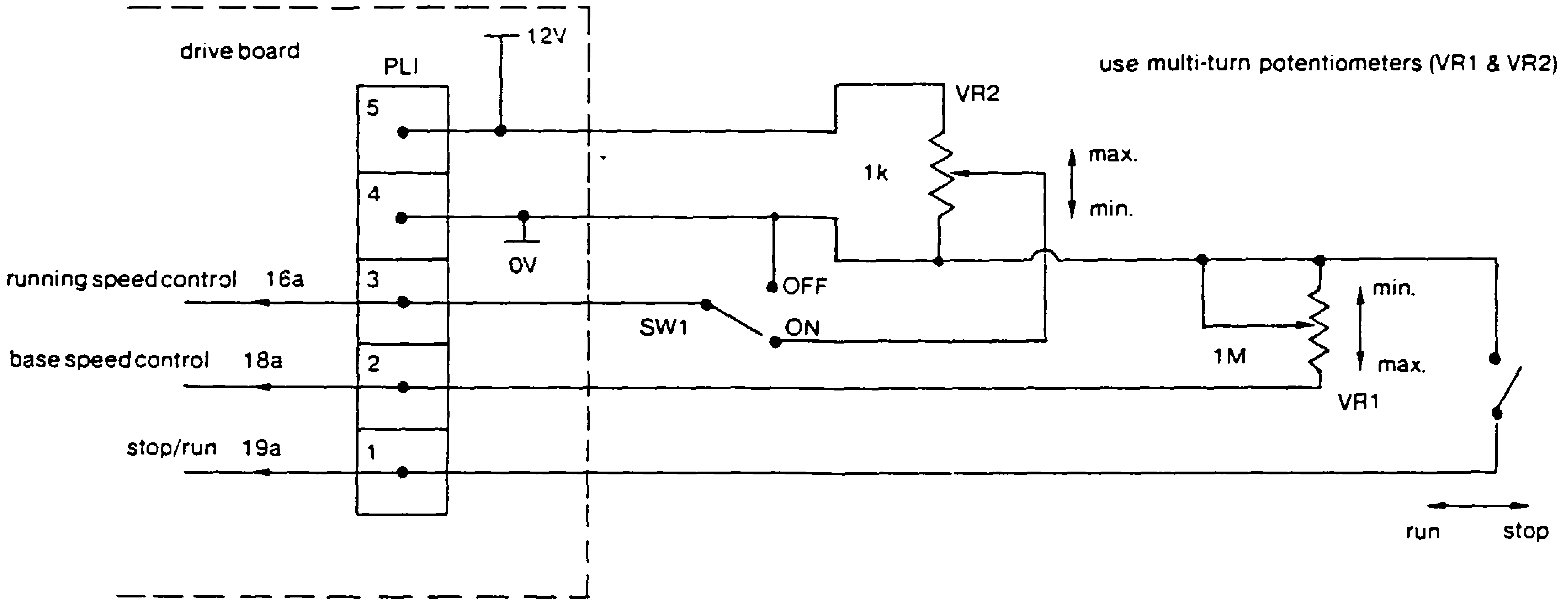


Fig. 5

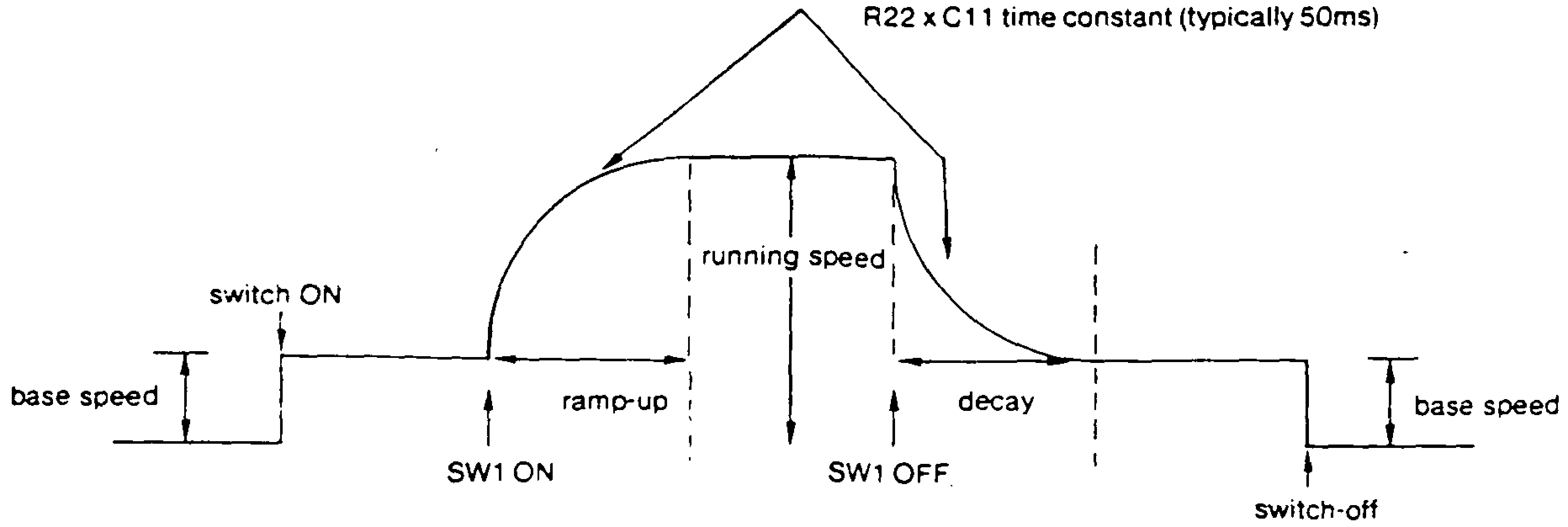


Fig. 6 Motor speed-ramping characteristic

Note: Oscillator frequency corresponds directly to motor speed in steps/s or half steps/s depending on motor drive mode.

For A 1.8° stepper motor
speed in revs/min = $\frac{60}{200}$ x speed in steps/s

or $\frac{60}{400}$ x speed in half steps/s

For A 7.5° stepper motor
speed in revs/min = $\frac{60}{48}$ x speed in steps/s

or $\frac{60}{96}$ x speed in half steps/s

Oscillator frequency setting

Recommended component values

VR1	0 – 1MΩ
VR2	1KΩ
R26	10KΩ – 1MΩ
C12	greater than 100pf

Determine the base frequency and maximum running frequency. Using Fig. 7 and the base frequency value choose a value for C12 and VR1. Calculate the ratio max. running frequency/base frequency to determine the ratio of $\frac{VR1 + R23 \text{ (fixed at } 10k\,\Omega\text{)}}{R26}$ and thus using Fig. 8 establish the required value for R26.

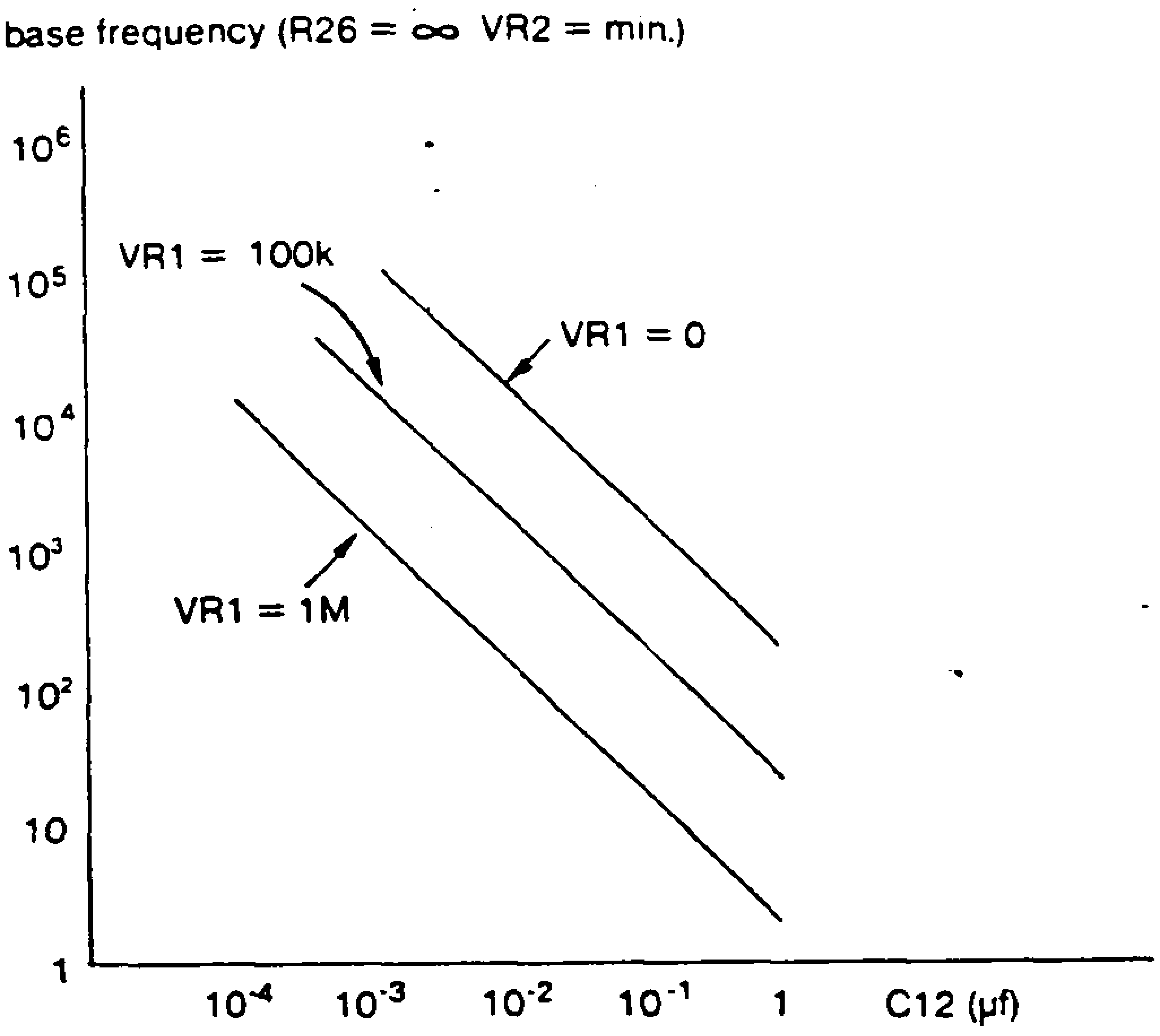


Fig. 7

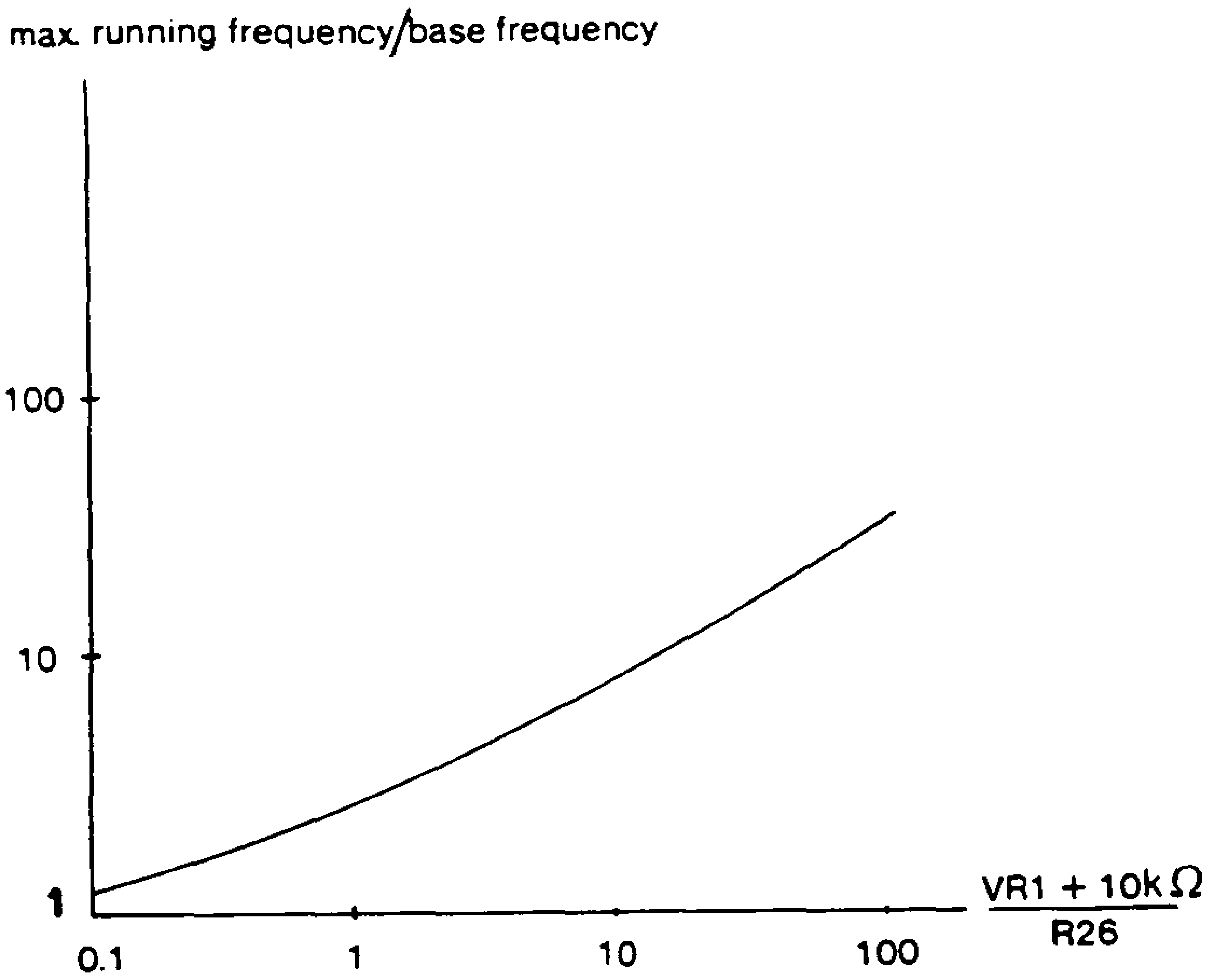


Fig. 8

Once all component values are established and assembled the oscillator frequency range is as shown in Fig. 9. If SW1 is OFF the oscillator runs at base frequency. When SW1 is ON the oscillator builds up (at a rate depending on R22 x C11 time constant) to a frequency determined by VR2 setting.

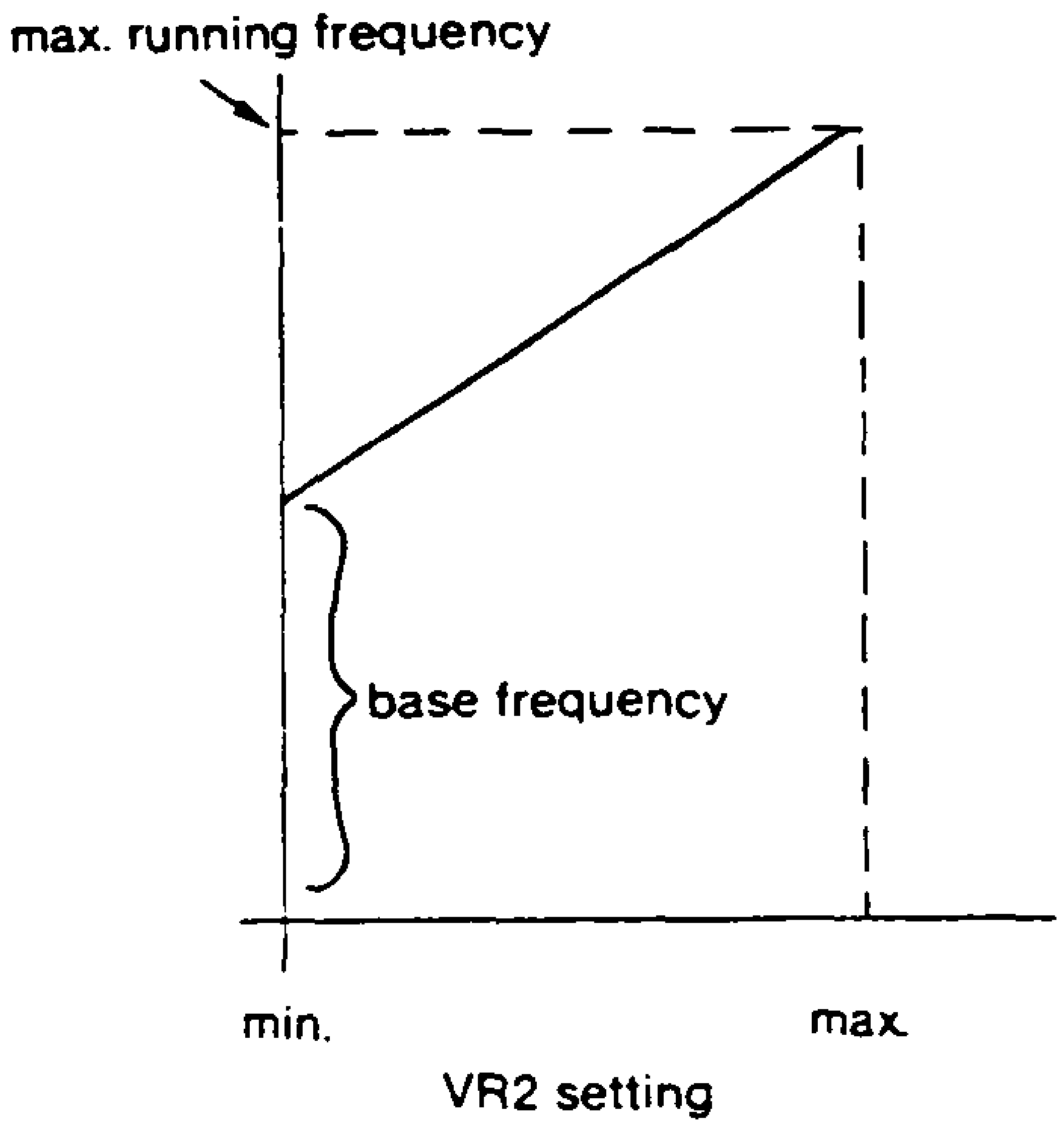
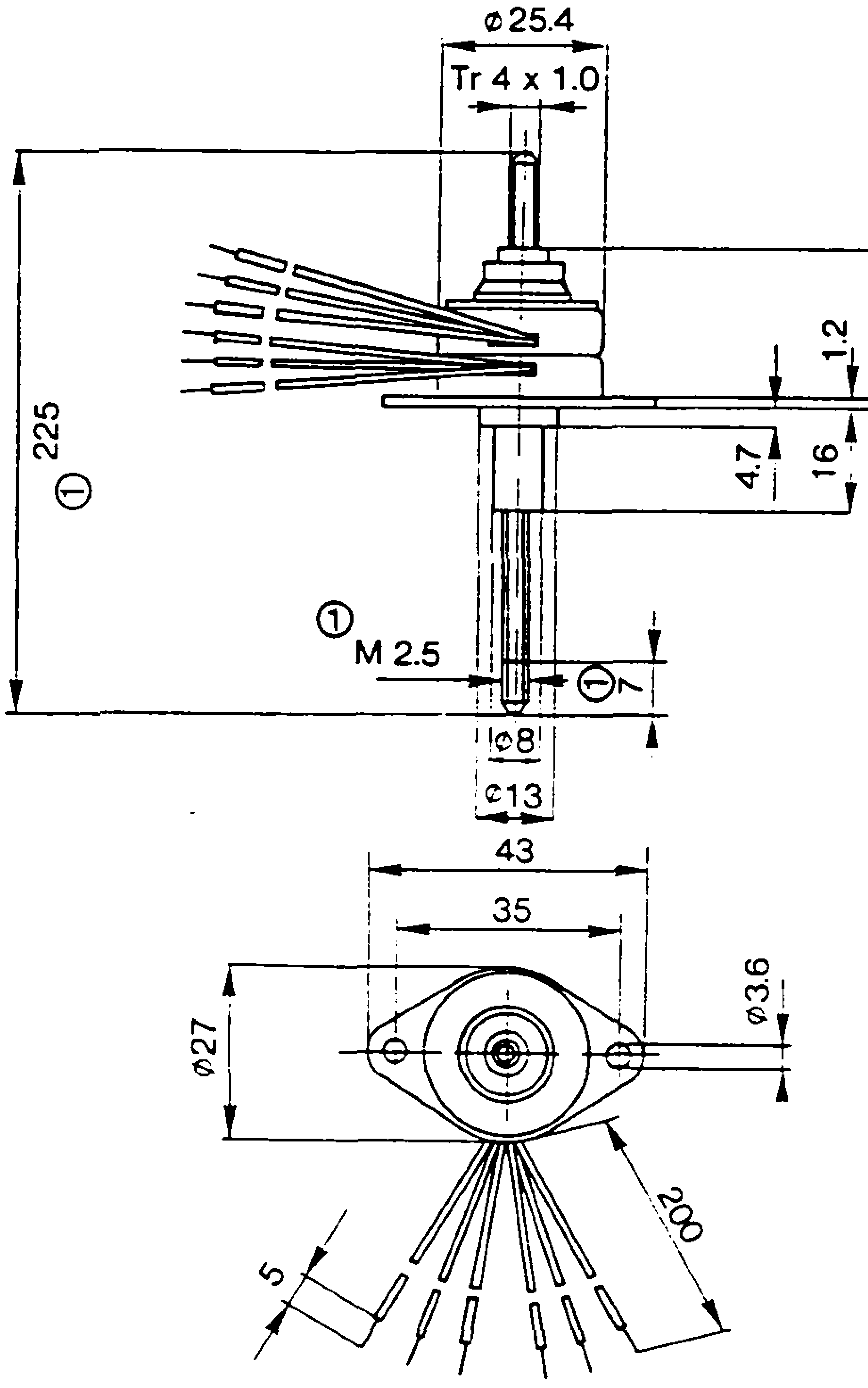


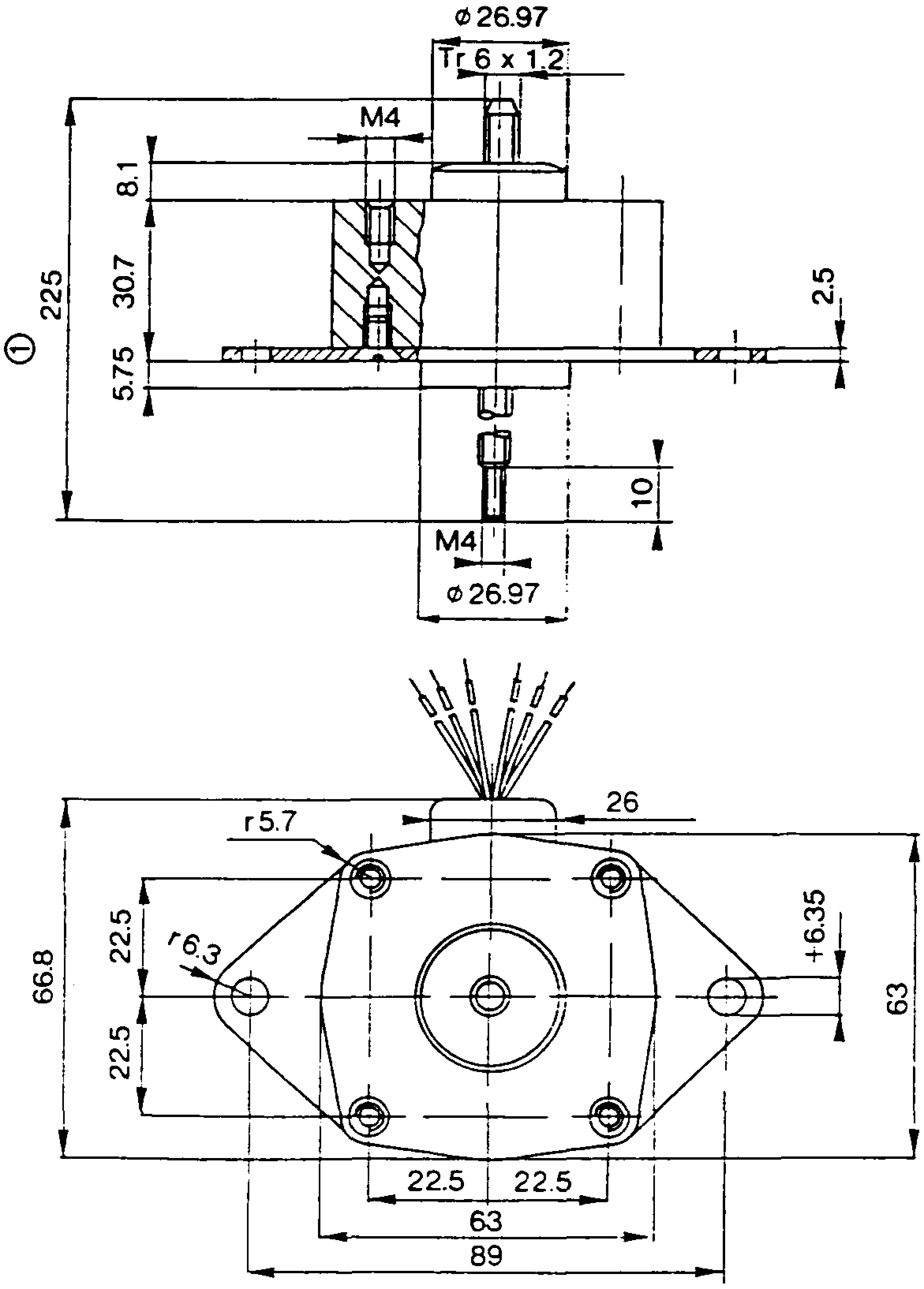
Fig. 9

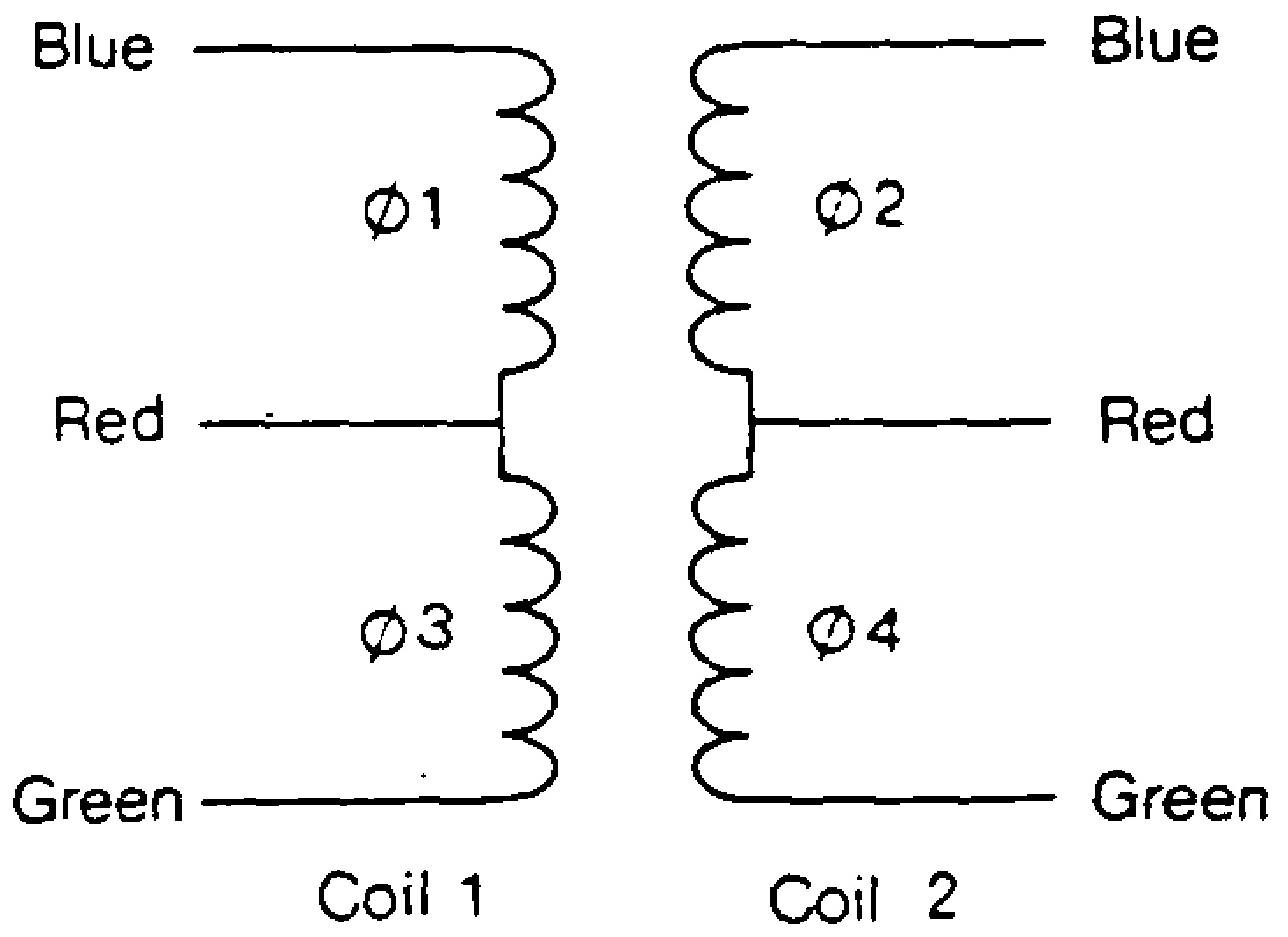
Stepping Linear Actuators

Miniature Stock No. 318-705
Standard Stock No. 318-711

Technical Specification	Miniature	Standard
Starting Force	4N	125N
Step	0.05mm	0.025mm
Travel (max)	176mm	170mm
Motor (4-phase unipolar)		
voltage	12V d.c.	12V d.c.
resistance/phase	84 Ω	25 Ω
Lead screw length	225mm	225mm
Lead screw termination	M2.5	M4
Step accuracy	±0.005mm	±0.005mm
Accuracy of repitition	±0.01mm	±0.01mm



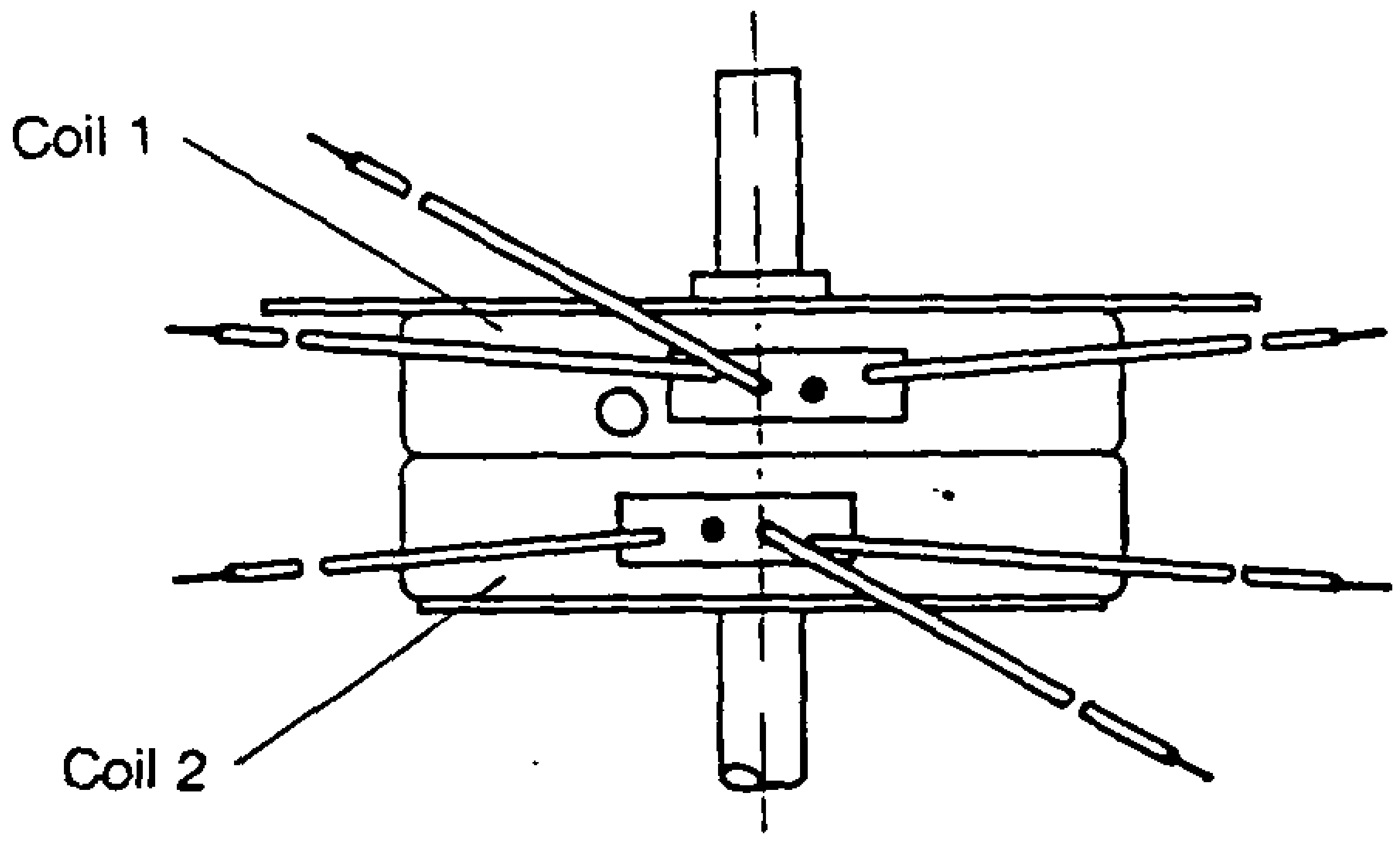




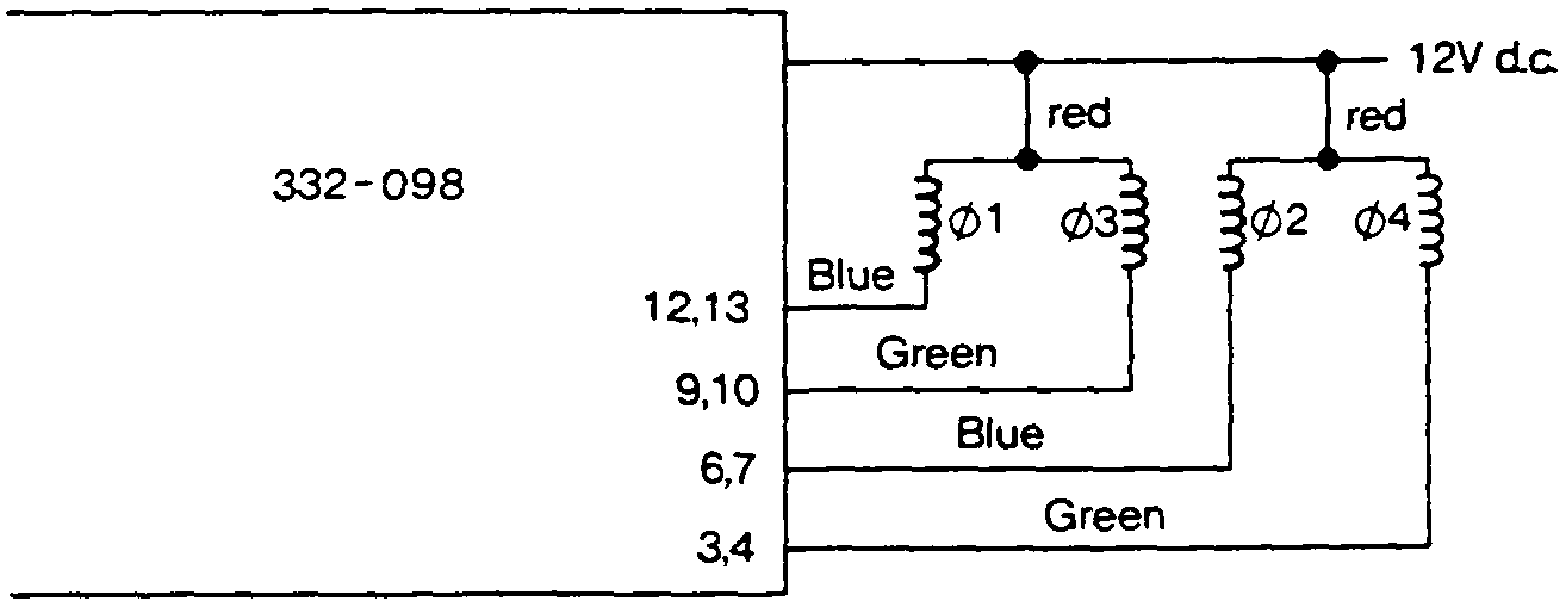
repeat

Step	Ø1	Ø2	Ø3	Ø4
0	On	Off	Off	On
1	On	On	Off	Off
2	Off	On	On	Off
3	Off	Off	On	On
4	On	Off	Off	On

4-phase drive sequence



Connections to stepper motor drive board 332-098



Each actuator is supplied with a 225mm lead screw which if necessary may be reduced in length by carefully cutting from the rear end. Always ensure the lead screw remains straight.

To achieve linear stepping movement the lead screw must be prevented from rotation by external load arrangement affixed at the metric thread end of it.

The user must ensure that throughout the travel range the lead screw is not subjected to any side bending forces.

Installation Notes

RBT Series
40 Watts
Triple Outputs

ASTEC

RS Stock nos. 595-851, 595-867,
595-873, 595-889

Output Characteristics

RS Stock Number	Model Number	Output Voltage	Minimum Load	Maximum Load w/Convection Cooling	Maximum Load w/20 CFM Air	Peak Load[1]	Regulation[2]	Ripple P/P(PARD)[3]
595-851	RBT42	5 V	0.5 A	3 A	5 A	7 A	±2%	50 mV
		12 V	0.2 A	2 A	2 A	3 A	±5%	120 mV
		-12 V	0 A	0.5 A	0.5 A	—	±5%	120 mV
595-867	RBT43	5 V	0.5 A	5 A	6 A	7 A	±2%	50 mV
		12 V	0.2 A	0.5 A	0.5A	—	±5%	120 mV
		-12 V	0 A	0.5 A	0.5 A	—	±5%	120 mV
595-873	RBT44	5 V	0.5 A	3 A	5 A	7 A	±2%	50 mV
		12 V	0.2 A	2 A	2 A	3 A	±5%	120 mV
		- 5 V	0 A	0.5 A	0.5 A	—	±5%	5 mV
595-889	RBT45	5 V	0.5 A	3 A	5 A	7 A	±2%	50 mV
		15 V	0.2 A	2 A	2 A	3 A	+10%/-3%	150 mV
		-15 V	0 A	0.5 A	0.5 A	—	±5%	150 mV

Notes 1) Peak current lasting <30 seconds with maximum 10% duty cycle.
2) At 25° C including initial tolerance, line voltage, load currents and output voltages adjusted to factory settings.
3) Peak to peak with 20 MHz bandwidth and 10 µF capacitor in parallel with 0.1 µF capacitor.

Input Specifications

Input range	90 VAC to 260 VAC
Frequency	47 - 63 Hz
Inrush current	15 A @ 115 VAC 30 A @ 230 VAC
Power factor	> 0.65
Efficiency	> 70 % typical at full load
EMI filter	Meets VDE class A and FCC class B
Fusing	Input fuse protected

Safety

VDE	EN60950 (IEC950)
UL	UL1950
CSA	CSA22.2-950

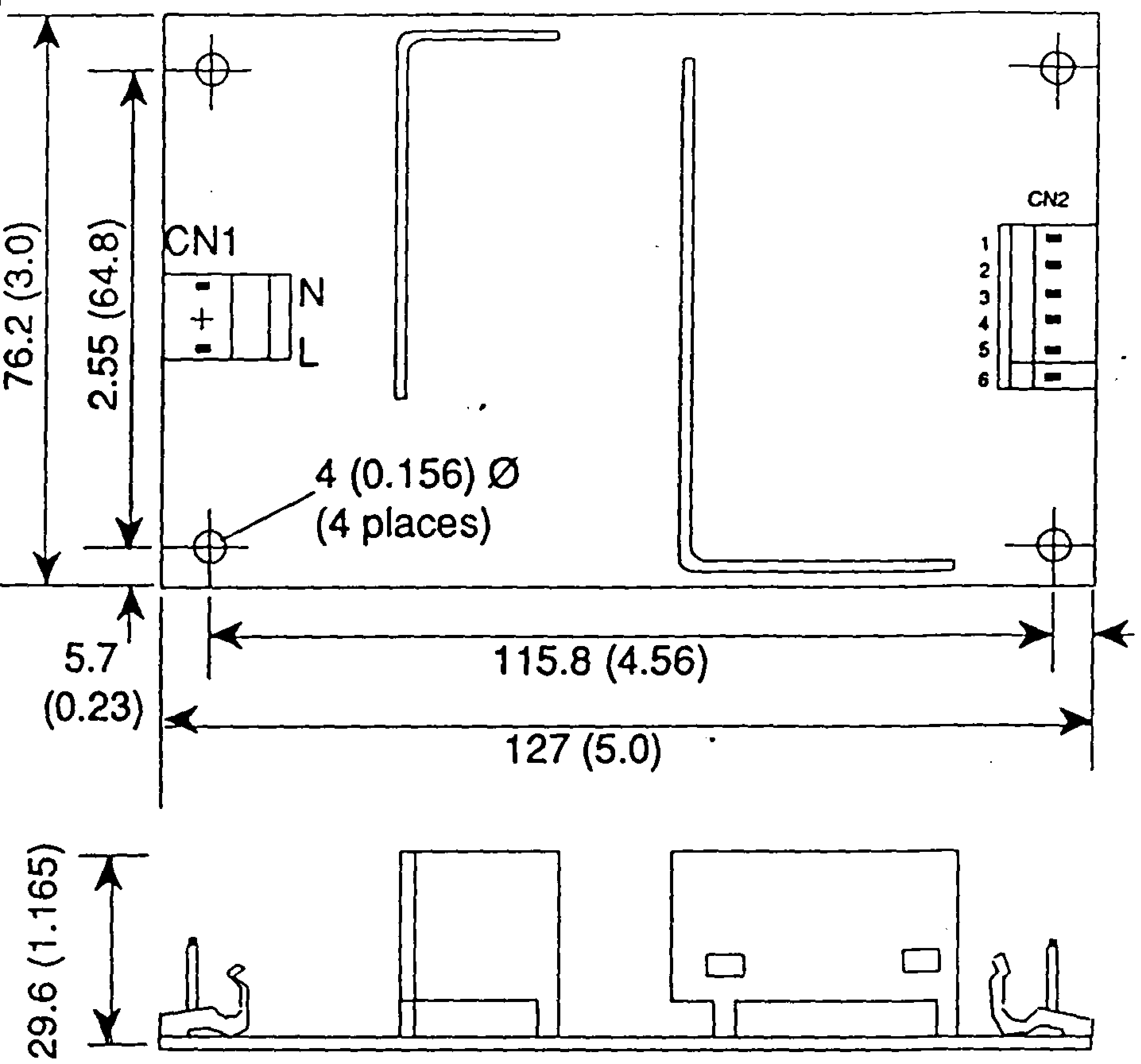
Output Specifications

Maximum wattage	40W convection 50W with 20 CFM forced air
Adjustment range	±1 %
Cross regulation	±2% on output1 ±5% on outputs2,3
Ripple and noise	0.3% RMS; 1% or 100 mVpp, whichever is greater
Overshoot	None
Hold up time	12 ms at full load and 115 VAC nominal line
Overload protection	Current foldback @ 105% to 125% of rated output. Automatic recovery.
Overvoltage protection	5.6 to 6.25 VDC on main output

Environmental

Operating temperature: 0°C to 50°C ambient; derate at 2.5 per degree from 50° to 70° C
Storage temperature: -25° C to 85° C
Thermal regulation: ±0.04% per degree C
MTBF: > 50 000 hours at full load and 25°C ambient conditions per MIL-HDBK-217E

Drawings



Fusing

Input fuse 2 A 20mm quick blow - only replace with same type and rating to maintain safety standards

Connectors

AC Input:	Housing	Molex 09-91-0300
	Pins	Molex 08-50-0106
DC Output:	Housing	Molex 09-91-0600
	Pins	Molex 08-50-0106

Pin Assignments

Connector	RBT42	RBT43	RBT44	RBT45
CN1-1	Line	Line	Line	Line
CN1-2	Neutral	Neutral	Neutral	Neutral
CN2-1	+12V	+12V	+12V	+15V
CN2-2	+5V	+5V	+5V	+5V
CN2-3	+5V	+5V	+5V	+5V
CN2-4	Common	Common	Common	Common
CN2-5	Common	Common	Common	Common
CN2-6	-12V	-12V	-5V	-15V

Notes

1. Specifications subject to change without notice.
2. All dimensions are in mm and (inches)

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