4210

Automatic
LCR Meter
GPIB Compatible (IEEE 488)

OPERATION
&
MAINTENANCE

WAYNE KERR

WAYNE KERR

MODEL 4210

AUTOMATIC LCR METER

OPERATION & MAINTENANCE

Attach to inside front cover of 4210 Operation & Maintenance handbook

AUTOMATIC SYSTEMS LCR METER 4210S
(GPIB Compatible - IEEE 488)

The 4210S is electrically the same as 4210 but is designed for use in an automatic test and measurement system. To this end, it is supplied in a case for rack mounting (19-inch) and the connections to the component under test are four BNC connectors on 24mm pitch (replacing the connection pillars of the 4210).

It is essential that side runners are provided in the rack to support the weight of the 4210S. It must not be suspended solely by front-panel screws.

Normally, the 4210S is supplied with the four connectors accessible through the front panel. They are colour-coded, the functions from left to right being:

Brown	I'	Current detector Sense
Red	I	Current detector
Orange	E	Source (& Bias +ve)
Yellow	E'	Source Sense

These BNC sockets are intended for 4-terminal measurements. If 2-terminal connections are necessary, link the inners of the red and brown sockets for one connection, and the inners of the yellow and orange sockets for the second connection. For 3-terminal measurements, the outers of the red and orange provide the Neutral (Ground) connection.

Should rear connections be required, the sub-panel carrying the four BNC connectors can be fitted to the back panel. First remove the top and bottom covers (two screws on each side of both covers). Then remove (two nuts) the blanking panel from the back to expose four holes. Undo the two nuts to release the BNC sub-panel and transfer it to the rear panel of the instrument so that, viewed from the rear, the brown BNC connector is on the left. Fit the two nuts and, similarly, fit the blanking panel to the inside front of the case. Two tie-wraps are provided on the right-hand side panel, and these must be used to hold the cables to the BNC sub-panel clear of the circuit-board. Re-fit top and bottom covers.

If it becomes necessary to change from rear connection to front-panel access, the procedure is the reverse of that described. Surplus cable to the BNC sub-panel should lie between the bottom cover and the lower metal screening plate and not adjacent to the circuit board.

The 4210S can be used for bench-top operation. Four feet are supplied, and are push-fitted in the holes provided and secured in position by tapping down the central locking-pin.

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Automatic LCR Meter 4210
GPIB Compatible (IEEE 488)

OPERATION & MAINTENANCE

The reference number of this publication is TP210/4

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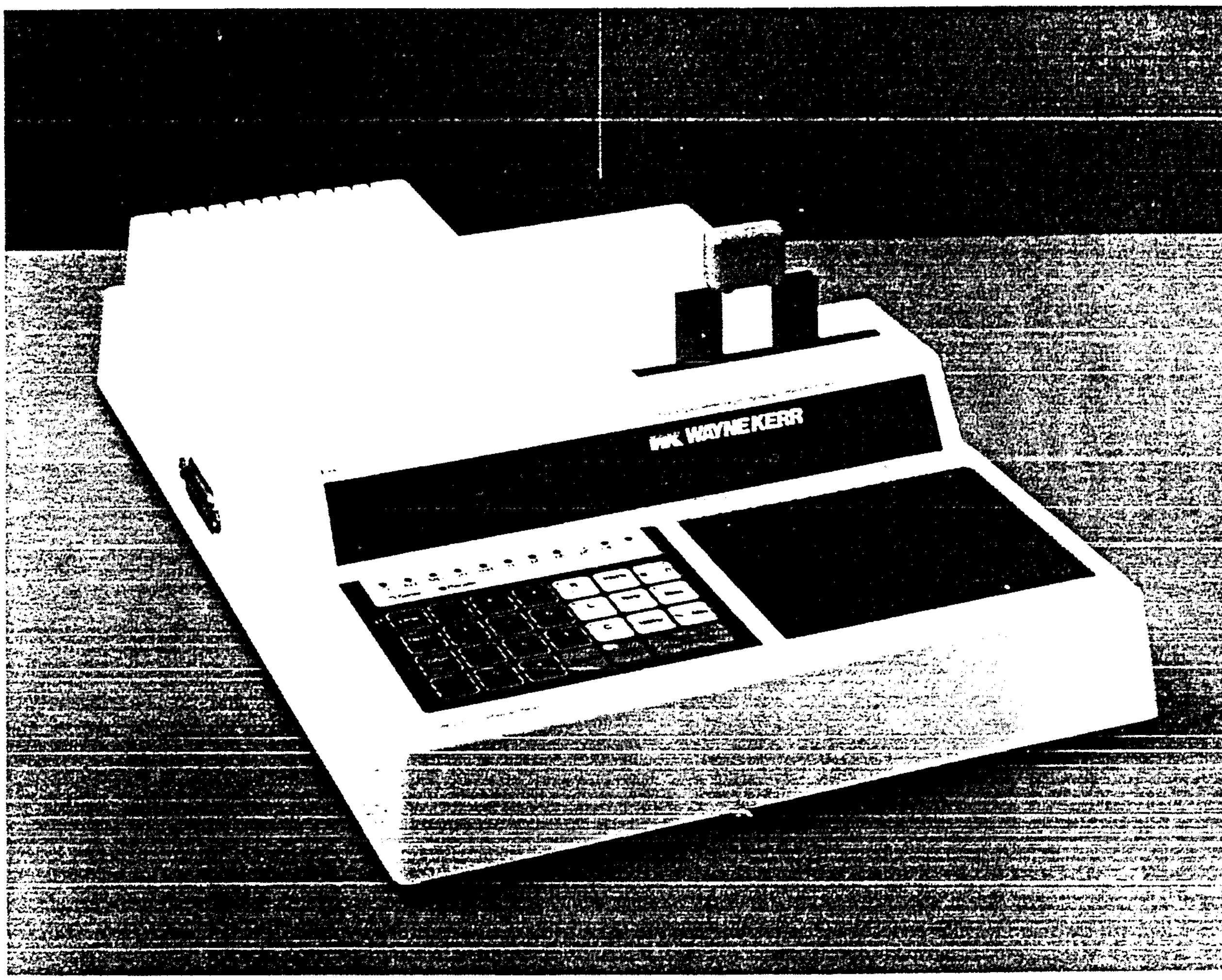

WAYNE KERR

INTRODUCTION

Automatic LCR Meter 4210 provides direct and accurate measurements on inductors, capacitors and resistors at any of three alternative frequencies. In addition to reading the major term (inductance L, capacitance C, or resistance R), it can be switched to measure the resistive loss term of inductors and capacitors, and any L or C term present with resistors. The instrument selects the more appropriate presentation of results - equivalent series or parallel components - but operators may select the alternative form whenever required.

Automatic readout of the Q-factor of inductors is available, the 4210 computing the ratio of reactance to resistance. Similarly, the dissipation factor D of capacitors can be read directly. An internal voltage is available for polarisation of capacitors when required.

Range switching is automatic, with a Range Hold facility available and manual range selection provided for. Users can also select either a continuous (repetitive) mode of operation or single-shot measurements. Open-circuit and short-circuit trimming are simply key-press operations : the appropriate corrections are established automatically, held in non-volatile memory, and applied by the instrument before any value is displayed.

Comprehensive facilities are provided for the binning of components, by % deviation or by absolute value, with ten bins available for each method. The selection process includes an initial check on the Q of inductors, or the D factor of capacitors, in each case to an acceptable limit set by the operator.

The 4210 has a General Purpose Interface Bus (GPIB) to the IEEE 488 Standard, allowing it to be used to drive a printer or to be remote-controlled on all functions, for example as in an ATE installation. These facilities are available in both measurement modes and in binning applications, allowing easy build-up of records for statistical analysis.

Ease of operation is a feature of this instrument: users have no controls to adjust. The two sets of spring-loaded jaws can be moved to suit the size of component under test, they accept radial or axial leads, and automatically make four-terminal connections to maintain 0.1% accuracy over an extremely wide measurement range. A fifth terminal - guard - is available for neutralising the effect of unwanted shunt impedances.

All functions are controlled, when manual intervention is needed, on the clearly-annotated pressure-sensitive keypad. A bold LED display shows numerical values (including any decimal point) and small LEDs indicate the appropriate units such as mH, pF or kΩ. The display also provides messages for helping operators whenever an incorrect key is pressed.

To cater for dependable measurements of transistor and diode junction capacitances, the test signal level of only 250mV rms, from a 100-ohm source, is constant on all ranges and for all types of component. The instrument is generously protected against damage should pre-charged capacitors be connected.

All L, C and R measurements can be displayed as absolute values or as % deviation from a specified nominal value.

Kelvin Lead Adaptor type 1042 simplifies connections to larger components not readily fitted to the spring-loaded jaws. A moulded box, designed to fit into the connection pillars of the instrument, has two pairs of screened leads terminated in Kelvin clips and a single lead terminated in a crocodile clip for the Guard connection. Between them, they provide all facilities for four-terminal measurements and in-situ tests.

The leads provided on the type 1042 can be removed and the required alternative leads substituted. Details of connections are described in the Lead Adaptor section of this manual.

> Please note that the EPROMs used in this instrument could lose data if exposed to direct sunlight for 1 week or room level fluorescent lighting for 3 years.

SPECIFICATION

MEASUREMENT FUNCTIONS	L,C,R,Q,D, percentage deviation and auto component mode.
MEASUREMENT FREQUENCIES	100Hz,1kHz,10kHz (50Hz version). 120Hz,1.02kHz,10.2kHz (60Hz version). Accuracy ±0.01%.
MEASUREMENT LEVEL	250mV ±15mV from 100Ω.
MEASUREMENT SPEED	Typically 650m sec.
DISPLAY	5 digit LED with decimal point plus individual LEDs for units/multipliers.
CONNECTION	4 terminal via integral test fixture. Optional Lead Adaptor for specialised measurements.
AUTOMATIC FUNCTIONS	Auto range, with manual lock. Series/Parallel equivalent circuit, with manual override. Auto component mode (R,L or C) with manual override.
CAPACITOR POLARISATION	Internal 2V supply, manually selected. Inhibited on L,R and Auto.
TRIMMING	Automatic compensation.
BINNING	8 bins with percentage limits 8 bins with absolute limits Reject and minor term reject bins.
IEEE INTERFACE	i) automatic output of measurement data. ii) full remote control of all functions.
PARAMETER STORAGE	Binning limits and trim compensation values are retained in a non-volatile store during power off.
PROTECTION	Fixture protected against connection of charged capacitors to 500V up to 2μF to 50V up to 50mF.

ACCURACY

Beyond the ranges shown, accuracy degrades linearly (see graphs)

RESISTANCE (Q<0.1)		Cal		Uncal	
100Hz/120Hz	0 - 500kΩ	±0.1%	±1mΩ		
1kHz	0 - 1MΩ	±0.1%	±1mΩ	±0.5%	±5mΩ
10kHz	0 - 1MΩ	±0.1%	±1mΩ	±0.5%	±5mΩ
Resolution	0.1mΩ				
Max Display	990MΩ				

CAPACITANCE (D<0.1)		Cal		Uncal	
100Hz/120Hz	0 - 1600μF	±0.1%	±2pF		
1kHz	0 - 160μF	±0.1%	±0.1pF	±0.5%	±0.5pF
10kHz	0 - 1.6μF	±0.1%	±0.01pF	±0.5%	±0.05pF
Resolution	0.001pF				
Max Display	990mF				

DISSIPATION (D)	Cal	Uncal
3.2nF - 1600μF	$\pm0.001(1+D^2)$	
160pF - 160μF	$\pm0.001(1+D^2)$	$\pm0.005(1+D^2)$
16pF - 1.6μF	$\pm0.001(1+D^2)$	$\pm0.005(1+D^2)$
	0.0001	
	9900	

INDUCTANCE (Q>10)		Cal		Uncal	
100Hz/120Hz	0 - 800H	±0.1%	± 1μH		
1kHz	0 - 160H	±0.1%	±0.1μH	±0.5%	±0.5μH
10kHz	0 - 1.6H	±0.1%	±0.01μH	±0.5%	±0.05μH
Resolution	1nH				
Max Display	9900H				

Q FACTOR	Cal	Uncal
1.6mH - 800H	±0.1(Q+1/Q)%	
160μH - 160H	±0.1(Q+1/Q)%	±0.5(Q+1/Q)%
16μH - 1.6H	±0.1(Q+1/Q)%	±0.5(Q+1/Q)%
	0.0001	
	9900	

OPERATING CONDITIONS

Temperature Range

Storage	-20°C to +60°C	(-4°F to 140°F)
Operation	0°C to 50°C	(32°F to 122°F)
For full accuracy	10°C to 30°C	(50°F to 86°F)

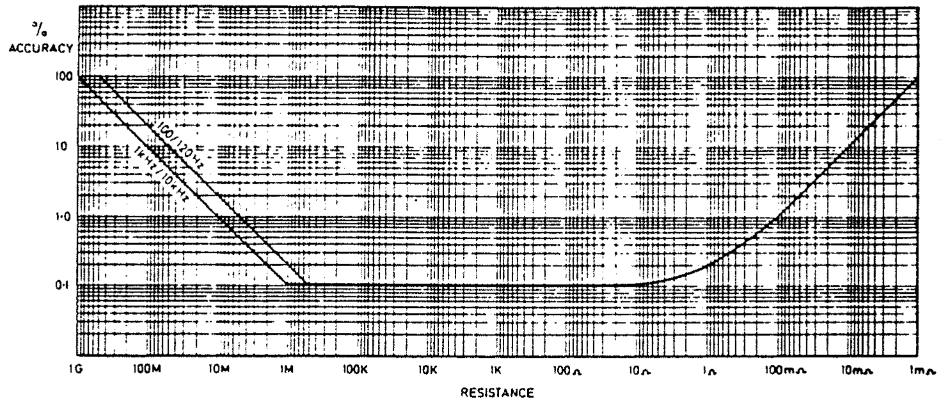
Power Supply 115V ±10%, 240V +6% -15%, 50/60Hz

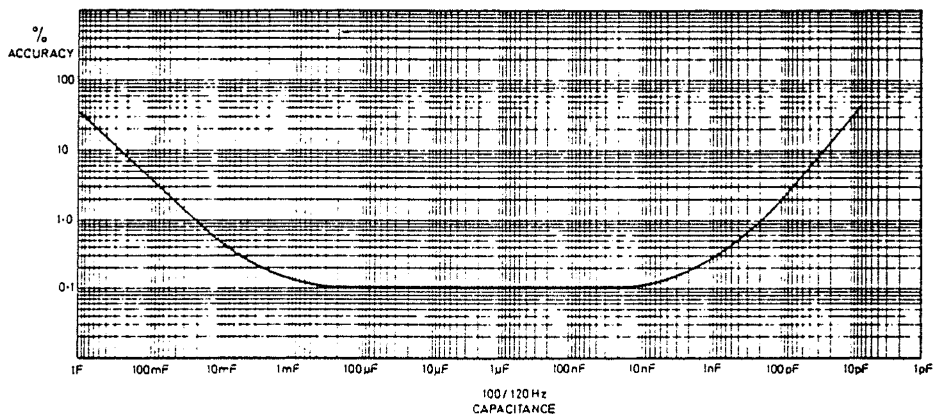
1035 204
1265 254

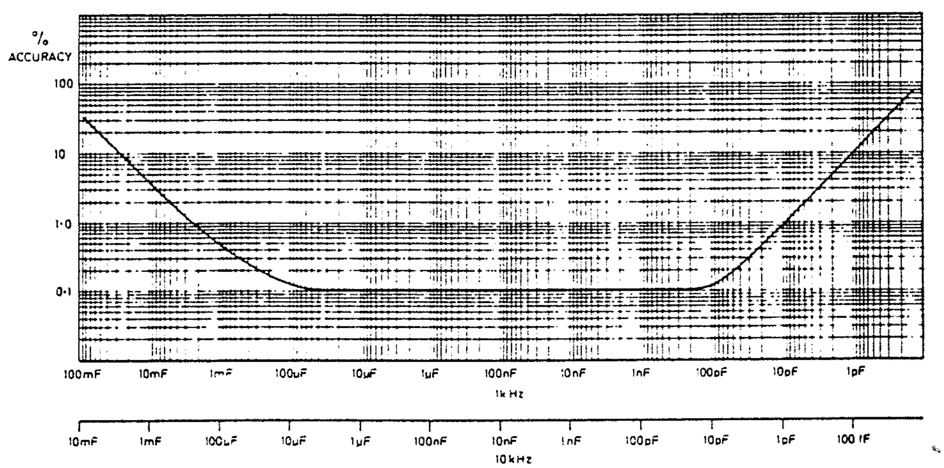
Overall Dimensions 400 x 270 x 150mm (16 x 11 x 6in).

Weight 3.8kg (8.7 lb)

In step with rapidly developing technology the Company is continually improving its products and therefore reserves the right at any time to alter specifications or designs without prior notice.


%
ACCURACY
100
10
1·0
0·1
100/120Hz
1kHz/10kHz
1G
100M
10M
1M
100K
10K
1K
100Ω
10Ω
1Ω
100mΩ
10mΩ
1mΩ
RESISTANCE


%
ACCURACY
100
10
1·0
0·1
1F
100mF
10mF
1mF
100μF
10μF
1μF
100nF
10nF
1nF
100pF
10pF
1pF
100/120Hz
CAPACITANCE


%
ACCURACY
100
10
1·0
0·1
100mF
10mF
1mF
100μF
10μF
1μF
100nF
10nF
1nF
100pF
10pF
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1kHz
10mF
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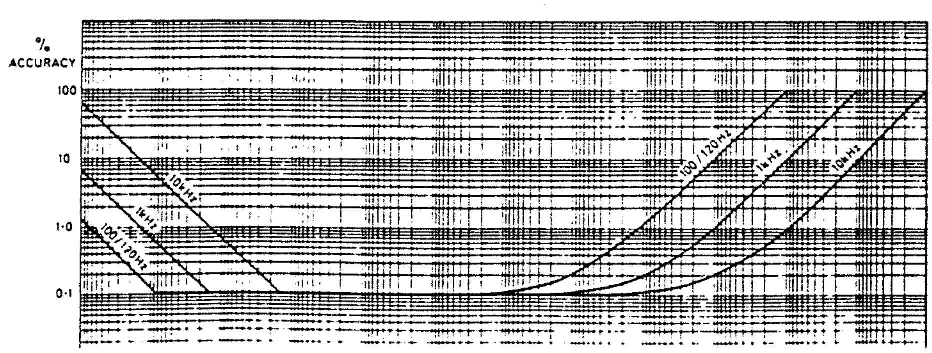
10pF
1pF
100fF
10kHz


%
ACCURACY
100
10
1·0
0·1
10kHz
1kHz
100/120Hz
100/120Hz
1kHz
10kHz

OPERATING INSTRUCTIONS

POWER CONNECTION

Check that the instrument is correct for the supply frequency (50 or 60Hz) and for the supply voltage (240V or 115V). To change over for different frequency or voltage, see Appendix. Fuse ratings are:

240V instruments	160mA-T
115V instruments	315mA-T

The power lead supplied with the instrument normally has the appropriate plug, to suit local a.c. supplies, moulded on. If for any reason the plug has to be replaced, the connections should be as follows:

Yellow/Green	to Earth (Ground)
Brown	to Live
Blue	to Neutral

If the plug is fused, a 3-amp fuse should be fitted.

The instrument is not suitable for battery operation.

The power on/off switch is on the back panel.

MEASUREMENT CONNECTIONS

Slide the two connection pillars to obtain a convenient spacing for the leads of the component to be measured. Axial and radial leads are equally well provided for. The jaws in each pillar are spring-loaded, providing positive four-terminal connections automatically when a component is placed in position.

Use of the optional Lead Adaptor is described on page 30 .

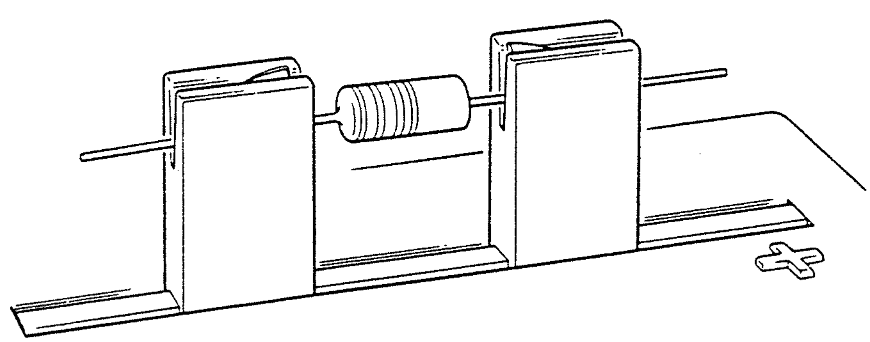


Fig. 1 Axial lead connections

INITIAL SETTINGS

At power-up, the instrument always selects a test frequency of 1kHz and operates in the Auto mode. In this condition, any type of component can be connected and its value obtained. The instrument determines automatically whether an inductor, capacitor or resistor has been connected, and automatically selects the correct range for accurate measurement.

When the instrument has already been used, possibly for other types of readout such as %, Q, D or Binning, these initial settings can be re-established most quickly by momentarily switching off. As the user gains familiarity with the instrument, however, the appropriate keyboard operations will become apparent. The sequence covering all situations (as an alternative to power off-on) is:

1 Press Value
2 Select Abs
3 Press Auto
4 Press 1kHz
5 Press Measure/Continuous until its LED has flashed at least TWICE.

The instrument is now in the same condition as at power-up.

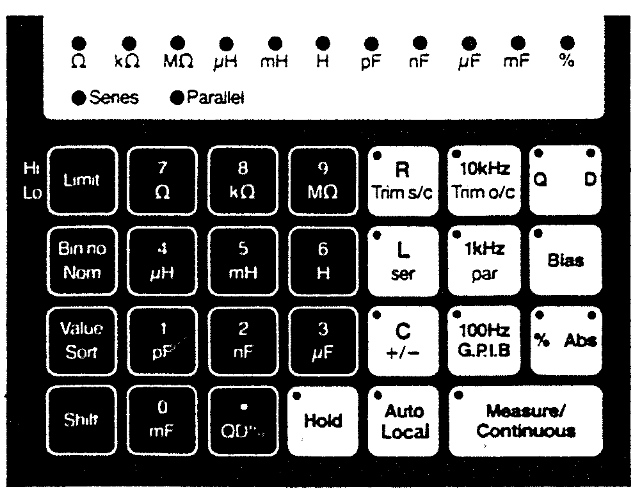


Fig. 2 Keypad

TRIMMING

For most measurements, no trimming operations are necessary. The very small corrections applied by the 4210 are held in non-volatile stores and are significant only when the highest possible accuracy is needed at the extremes of high or low impedance. To update the stored values, the 4210 should be set up with the connection pillars, Lead Adaptor, and any test fixture or measurement leads arranged as they will be used for a measurement.

It is not necessary to re-set both trim values : Trim s/c is applicable only to low impedances and Trim o/c to high impedances. For Trim s/c a solid, heavy conductor should be connected. If double-sided printed circuit board is used in the jaws, the two sides MUST be connected together on the board itself or a 4-terminal short-circuit will not be obtained. For Trim o/c make no connections at the point of measurement.

Press Shift and Trim s/c or Trim o/c as appropriate. It takes several seconds for the 4210 to complete a sequence of measurements of the series impedance of leads (on s/c) or shunt impedance (on o/c). Completion is indicated by the display changing from S.C. or O.C. to a numerical readout. The trim value obtained on short-circuit is applied automatically as a correction to all measurements made on ranges 0-3 inclusive (up to 1000Ω). The value on open-circuit is applied on ranges 4-6 (above 1000Ω).

Although the degree of trim required is quite small, the memory for trim s/c has a coverage equal to that of range 0 (see Fig. 7) and that for trim o/c equal to range 6. This capability may be useful for establishing an offset for specialised applications : it also means that for normal use an operator must ensure that, when trimming, only the appropriate short or open is used. A component connected when trimming could lead to large errors in measured values.

Each trim operation results in a pair of vector values being stored. It is therefore unnecessary to make any particular selections of R,L,C or frequency.

UNKNOWN COMPONENT TESTS

Assuming the instrument has the Initial Settings (see page 13), simply

1 Place the component in position so that its leads enter the spring-loaded connections in each pillar.

2 Read the value from the display, in association with the units indicated by an LED:

Ω, kΩ or MΩ for resistors
μH, mH or H for inductors
pF, nF, μF or mF for capacitors.

3 Another LED will show Series (impedances below 1000 ohms) or Parallel (above 1000 ohms). Further information on this is on page 47.

4a If the component is an inductor and the Q factor is required, see page 18.

4b If the component is a capacitor and the dissipation factor (D) is required, see page 22. Information on polarising capacitors is on page 23.

5 Remove the component and substitute the next unknown component.

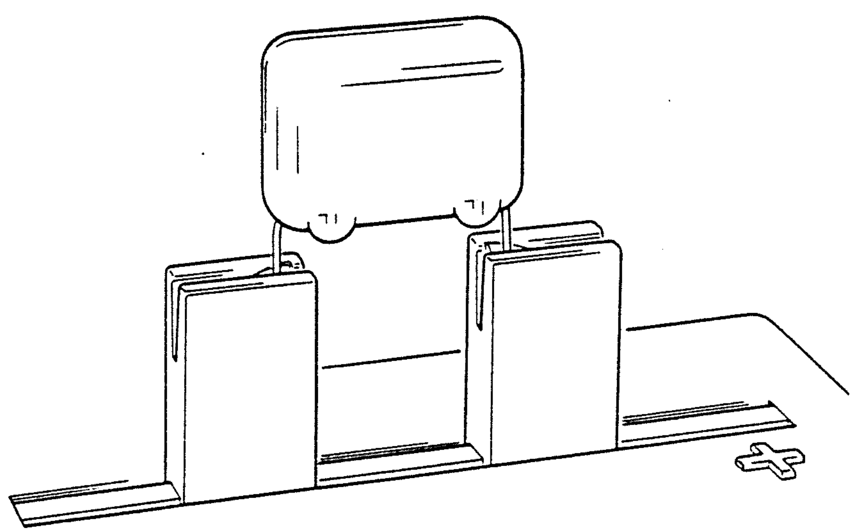


Fig. 3 Radial lead connections

TEST FREQUENCY SELECTION

The Initial Settings, as produced at switch-on, include the selection of 1kHz as the test frequency. However, users may at any time choose any one of the three test frequencies available:

50Hz operation:	100Hz	1kHz	10kHz
60Hz operation:	120Hz	1.02kHz	10.2kHz

An LED shows which frequency is in use.

Note: A change of frequency will often result in the measured impedance crossing the 1000-ohm change-over point between Series and Parallel readout. Further information on this is on page 47.

Text references to 100Hz, 1kHz and 10kHz, for 50Hz operation, apply to 60Hz operation as 120Hz, 1.02kHz and 10..2kHz, respectively.

RESISTANCE MEASUREMENT

Assuming the instrument has the Initial Settings (see page 13), simply

1 Select R and place the resistor in position so that its leads enter the spring-loaded connections in each pillar.

2 Read the value from the display, in association with the units indicated by an LED (Ω, kΩ or MΩ).

3 Remove the resistor and substitute the next one to be measured.

Note: It is not unusual for small changes to occur in the measured value of a resistor when the test frequency is changed. The effect is caused by small reactive terms which are present with all resistors. Their effect is minimal when tests are made at 100/120Hz.

The high resolution of the instrument may also show up variations in resistance due to temperature changes.

INDUCTANCE MEASUREMENT

Assuming the instrument has the Initial Settings (see page 13), simply

1 Select L and place the inductor in position so that its leads enter the spring-loaded connections in each pillar.

2 Read the value from the display, in association with the units indicated by an LED (μH, mH or H).

3 Remove the inductor and substitute the next one to be measured.

Measurement of Q Factor & Loss Resistance

With the inductor in position as described above, press L followed by the Q/D key. (The L key must have been used : Q is not available when reading inductance in the Auto mode). The display gives the Q factor. To return to inductance measurement, re-press either Q or L.

If required, the loss resistance of the inductor can be measured by selecting R, or it can be calculated from the expressions

Series: $R = \omega L/Q$

Parallel: $R = \omega LQ$

where $\omega = 2\pi \times$ frequency.

Note: Because both the inductance and the effective loss resistance of iron-cored coils vary with the frequency and level of the test signal, and with any d.c. passed, the measured Q value will be subject to variations and these can be substantial.

Measuring small-value inductors

Small-value inductors are usually best measured at 10kHz. For the best accuracy when measuring small-value inductors it is necessary to ensure that the values stored for the Trim s/c automatic correction are appropriate for the configuration in use (see page 14). After trimming, press Value to restore normal operation.

It must be appreciated that when an inductor is measured at a frequency much lower than that for which it is designed (e.g. an h.f. choke tested at a.f.) it will tend to behave as an inductive resistor. Also, in the Auto mode, the value displayed will be resistance. In these circumstances, the inductance measurement accuracy is widened by the factor (1 + 1/Q). The value of this factor can be determined by using the Q facility. Air-cored coils are particularly susceptible to hum pick-up. For this reason, keep them well clear of power transformers and, whenever possible, measure at 10kHz. Tests at 100Hz may be marred by noise.

Measuring iron-cored inductors

Ferrite-cored coils are usually best measured at 1kHz. Larger audio inductors, with laminated cores, are normally checked at 100Hz. When core materials can be damaged by excessive magnetisation (for example, some tape heads and microphone transformers), check before connection that the test signal level (250mV via 100Ω) is acceptable. It should also be noted that a residual 20mV d.c. is present at the measurement connections. If this is unacceptable, use the Lead Adaptor and insert a series blocking capacitor of not less than 100μF (C1 in Fig.4).

The effective value of all iron-cored inductors can vary widely with the magnetisation and, therefore, with the level of the test signal. Ideally, they should be measured at the frequency of use, with the same a.c. and d.c. levels as apply in use. However, valuable results - especially comparative values - can usually be obtained by passing a direct current through the inductor while under test.

The essential requirements are to prevent this current entering the instrument measurement circuits, and to minimise the effect of the d.c. supply components on the measured value. To achieve this, the optional Lead Adaptor (see page 30) is required. The circuit arrangement

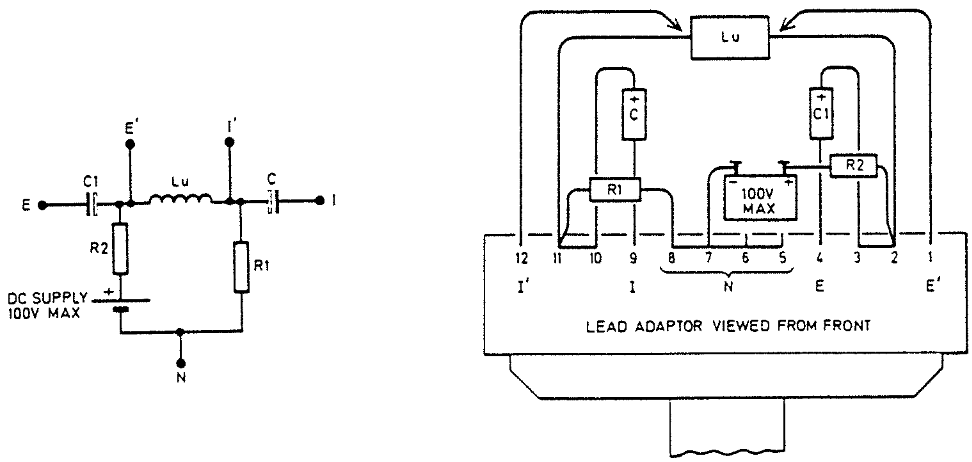


Fig. 4 Energising Inductors

Absolute maximum voltage of the supply is 100V. Care must be taken to ensure correct polarity - failure to observe this will result in permanent damage to the instrument, not covered by the Warranty, and may put the user at risk.

Lu is the inductor under test.

C1 should be ≧ 100μF and of a working voltage to suit the voltage of the d.c. supply.

The direct current through the inductor is also passed by resistors R1 and R2, which must have an adequate wattage rating. On the other hand, measurement errors will arise if the resistance values are made too low. For 1% accuracy, the minimum values for C and R1 are:

C = 1000μF R1 = 500Ω

The minimum value of R2 can be found by first calculating Zu:

$$Zu = \sqrt{[Ru^2 + (2\pi f Lu)^2]}$$

where
Ru = resistance of unknown (Series, ohms)
f = test frequency
Lu = inductance of unknown (Series)

and, from this value of Zu, using the graph (Fig. 5) to read R2.

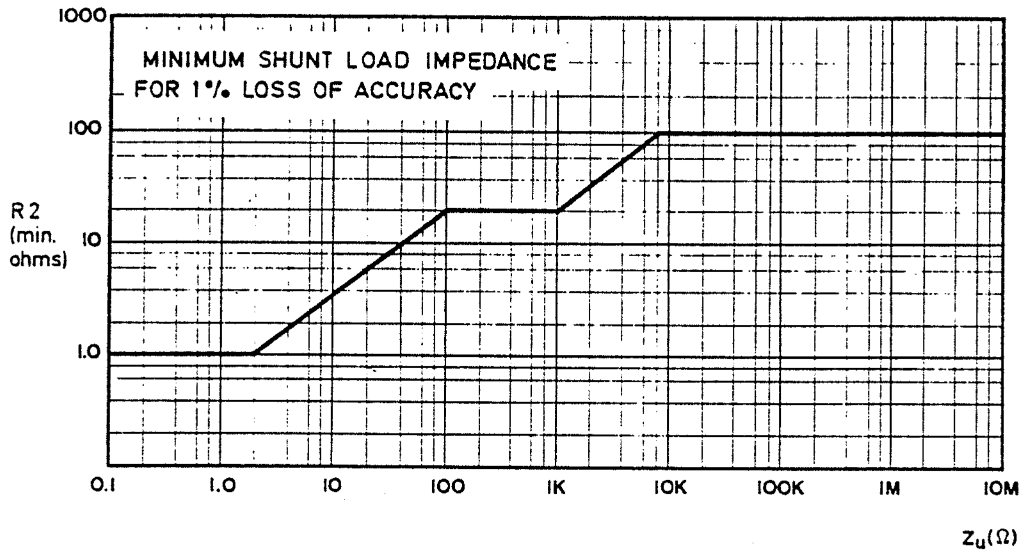


Fig. 5 Permissible Shunt Loading

The shunting effect of R1 and R2 in a given measurement can easily be assessed by substituting a short-circuit for the d.c. supply, and then noting the change in measured value when R1 and R2 are disconnected.

CAPACITANCE MEASUREMENT

Assuming the instrument has the Initial Settings (see page 13), simply

1. Select C and place the capacitor in position so that its leads enter the spring-loaded connections in each pillar.

2. Read the value from the display, in association with the units indicated by an LED (pF, nF, μF or mF).

3. Remove the capacitor and substitute the next one to be measured.

Measurement of D Factor & Loss Resistance

With the capacitor in position as described above, press C followed by the Q/D key. (The C key must have been used: D is not available when reading capacitance in the Auto mode). The display gives the dissipation factor. To return to capacitance measurement, re-press either D or C.

If required, the loss resistance of the capacitor can be measured by selecting R, or it can be calculated from the expressions

Series: $R = D/\omega C$

Parallel: $R = 1/\omega CD$

where $\omega = 2\pi \times$ frequency.

Measuring small-value capacitors

For the best accuracy when measuring small-value capacitors it is necessary to ensure that the values stored for the Trim o/c automatic correction are appropriate for the configuration in use. Set the separation of the connection pillars (or other connection system) at the settings to be used for measurement and, with no component connected, press Trim o/c. The 4210 will re-set the stored correction figure for stray impedance and this will be deducted automatically from all subsequent measurements. Press Value to restore normal operation.

Measuring electrolytic capacitors

With a capacitor in position and with C selected (NOT Auto), pressing the Bias key will apply 2V positive bias - from an internal supply - to the right-hand connection pillar. An LED is illuminated on the Bias key while the 2V is applied : a second press of the key removes the bias.

If bias exceeding 2V is required, the optional Lead Adaptor (see page 30) is used in association with the circuit shown below:

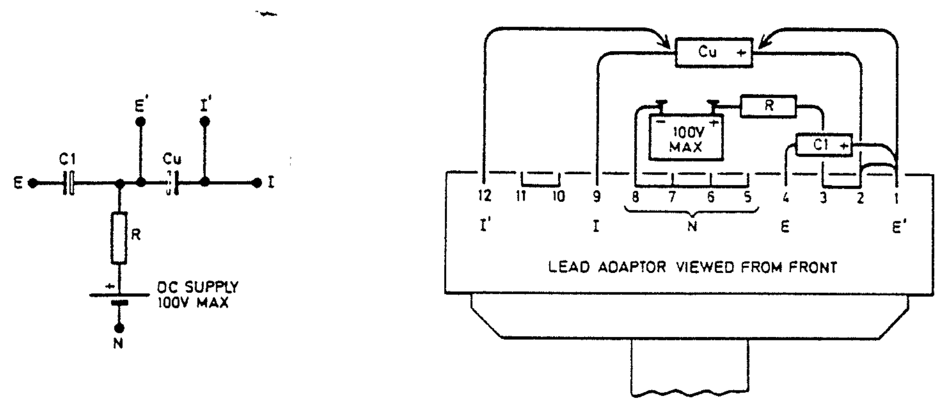


Fig. 6 Capacitor Bias exceeding 2V

Cu is the capacitor under test.

C1 should be ≥100μF and of a working voltage to suit the voltage of the d.c. supply.

Absolute maximum voltage of the supply is 100V. Care must be taken to ensure correct polarity - failure to observe this will result in permanent damage to the instrument, not covered by the Warranty, and may put the user at risk.

R should be ≥330Ω and of adequate power rating to take account of short-circuit capacitors (i.e. 100V, 330Ω, 30W).

Charged capacitor protection

Capacitors not exceeding 2µF can be charged up to 500V prior to connection to the 4210, and will cause no damage. However, larger values, up to 50mF (50,000µF) must be limited to 50V charge.

Semiconductor junction capacitance

Because of the small value of the test voltage and the availability of 2V bias, the 4210 provides quick and reliable readout of semiconductor junction capacitance.

1 Select C, Bias, and the required frequency.

2 Connect the semiconductor so that it is reverse-biased (i.e. cathode to the right-hand measurement pillar).

3 Note the value and substitute the next component to be checked, again taking care to obtain reverse bias.

% DEVIATION READOUT

As an alternative to reading resistance, inductance or capacitance as an absolute value, the 4210 can provide direct readout of these three properties in terms of % deviation from a specified nominal value. The procedure for setting a nominal value and subsequent tests, is as follows:

1 Press: Value

Select: % (on the %/Abs white key)

Press: Shift

" Nom

The existing stored value will be displayed.

2 Key in up to five digits and (if needed) a decimal point for the required nominal value.

3 Press: Shift

Units required (Ω , μH, pF, etc)

Wait until the nominal value is displayed.

4 Press: Value

5 Connect each component in turn to obtain a reading of % deviation from the nominal value entered. Maximum reading is ± 99.9%. Components whose value deviates by more than this (or components of the wrong type) will produce a display of o.d.r.(outside display range).

Most of the facilities for Absolute measurements are available also in the % mode. Note that the 4210 cannot provide % deviation readout on Q and D values. The nominal value for % deviation readout is the same as that used for binning.

CONTINUOUS/SINGLE-SHOT MEASUREMENTS

In normal use, the 4210 makes a new measurement, and updates the display, at intervals of approximately 650 milliseconds. This provides a convenient readout of changing values and - where values fluctuate very widely - indicates that the measured component is unstable or that the term requested either lies outside the coverage of the instrument or is virtually swamped by another term.

For some applications, it may be more convenient to have a one-off measurement, the result being shown on the display for as long as required. To obtain this condition, momentarily press Measure/Continuous. A measured value will then be stored and removal of the component under test, or substitution of another one, will not affect the readout. When another single-shot measurement is required, again momentarily press Measure/Continuous. To return to normal (Continuous) mode, press the key for at least two flashes of the LED. The mode in use is shown by this LED:

Flashing:	Continuous
Off:	Single-shot

RANGE SELECTION

Normally the 4210 automatically selects the correct range for accurate measurement. This occurs in the Value or Sort mode, for single-shot or repetitive measurement. The Hold key can be used to lock the instrument on to the range it has selected in this way (described in the next section). However, it is also possible to pre-select a particular range. The key sequence to achieve this is:

a Shift

b Hold

c Any key 0-6, according to the range required.

Coverage of the seven ranges is shown on Fig. 7. It should be borne in mind that pre-selection of a particular range to examine one term of a complex impedance may cause an overload by the major term. Also, changing frequency may necessitate a change of range.

HOLD FACILITY

When a number of similar components are to be checked, the short time taken by the instrument for the autoranging function can be eliminated. With a component connected, and its value displayed, press Hold. The range in use (selected by the instrument) will now be held for all subsequent tests (Value or Sort). The Hold function is indicated by the LED illuminating by the Hold key. To return to autoranging, re-press Hold.

DISPLAY CHARACTERISTICS

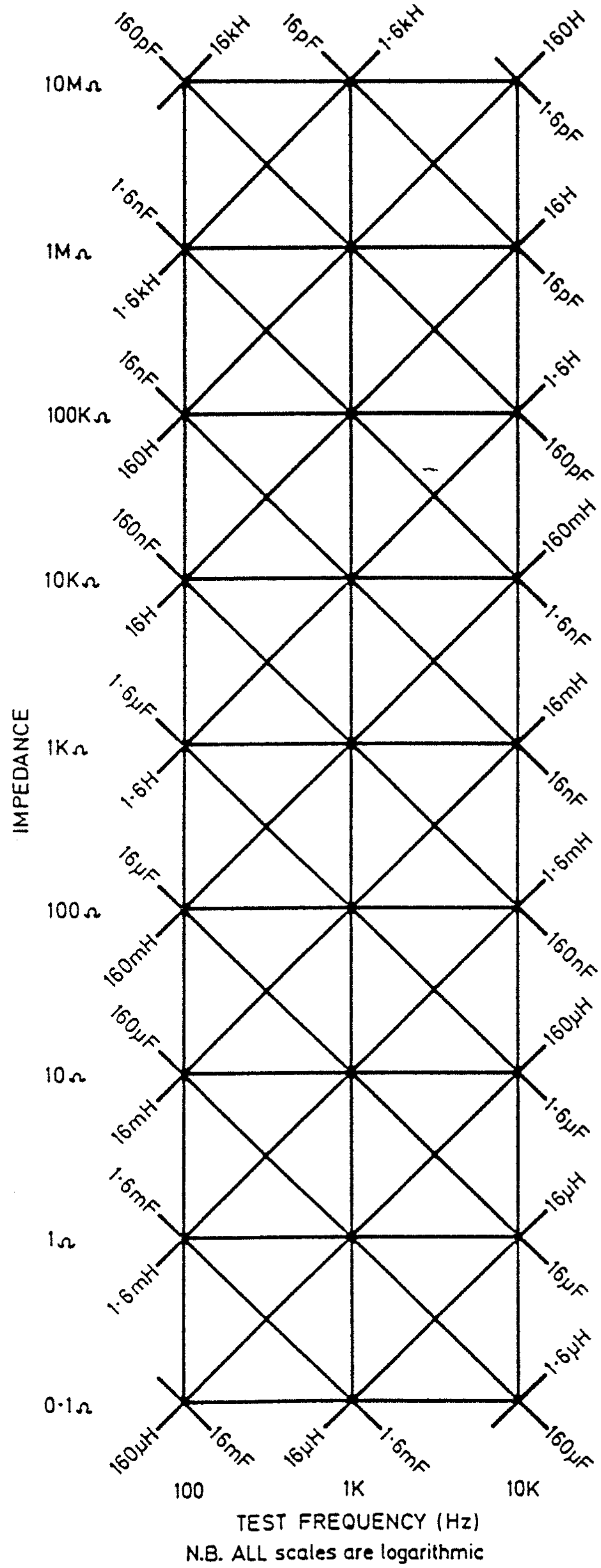
All values displayed by the 4210 are derived by internal computation. Some of these computations may involve denominators whose value approaches zero, giving rise to large, unstable results. If a value is too large to be displayed (i.e. exceeding 99MΩ, 99mF or 9900H), the over-range indication will appear: [or]

If Hold has been selected, and a component connected subsequently causes an overload, the display will be: [Hold.r]

The impedance may lie outside the range capability because it is an extreme value, because the frequency selected is unsuitable, or because the range Hold has been used inappropriately.

Negative Reactance

If C is selected with an inductor connected, or L with a capacitor connected, the 4210 will, within the capability of the display, show a negative value in the terms selected. This will be the value of capacitance (or inductance) whose reactance at the test frequency is equal to that of the component connected. It is, of course, the value to produce resonance with the component, at the test frequency. An impedance chart is shown in Fig. 7.



Range	V_s (mV)	E_u (mV)	E_s (mV)	A_u	A_s
6	250	250 / 250	0·25 / 2·5	x2	x200
5	250	250 / 250	2·5 / 25	x2	x20
4	250	250 / 249	25 / 249	x2	x2
3	250	249 / 177	249 / 1770	x2	x0·2
2	250	177 / 24·9	1770 / 2490	x2	x0·2
1	250	24·9 / 2·5	2490 / 2500	x20	x0·2
0	250	2·5 / 0·25	2500 / 2500	x200	x0·2

↑ $E_u > E_s$ (ranges 4–6)

↓ $E_u < E_s$ (ranges 0–3)

E_u and E_s are based on reactive impedances and are therefore maximum values.

Fig. 7 Impedance Chart

LEAD ADAPTOR

Connection pillars of the 4210 provide automatic 4-terminal connections to component leads. The right-hand pillar has the two contacts for E and E', the drive and measurement connections, respectively, for the source circuits. The left-hand pillar has I for the unknown current input connection to the Meter and I' as the common reference point for comparing Unknown and Standard signals.

For some applications, separate access to these four points will be required. Two instances have already been described : Energising Inductors (see Figure 4) and Capacitor Bias Exceeding 2V (Figure 6). Another valuable application is the measurement of components connected into a circuit (in-situ tests). In all these instances, the use of a neutral (N) terminal substantially eliminates the effect of components which would otherwise shunt the component under test. In Fig. 8 , for example, a measurement of Zu with:

a) Z1 not less than 500Ω , and

b) Z2 not less than the value (for R2) obtained by reference to Fig. 5 ,

will be subject to an additional tolerance of not more than 1% from each cause. The leads from I' and E' must NOT be commoned with the I and E leads, respectively. If screened leads are used, connect the braids to Neutral.

References in this Manual to the optional Lead Adaptor relate to Kelvin Lead Adaptor type 1042. This item is described in the last two paragraphs of the Introduction (see page 8). Connections to the Kelvin clips are coded by coloured sleeves. Their relationships to Fig. 8 are as follows:

Brown	E'	1
Red	E	4
Orange	I	9
Yellow	I'	12
Guard & Screens	N	5,6,7,8

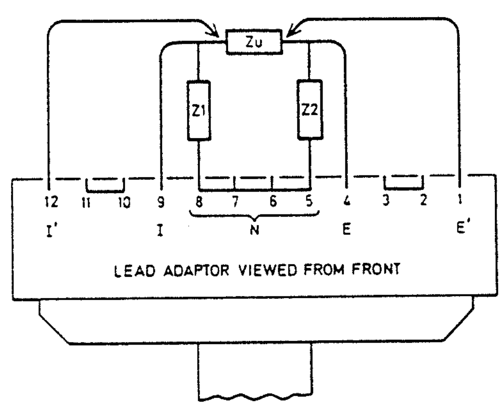


Fig. 8 Lead Adaptor for In-situ tests

BINNING

General

This facility allows a number of broadly similar components to be sorted into up to eight bins according to their value. A preliminary check on the loss characteristic (the Q of an inductor, the dissipation factor D of a capacitor) places failed components in a bin 0 classification. Components not placed in any bin from 0 to 8 are classified as bin 9. The binning can be in terms of percentage deviations from a nominal value or can be based on absolute values. Separate sets of bins are provided for each of these methods of use : they do not interact. When the binning interface is required, select GPIB address 99 (see page 49).
When setting limits, in the % or Abs mode, there is a particular operation which defines the type of component to be sorted (i.e. R,L or C):

In the % mode, it is the entry of the nominal value (Nom). Whenever the units entered at this stage are of a different type to those existing, all previous % limits are cleared (and any Bin 0 limit), leaving only the new nominal.* A change of numerical value alone, and/or of the magnitude of the units (e.g. from pF to nF), does NOT cause such clearance of limits provided the new nominal value is of the same type.

In the Abs mode, the operation defining the type of component to be sorted is the latest value entered for Bin 1, whether Hi or Lo. A change of type at this stage will clear all previous Abs limits (and any Bin 0 limit), leaving only the new Bin 1 value.* Once the type of component has been so defined, the instrument will reject attempts to set any Abs limits not of the same type. It will accept changed numerical values, or units for any limits of different magnitude but of the same type (e.g. Ω and kΩ), without clearing down.

Existing limits can always be altered, but when it is required to clear limits and there is not a change in the type of component to be sorted, the procedure is to deliberately enter a number with a different type of unit into Nom (in % mode) or Bin 1 (in Abs mode). This will cause the

* Because these values are held in non-volatile memory, there is always a nominal value present and at least one absolute limit in Bin 1.

clearance just described. The user can now proceed to make the new entries, using the original type of units.

A change or clear-down of % limits does not affect any Abs limits, nor are % limits affected by changed or cleared Abs limits.

A Bin 0 limit must be set for sorting inductors or capacitors, whether in the % or Abs mode. (Bin 0 is not applicable to resistor sorting). Although the single limit for Bin 0, together with the two limits for all other bins to be used, can be set in any sequence, because of the clearances just described which occur when a new type of entry is made for Nom (in % mode) or for Bin 1 (in Abs mode), it is good operation practice to set the Nom - or Bin 1 - before setting Bin 0 or other bins.

The address of Bin 0, for setting-up capacitor or inductor loss checks, is Bin 0H(Hi). However, in the Sort mode, the limit entered in Bin 0 is applied as an acceptable maximum for D (when the defined operation is capacitance) while it is applied as an acceptable minimum for Q (when the defined operation is inductance).

In the Sort mode, the instrument checks components for classification in the sequence bin 0 to bin 9. Consequently, the limits set for any bin should not embrace values to be selected for succeeding bins.

Whenever the required function is shown in red on the keypad, Shift must first be pressed or the alternative (black/white) function will be selected. When setting limits (in % or Abs mode), the 4210 must be in the Value mode (in the Sort mode, the only active keys are Measure/Continuous and Value).

Because the display may produce a short sequence of messages from a single key operation, it is desirable to develop the habit of watching the display whenever a key is operated and not to make further key operations until it is seen that the first operation has been accepted properly.

Keying errors

These can be grouped into two classes:

1 A valid command (i.e. one that the 4210 will accept) but not what the user intended (for example the entry of an incorrect numerical value for a limit). The procedures for correcting this type of error are given at the end of the operating instructions under 'Revision and correction of entries' (page 44).

2 An invalid command - one that is not logical or for some other reason is not accepted by the 4210. In this situation, an appropriate error message is displayed, the invalid command is ignored and the instrument remains in the condition it was in before the offending keystroke was made. A list of Displayed messages, and their significance, is given at the end of the operating instructions (pages 45 and 46).

Sorting by % Deviation

1 Press: Value

Select: % (on the %/Abs white key)

Press: Shift

" Nom

The existing stored value will be displayed.

2 Key in up to five digits and (if needed) a decimal point for the required nominal value.

3 Press: Shift

units required (Ω , μH, pF, etc)

4 Press: Bin no

1

Limit (Hi)

The display will initially show bin1H and will then either go blank or show any existing limit.

5 Key in up to THREE digits and (if needed) a decimal point for the upper* limit. If negative, press:

Shift

+/-

This sign selection can be made at any stage in entering a number. If no selection is made, the default is +.

6 To store the displayed limit, press:

Shift

QD% (on decimal point key)

* With one positive and one negative % limit, 'upper' refers to the + limit and 'lower' to the - limit. With both limits of the same sign, 'upper' refers to more positive (or less negative), and 'lower' refers to less positive (or more negative).

7 Press: Shift
Limit (Lo)

The display will initially show bin1L and will then either go blank or show any existing limit.

8 Key in up to three digits and (if needed) a decimal point for the lower limit. If negative, press:

Shift
+/-

(See step 5 on use of +/- key).

9 Press: Shift
QD%

10 If further categories are required, repeat steps 4-9 using bin 2, bin 3 etc as needed, setting the appropriate pair of limits for each bin.

11 For resistors, the setting-up is completed when the second limit has been entered for the last bin required : go to step 13. For inductors and capacitors, press:

Bin no
0
Limit (Hi)

The display will initially show bin0H and will then either go blank or show any existing limit. Then carry out 12a or 12b, as appropriate.

12a For inductors, key in the minimum numerical value acceptable for Q. Up to five digits and a decimal point may be used. If no Q value is known, either measure the Q (see page 18) and use a figure smaller than the one obtained, or key in 1. Store by pressing Shift and QD%.

12b For capacitors, key in the maximum numerical value acceptable for the dissipation factor D. Up to five digits and a decimal point may be used. If no D value is known, either measure it (see page 22) and use a figure larger than the one obtained, or key in 1. Store by pressing Shift and QD%. If bias is required, select Bias <u>before</u> selecting Sort (step 13).

13 Press: Shift
Sort

Connecting components of the type for which % limits have been set (i.e. either resistors, or inductors, or capacitors) will produce a display of the Bin no in which the value lies.

Example - Resistors (by % deviation)

From a quantity of 27k (±10%) resistors, it is required to select components whose value lies within ±3% of 28k.

1 Select: % (on the %/Abs white key)
Press: Shift
Nom

The display will show the nominal value already existing in memory.

2 Key in 28

3 Press: Shift
kΩ

4 Press: Bin no
1
Limit (Hi)

The display will initially show bin1H and will then either go blank or show any existing limit.

5 Key in 3

6 Press: Shift
QD%

7 Press: Shift
Limit (Lo)

The display will initially show bin1L and will then either go blank or show any existing limit.

8 Key in 3

9 Press: Shift
+/-

Check that the minus sign is displayed.

10 Press: Shift
QD%

11 Press: Shift
Sort

Connect each resistor in turn. Those whose value is within ±3% of 28k will be classified as Bin 1 : those outside these limits will be classified as Bin 9 (unless any other bin has existing limits wider than ±3%).

Example - Capacitors (by % deviation)

From a quantity of 680pF (±10%) capacitors, it is required to select components whose value lies within ±1% of 700pF, and those between +1% and +2% of 700pF. Those with a dissipation factor (D) exceeding 0.005 are to be rejected.

1 Select: % (on the %/Abs white key)
Press: Shift
Nom

The display will show any nominal value already existing in memory.

2 Key in 700

3 Press: Shift
pF

4 Press: Bin no
1
Limit (Hi)

The display will initially show bin1H and will then either go blank or show any existing limit.

5 Key in 1

6 Press: Shift
QD%

7 Press: Shift
Limit (Lo)

The display will initially show bin1L and will then either go blank or show any existing limit.

8 Key in 1

9 Press: Shift
+/-

Check that minus sign is displayed.

10 Press: Shift
QD%

11 Press: Bin no
2
Limit (Hi)

(Display as in step 4, but bin2H).

12 Key in 2

13 Press: Shift
QD%

14 Press: Shift
Limit (Lo)

(Display as in step 7, but bin2L).

15 Key in 1

16 Press: Shift
QD%

17 Press: Bin no
0
Limit (Hi)

(Display as in step 4, but bin0H).

18 Key in ·005

19 Press: Shift
QD%

(If the capacitors were such as to need bias, the Bias would be selected at this point).

20 Press: Shift
Sort

Connecting each capacitor in turn will produce displays of:

a) Bin 0 (capacitors with loss factor, D, exceeding 0.005), or

b) Bin 1 (capacitors within ±1% of 700pF), or

c) Bin 2 (capacitors between +1% and +2% of 700pF), or

d) Bin 9 (capacitors lying outside 700pF -1% +2% - assuming no other bin has existing limits wider than -1% and +2%).

Sorting by Absolute value

1 Press: Value
Select: Abs (on the %/Abs white key).

2 Press: Bin no
1
Limit (Hi)

The display will initially show bin1H and will then either go blank* or show any existing limit.

3 Key in up to five digits and (if needed) a decimal point for the first high limit required.

4 Press: Shift
units required (kΩ , mH, μF etc).

5 Press: Shift
Limit (Lo)

The display will initially show bin1L and will then either go blank or show any existing limit.

6 Key in up to five digits and (if needed) a decimal point for the first low limit required.

7 Press: Shift
units required

* Since, as stated earlier, there is always at least one limit stored in bin 1 for the Abs mode, a blank display at this stage indicates the presence of a bin 1Lo value in memory. Where the units keyed in at step 4 are of a different type, the bin 1 Lo value will be cleared. If, however, the units are of the same type, and the value keyed in for bin 1Hi is smaller than the existing bin 1Lo value, the 4210 will initially display

no.bin
SPACE

and the display will then show the offending digits but no units LED. In this situation, use Shift and Limit (Lo) and enter the new low limit before entering the high limit. A similar procedure applies if the sequence Hi/Lo is attempted in the reverse order.

8 If further categories are required, using different Hi and/or Lo limits, repeat steps 2-7 inclusive, substituting Bin 2, Bin 3, etc as required and the appropriate maximum (Hi) and minimum (Lo) values for each bin. Both limits must be entered for any bin selected.

9 For resistors, the setting-up is completed when the second limit has been entered for the last bin required : go to step 11. For inductors and capacitors, press:

Bin no
0
Limit (Hi)

The display will initially show bin 0H and will then either go blank or show any existing limit. Then carry out 10a or 10b, as appropriate.

10a For inductors, key in the minimum numerical value acceptable for Q. Up to five digits and a decimal point may be used. If no Q value is known, either measure the Q (see page 18) and use a figure smaller than the one obtained, or key in 1. Store by pressing Shift and QD%.

10b For capacitors, key in the maximum numerical value acceptable for the dissipation factor D. Up to five digits and a decimal point may be used. If no D value is known, either measure it (page 22) and use a figure larger than the one obtained, or key in 1. Store by pressing Shift and QD%.

11 Press: Shift
Sort

Connecting components of the type for which Absolute limits have been set (i.e. either resistors, or inductors, or capacitors) will produce a display of the Bin no in which the value lies.

Example - Inductors (by Abs value)

From a quantity of "1mH" inductors it is required to select those whose value lies between 800μH and 1.4mH. Components with a Q value of less than 5 are to be rejected.

1 Select: Abs (on the %/Abs white key)

2 Press: Bin no
1
Limit (Hi)

The display* will show any limit already existing in memory.

3 Key in 1 · 4

4 Press: Shift
mH

5 Press: Shift
Limit (Lo)

6 Key in 8 0 0

7 Press: Shift
μH

8 Press: Bin no
0
Limit (Hi)

9 Key in 5

continued.......

* See Footnote on page 40

10 Press: Shift
QD%

11 Press: Shift
Sort

Connecting each inductor in turn will produce displays of:

a) Bin 0 (inductors with Q less than 5), or

b) Bin 1 (inductors between 800μH and 1.4mH), or

c) Bin 9 (inductors less than 800μH or exceeding 1.4mH - unless existing limits for any bins 2-8 cover values within these two bands).

Revision and correction of entries

This section relates to the amendment of numerical values, or units, and to the procedures for recovering the situation when an incorrect key-stroke has been made and has been accepted by the instrument. (An unacceptable command produces an error message - see next section). Also described are situations where the instrument shows no response to a command.

If Auto cannot be selected, check that Abs is selected on the %/Abs Key.

If %/Abs cannot be selected as required, press Value. (The %/Abs change-over is not available in the Sort mode). Then select %/Abs as required.

If an error is made in keying-in a limit, simply re-press Limit(Hi) - or Shift, Limit(Lo) - and key the correct numbers.

To change a limit already stored (i.e. after the units have been entered), first press Bin no, and the number of the bin required, and then set the new Limit(s) as above.

If Shift is pressed in error, press Auto to 'use up' the Shift action and then press the required white or black function key.

If the units selected are of the wrong type (e.g. μH when setting-up capacitor sorting), the result will be an error message (details in the next section). If, however, they are of the correct type but not the intended magnitude (e.g. if mF is entered when μF was intended) it is necessary to re-select the appropriate Limit (Hi, or Shift,Lo), re-enter the number and then press Shift and the correct units.

To discontinue use of a bin, without having to re-set the limits for all other bins, the easiest procedure is to enter Hi and Lo limits which lie within the limits set for any lower-numbered bin. Do not attempt to set Hi and Lo at the same value (this would produce an error message).

<u>Displayed messages</u>

Message	Meaning
Auto.r	Auto-ranging in progress. The 4210 selects automatically the range for the best available resolution.
bin "n"	During Limit setting, confirms the bin number selected by the operator. During sorting, shows the bin number into which the 4210 has sorted the component.
bin "n"H bin "n"L	The higher limit of bin "n" " lower " " " "
cLEAr AbS	<u>All</u> bin memories for absolute mode have been cleared, <u>except</u> the bin 1 limit just entered.
cLEAr PErc	<u>All</u> bin memories for percentage deviation have been cleared, <u>except</u> the nominal just entered.
c not l c not r	Limit required is capacitance, not inductance. " " " " " resistance.
Error	The last key instruction did not make sense and so has been ignored.
Hold.r	Overload when range Hold has been selected.
l not c l not r	Limit required is inductance, not capacitance " " " " " resistance
nEEd bin "n"H(orL)	Bin "n" has only one limit and the limit requested must be entered before sorting can occur.

no.bin SPACE	Attempted limit entry is illogical (e.g. Lo value proposed exceeds existing Hi value). Also shown if same value attempted for Hi and Lo. Use correct units or recall appropriate Limit (Hi or Lo) and key in correct value and units.
not PErc	Displayed when in Abs mode and operator wrongly attempts to obtain nominal - which is available only in percentage mode. The offending key-stroke is ignored.
O.C.	Open-circuit trim in progress.
o.d.r	Outside % display range. Magnitude > 99.99%.
o.r.	Outside range. Beyond the computation capability of the instrument (e.g. if L or R is selected, in the Parallel mode, at 1kHz, with no connection to the measurement pillars).
r not c r not l	Limit required is resistance, not capacitance. " " " " " inductance.
S.C.	Short-circuit trim in progress.
Sort	Sorting into bins is about to be started.
StorE	The value displayed after this has now been stored in the memory for the limit currently being dealt with.
t.FAIL	Trim not possible : impedance at measurement point too large for Trim s/c or too small for Trim o/c. Check connections.

HANDLER INTERFACE

INTRODUCTION

The GPIB (IEEE-488) interface port can be used to interface to component handlers, making use of the binning features of the 4210 and, when required, the high speed operation (page 48). The Handler Interface enables the 4210 to measure a component, sort it into one of eight bins according to the measurement results, and then provide the signals for external bin handling hardware to physically 'bin' the component. The Interface supports up to eight external bins and provision is made for the external bin handler hardware to trigger a measurement directly.

Note that in this text "low" refers to a TTL logic level between 0 and 0.8V and "high" is a TTL level between 2.4 and 5V.

All 4210 LCR meters have the hardware to support the Handler : the software enhancement was introduced with revision 2.

OPERATION

1 Select Sort mode

2 Select single-shot mode (LED on Measure/Continuous key extinguished - see page 26).

3 Enter GPIB address 99. This brings the Handler into operation and inhibits normal operation of the GPIB facility.

INTERFACE DETAILS

The functions of the Interface lines are defined in the following table.

Pin No.	Name	Function
8	$\overline{\text{TRIGGER}}$	External trigger input. Pulling this line low while $\overline{\text{BDA}}$ is low and $\overline{\text{BUSY}}$ is high will cause a measurement to be started.
10	$\overline{\text{BUSY}}$	Output signal. When low, the component at the measurement terminals is being measured and should not be removed.
5	$\overline{\text{BDA}}$	Bin Data Available. Going low indicates the completion of a measurement cycle and that the data on the $\overline{\text{BIN}}$ lines is valid.
1	$\overline{\text{BIN 0}}$	Going low indicates a result in bin 0
2	$\overline{\text{BIN 1}}$	" " " " " " " 1
3	$\overline{\text{BIN 2}}$	" " " " " " " 2
4	$\overline{\text{BIN 3}}$	" " " " " " " 3
13	$\overline{\text{BIN 4}}$	" " " " " " " 4
14	$\overline{\text{BIN 5}}$	" " " " " " " 5
15	$\overline{\text{BIN 6}}$	" " " " " " " 6
16	$\overline{\text{BIN 7}}$	Going low indicates a result in either bin 7, 8 or 9.
24	GND	Electrical Ground.

All output pins are open collector types capable of driving relays for isolation purposes.

The two output signal lines, $\overline{\text{BUSY}}$ and $\overline{\text{BDA}}$ (Bin Data Available), jointly define one of four different states :

1 Null

2 Ready for Trigger

3 Busy

4 Not Busy

1 Null State

The Null state is defined as:

$\overline{BUSY}$ low (ie machine is busy)

$\overline{BDA}$ high (ie no data available)

All $\overline{BIN}$ lines high (ie no bins selected)

This state is adopted when the machine is unable to perform binning due to one of the following reasons:

i) The machine is not in SORT mode.

ii) The machine is not in Single shot mode.

iii) The machine is Trimming.

When this state is detected by external hardware it must be assumed that the current signals on the $\overline{BIN}$ lines are invalid and should be ignored and also that the machine is not ready for an external $\overline{TRIGGER}$ signal.

When the above conditions have cleared, the next state will be entered.

2 Ready for Trigger

In this state:

$\overline{BUSY}$ is high (ie not busy)

$\overline{BDA}$ is low (ie bin data is valid)

All $\overline{BIN}$ lines will be unchanged. If the previous state was a null then all $\overline{BIN}$ lines will be high, meaning no bin selected, although $\overline{BDA}$ suggests that valid bin data is present.

This state indicates that the machine is awaiting a trigger, whether from the front panel push button, or from the $\overline{TRIGGER}$ line.

When the machine receives a trigger it will respond by entering the

3 Busy

In this state:

$\overline{\text{BUSY}}$	is low	(ie the machine is busy)
$\overline{\text{BDA}}$	is low	(ie bin data is valid)

All $\overline{\text{BIN}}$ lines are unchanged.

The $\overline{\text{BUSY}}$ line goes low to acknowledge the trigger and also to indicate that the component between its terminals is in the process of being measured and should not be removed until the $\overline{\text{BUSY}}$ line goes high again, when the Meter enters the next state.

4 Not Busy

In this state:

$\overline{\text{BUSY}}$	is high	(ie the machine is not busy)
$\overline{\text{BDA}}$	is high	(ie bin data is not valid)
All $\overline{\text{BIN}}$ lines high		(ie no bins selected)

In this state the machine has finished with the component under test, which may be removed and replaced with the next component. However, the machine has still to sort the component into the relevant bin and, as the current bin is being updated, all the $\overline{\text{BIN}}$ lines are made invalid.

If this sequence of 4 states has been completed without interruption, the 4210 will re-enter the "Ready for Trigger" state, waiting to measure the next component. This sequence will only be interrupted if a key on the front panel of the Meter is pressed, when the machine will enter the Null state.

Similarly, after the conditions leading to the null state have been rectified, another measurement may be attempted. For this to be transparent to the bin handler hardware it is recommended that it responds to the negative-going edges of the $\overline{\text{BDA}}$ line and the relevant $\overline{\text{BIN}}$ line, which will occur only when a component has been successfully measured and sorted.

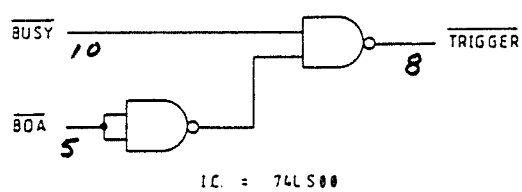
Note that if the component is removed after the $\overline{\text{BUSY}}$ line goes true and is replaced by another, then the second component will be measured and the first result will be lost. For reliable results it is recommended that components are removed only when the machine has completely finished sorting and has re-entered the "Ready for Trigger" state. Removing the component upon $\overline{\text{BUSY}}$ going high should only be used for maximum speed, when the bin handling mechanism should be disabled before the operation of the Meter is disturbed.

Note that only 8 $\overline{\text{BIN}}$ lines are available, although 10 are provided in the Software. Results indicated in bins 7, 8 and 9 will all make the $\overline{\text{BIN 7}}$ line go low, as will an error report (eg Hold.r).

EXTERNAL TRIGGER

Measurements may be triggered by pulling the $\overline{\text{TRIGGER}}$ line low but ONLY while the machine is in the "Ready for Trigger" state. If the $\overline{\text{TRIGGER}}$ line is pulled permanently low, the $\overline{\text{BDA}}$ line will also be pulled low, impeding its operation.

If it is desired to make continuous measurements, the completion of one triggering the next, then a circuit such as that given below should be used.



Note that the $\overline{\text{TRIGGER}}$ line is scanned only while in the "Ready for Trigger" state and, unlike the front panel keys pulling it low at any other time, will not abort a measurement and re-start another.

OUTPUT DRIVE LEVELS

Low state:	<0.5V	at	48mA			
High state:	$\overline{\text{BIN 0}}$	to	$\overline{\text{BIN 7}}$	>2.4V	at	-5.2mA.

SERIES/PARALLEL EQUIVALENT CIRCUITS

At a given frequency, a two-terminal R,C,L network can be represented in fully equivalent series or parallel circuits. The 4210 determines automatically which form is the more generally useful (series for impedances below 1000 ohms, parallel above 1000 ohms). However, the operator can always select the alternative representation simply by pressing Shift and ser or par. It is worth noting that, for a relatively pure component, the major term will remain substantially the same in series or parallel representation. A small minor term in a series circuit is equivalent to a large term in the parallel equivalent, and vice versa.

The two forms of circuit are shown below.

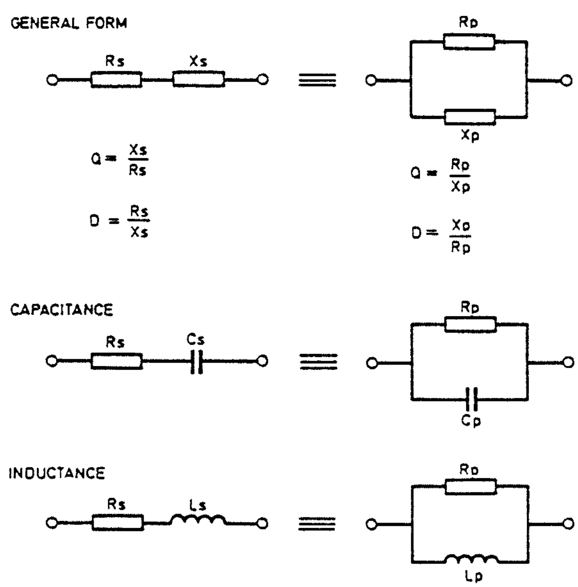


Fig. 9 Series/Parallel Equivalent Circuits

The computations made by the 4210 in converting from one form of representation to the other are:

$$Rp = Rs(1 + Q^2) \qquad Rs = \frac{Rp}{1 + Q^2}$$

$$Cp = \frac{Cs}{1 + D^2} \qquad Cs = Cp(1 + D^2)$$

$$Lp = Ls(1 + 1/Q^2) \qquad Ls = \frac{Lp}{1 + 1/Q^2}$$

It must be remembered that series/parallel equivalents obtained at one frequency are NOT applicable at any other frequency.

HIGH SPEED OPERATION

A fast mode enables the 4210 to achieve a measurement cycle in 200-350ms (dependent upon range) at 1kHz and at 10kHz with a basic accuracy of 0.5%.

SELECTION

1 Press: Shift
Q/D

2 Utilising GPIB Interface (address lower than 30 selected), use GPIB command UNCAL

DESELECTION

1 Press: Shift
Q/D

2 Utilising GPIB Interface, use GPIB command CAL

GENERAL PURPOSE INTERFACE BUS (GPIB)

IEEE Std 488-1978

The 4210 has a GPIB to the IEEE Std 488-1978, operating as a talker/listener. This means that it can output data onto the common bus, and can also be fully controlled from the bus. Every keypad facility (except Continuous) is available on the GPIB.

To permit simultaneous parallel operation of several devices on the bus, fairly complex device addressing and hand-shaking routines are necessary. These are fully defined by the IEEE Standard and a thorough understanding of them is necessary if the 4210 is to be successfully incorporated into a system.

Addresses Ø to 30 inclusive are for the full remote control mode. From 31 to 98 cover the data output only mode. Address 99 is the bin handler interface. To change address, press Shift followed by G.P.I.B. The current address will then be displayed. Use the keypad to over-write this with the new address required, which will be retained until a further change is made. After the keying, the instrument will shortly revert to the normal mode but it can be set to this at once, if required, by pressing the Value key.

On some earlier models of the 4210, the keypad does not show two of the alternative functions which appear on later models:

G.P.I.B	(below '100Hz')
Local	(below 'Auto)

These instruments, however, do have the appropriate circuitry to provide these facilities.

COMMAND and DATA FORMATS

The GPIB conforms to IEEE Std 488-1978 in the following categories of allowable sub-functions:

SH1 Source Handshake - complete capability
AH1 Acceptor Handshake - complete capability
T5 Basic Talker - Serial Poll, Talk Only, Unaddressed if MLA

TEØ	Extended Talker - no capability
L4	Basic Listener - no Listen Only, Unaddressed if MTA
LEØ	Extended Listener - no capability
SR1	Service Request
RL1	Remote/Local Function - complete capability
PPØ	Parallel Poll - no capability
DC1	Device Clear - complete capability
DT1	Device Trigger - complete capability
CØ	Controller - no capability

Command format

The command set (GPIB Appendix A) contains both full commands and minimum abbreviations. Between the minimum abbreviation and the delimiter, letters may be inserted as required to improve readability.

Some commands require a numeric value to follow (e.g. bin 1): if this is omitted a command error will be reported.

Commands will be implemented as they are received with the exception of Measure, which will be implemented on receipt of end of line.

If a command error or trim failure is encountered, the remainder of the string will be absorbed, but not implemented.

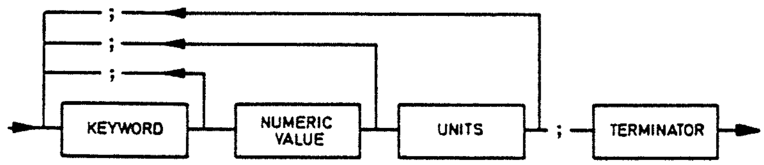
If more than one measure command is sent in a single string, only one measurement will be performed.

Upper and lower case letters will be interpreted as being the same.

Each command field must be terminated in a delimiter (;).
Each command string must be terminated in one of the following ways:

a) carriage return with EOI
b) carriage return and line feed
c) carriage return and line feed with EOI
d) space with EOI

The command syntax is:



Spaces will be ignored.

Numeric data and units must be entered in the same way as they would be from the keypad.

A typical command string might be

R;fupper;bin1;Hilim 1kohms;LO 900 oh;SORT;

terminated as in a) b) c) or d) shown on previous page.

Command Errors

Command errors will be encoded in the status byte (see GPIB - Appendix B). When a command error is detected, a service request will be generated and should be responded to in the same manner as the SRQ for data output.

Data Output

Output consists of measurement results.

Output comprises a single numerical value terminated by carriage return and line feed with EOI.

If an error has occurred during the execution of the last command string, the value 999.9E15 will be output.

Values will be in exponential format with no units, of variable length corresponding to the LED display.

On completion of a measurement, a value will be output if addressed to talk. Otherwise a service request will be generated.

If the instrument is sent to the listen state from another state, while the return of data is pending, the data will be discarded.

Restrictions

If any of the following IEEE commands are sent over the bus while the instrument is making a measurement, the measurement will be aborted, and restarted or not as indicated in the table below:

Command	Restart Y/N
MLA AND REN	N
SPE	Y
DCL	N (IF REMOTE), Y (IF LOCAL)
GET AND ADDRESSED	Y

Associated Local Controls

While in REMOTE, the AUTO button has the function GO TO LOCAL if local lockout has not been sent.

The key sequence Shift, 100Hz, will display the current address (in decimal) which may be modified by keying in two new digits. If the address keyed in is greater than 3Ø, the Talk Only mode will be selected as indicated by t.o. in the display window.

Talk Only mode

If a 'listen always' printer is connected to the GPIB port after this mode has been selected, the manual controls and display work in the same way as local control, with the result of each measurement being printed out as in the example:

105.07kohm 1kHz Par

105.10kohm 1kHz Par

105.10kohm 1kHz Par

105.07kohm 1kHz Par

105.10kohm 1kHz Par

105.13kohm100Hz Par

105.12kohm100Hz Par

105.12kohm100Hz Par

11.8pF 100Hz Par

13.3pF 100Hz Par

8.1pF 100Hz Par

13.7pF 100Hz Par

Programming

When using the 4210 on the GPIB, it is necessary to take some basic precautions when the command string to the 4210 contains a MEasure command. Because this command takes a period to complete its action on the equipment, it is vital that some delay is allowed by the controller before gaining access to the measured value.

Assuming the controller has a SERVICE REQUEST capability then, after requesting a MEasure, await a SERVICE REQUEST, and then perform a SERIAL POLL to establish that the 4210 has completed the measurement successfully.

GPIB - Appendix C contains some sample programs for control of the 4210 from typical GPIB controllers.

GPIB - Appendix A

IEEE bus control codes

Minimum Abbreviation	Full Expression	Remarks
AB	Absolute	no toggle
AU	Auto	
BIA	Bias	
BIN	Bin no	
C	Capacitance	
CAL	Calibrated	
D	Dissipation factor	
FA	fast	Value not displayed
FU	f upper	10kHz or 10.2kHz
FL	f lower	100Hz or 120Hz
FM	f middle	1kHz or 1.02kHz
HI	Hi limit	
HO	Hold	
H	Henrys	
K	kohms	
L	L	inductance
LO	Lo limit	
ME	Measure	
MF	mFarads	milli Farads
MH	mHenrys	milli Henrys
MO	Mohms	Meg ohms
NO	Nominal	
NF	nFarads	nano Farads
OH	ohms	
O/	O/C trim	open circuit trim
PA	Parallel	
PF	pFarads	pico Farads
Q	Q value	
R	Resistance	
RA	range	= Shift, Hold

continued.........

Minimum Abbreviation	Full Expression	Remarks
SE	Series	
SL	Slow	Value displayed under remote control
SO	Sort	
S/	S/C trim	short circuit trim
T	Test	select 50Hz option
UF	uFarads	micro Farads
UH	uHenrys	micro Henrys
UNC	Uncalibrated	
V	Value	
%	%	no toggle

GPIB - Appendix B

Error reporting codes

Display	Error Code (Decimal)	Description
	0	no error :valid result
t.Fail	1	trim failure
Hold.r	2	out of range :range hold selected
o.r.	3	over range - value too big to be displayed
o.d.r	4	outside display range i.e value >99.9%
Error	10	keystroke out of context
xnoty	11	units mismatch; y is wrong, should be x
no.bin space	12	upper and lower limits transposed or coincident
bin0H	15	bin 0 entry missing
bin1L	16	bin 1 Lo entry missing
bin1H	16	bin 1 Hi entry missing
bin2L	17	bin 2 Lo entry missing
bin2H	17	bin 2 Hi entry missing

continued........

Display	Error Code (Decimal)	Description
bin3L	18	bin 3 Lo entry missing
bin3H	18	bin 3 Hi entry missing
bin4L	19	bin 4 Lo entry missing
bin4H	19	bin 4 Hi entry missing
bin5L	20	bin 5 Lo entry missing
bin5H	20	bin 5 Hi entry missing
bin6L	21	bin 6 Lo entry missing
bin6H	21	bin 6 Hi entry missing
bin7L	22	bin 7 Lo entry missing
bin7H	22	bin 7 Hi entry missing
bin8L	23	bin 8 Lo entry missing
bin8H	23	bin 8 Hi entry missing
not PErc	24	the Nominal key has been pressed while in Absolute mode
	30	IEEE command does not exist

GPIB - Appendix C

Sample programs for control of 4210 from typical IEEE controllers

Program 1

```
5 REM CONTROL OF LCR METER 4210 FROM COMMODORE 8000
10 OPEN 1,10 :REM METER AT ADDRESS 10
15 A=PEEK(59426):REM RESET SRQ INPUT
20 PRINT#1, "R;FLOW;%;NOMINAL 150 OHMS;MEASURE;"
25 GOSUB500
30 GOSUB 100:REM WAIT FOR SRQ AND GET STATUS IN S
40 PRINT#1, "ME;"
45 GOSUB500
50 GOSUB 100
60 PRINT "MEASURED VALUE=";V;"%"
70 CLOSE1:END
100 A=PEEK(59427):B=A AND 128
110 IF B=0 GOTO 100:REM LOOP TILL BIT 7 HIGH
120 A=PEEK(59426):REM RESET SRQ INPUT
130 REM PERFORM SERIAL POLL OF DEVICE 10
140 Z=24:GOSUB 700:REM SERIAL POLL ENABLE
150 GET#1,S$:REM GET STATUS BYTE
155 GOSUB500
160 Z=25:GOSUB 700:REM SERIAL POLL DISABLE
165 INPUT#1,V :REM GET MEASURED VALUE
170 GOSUB500
171 GET#1,D$:REM THROW AWAY LINE FEED
175 GOSUB500
180 S=ASC(S$)AND (NOT 64):REM MASK SRQ BIT
190 IF S=0 THEN RETURN
200 PRINT "FAIL AT ERROR NO.";S
210 CLOSE1:END
500 IF (ST)=0 THEN RETURN
510 PRINT "I/O STATUS NO. ";(ST)
520 RETURN
700 GOSUB 800:REM PET TALK HANDSHAKE
710 IF (PEEK(59456)AND 64)<>64 GOTO 710
715 REM WAIT FOR NRFD FALSE
720 POKE 59426,255-Z
725 REM INVERT DATA AND OUTPUT
730 POKE 59456, 251:REM SET ATN TRUE
740 POKE 59427, 52:REM SET DAV TRUE
750 IF (PEEK(59456)AND1)<>1GOTO 750
755 REM WAIT FOR NDAC TRUE
760 GOSUB800:RETURN
800 REM HOUSEKEEPING
805 POKE59427,60:REM SET DAV FALSE
810 POKE59456,255:REM SET ATN FALSE
820 POKE59426,255:REM SET DATA HIGH
830 POKE59425,60:REM SET NDAC HIGH
840 RETURN
```

Program 2

```
00000E
S5 OUT,P1,"CONTROL OF LCR METER 4210 FROM A8000",'OD','OA'
S10 IEEE CMD,IFC
S20 IEEE OUT,L10,"R;FLOW;%;NOMINAL 150 OHMS;MEASURE;",'OD'
S25 IEEE SRQ,T10,N3
S26 GOIF, F1,S30
S27 GOTO,S25
S30 IEEE IN,T10,N4
S40 SCOMP, N3(2),"@"
S50 GOIF,NOGO,S500
S60 IEEE OUT,L10,"MEASURE;",'OD'
S70 IEEE SRQ,T10,N3
S75 GOIF, F1,S80
S77 GOTO,S70
S80 IEEE IN,T10,N4
S90 SCOMP, N3(2),"@"
S95 GOIF,NOGO,S500
S100 SLET, M1= N4
S110 PRINT,W40,"MEASURED VALUE", M1,"%"
S115 GOTO,S10
S120 END
S500 SLET, N3= N3(2)
S510 SLET, N2="UNRECOGNISED ERROR ", N3
S520 SCOMP, N3,"A"
S530 GOIF,NOGO,S550
S540 SLET, N2="TRIM FAILURE"
S550 SCOMP, N3,"B"
S560 GOIF,NOGO,S580
S570 SLET, N2="OUT OF RANGE"
S580 SCOMP, N3,"C"
S590 GOIF,NOGO,S610
S600 SLET, N2="OVER RANGE"
S610 SCOMP, N3,"D"
S620 GOIF,NOGO,S640
S630 SLET, N2="VALUE<>100%"
S640 SCOMP, N3,"J"
S650 GOIF,NOGO,S670
S660 SLET, N2="COMMAND OUT OF CONTEXT"
S670 SCOMP, N3,"K"
S680 GOIF,NOGO,S700
S690 SLET, N2="BIN LIMITS TRANSPOSED"
S700 SCOMP, N3,"L"
S710 GOIF,NOGO,S740
S720 SLET, N2="BIN 0 ENTRY MISSING"
S740 SCOMP, N3,"M"
S750 GOIF,NOGO,S770
S760 SLET, N2="BIN 1 ENTRY MISSING"
S770 SCOMP, N3,"N"
S780 GOIF,NOGO,S800
S790 SLET, N2="BIN 2 ENTRY MISSING"
S800 SCOMP, N3,"O"
S810 GOIF,NOGO,S830
S820 SLET, N2="BIN 3 ENTRY MISSING"
S830 SCOMP, N3,"P"
S840 GOIF,NOGO,S860
```

continued.......

Program 2 (continued)

```
S850 SLET, N2="BIN 4 ENTRY MISSING"
S860 SCOMP, N3,"Q"
S870 GOIF,NOGO,S890
S880 SLET, N2="BIN 5 ENTRY MISSING"
S890 SCOMP, N3,"R"
S900 GOIF,NOGO,S920
S910 SLET, N2="BIN 6 ENTRY MISSING"
S920 SCOMP, N3,"S"
S930 GOIF,NOGO,S950
S940 SLET, N2="BIN 7 ENTRY MISSING"
S950 SCOMP, N3,"T"
S960 GOIF,NOGO,S980
S970 SLET, N2="BIN 8 ENTRY MISSING"
S980 SCOMP, N3,"Λ"
S990 GOIF,NOGO,S2000
S1000 SLET, N2="UNRECOGNISED COMMAND"
S2000 PRINT,W10,"ERROR"
S2010 PRINT,W40, N2
S2020 END
```

Program 3

```
100 REM Example program to control LCR meter 4210 from Tektronix 4051
105 REM
110 REM LCR meter at device 10 on IEEE 488 bus
120 INIT
130 REM change input delimiter to cr/lf
140 PRINT @37,0:10,255,128
150 ON SRQ THEN 240
160 REM Set up measuring conditions
170 PRINT @10:"r;flow;%;nominal 150 ohms;"
180 REM Make measurement
190 PRINT @10: "measure;"
200 REM Wait for measurement to finish, when SRQ will be generated
210 WAIT
220 REM program complete
230 END
240 REM handle SRQ
250 POLL A,B ;10
260 INPUT @10:X
270 REM remove SRQ bit from status byte, saved in B
280 B=B-64
290 REM test for an error code
300 IF B=0 THEN 330
310 PRINT "Failed at error no.";B
320 RETURN
330 REM display answer
340 PRINT "Measured value";X;"%"
350 RETURN
```

SYSTEM DESCRIPTION

MICROPROCESSOR CONTROL

All functions of the system are under the direct control of a microprocessor. Each automatic cycle of operations includes an interrogation of the keypad selections - the keys do not operate directly on the measurement circuits. The MPU then controls these circuits to obtain comparative voltages for the Unknown and Standard impedances at the selected frequency. By resolving these voltages into orthogonal components, and subsequent computation, the selected type of readout information is used to update the LED display. The computation can derive the L, C or R value of equivalent series or parallel circuits, or the ratios Q or D. Ranging is a branch from the normal measure cycle. The full sequence of operations controlled by the microprocessor is:

1 Read keypad selections

2 Select frequency

3 Select signal to be measured (Es or Eu)

4 Select measure gain

5 Select appropriate PSD reference phase

6 Control dual slope A - D converter and store results

7 Repeat steps 3 - 6

8 Apply trim corrections

9 Calculate required parameter

10 Update display

BASIC MEASUREMENT

Refer to Fig. 10. The guard amplifier produces a feedback current through the Standard resistor, Rs, exactly matching the current through the component under test, Zu. A single measurement channel

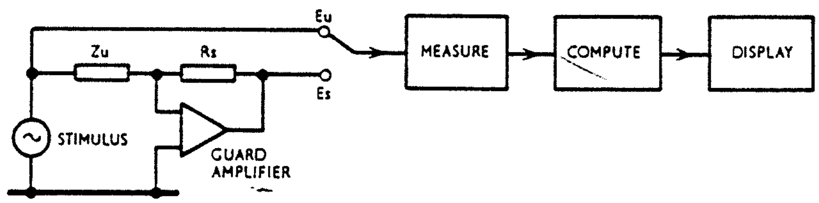


Fig. 10 Basic Measurement

is switched electronically to measure the corresponding two voltages produced, Es and Eu. Resolution of these into in-phase and quadrature components, and subsequent computations, provides the required information for the display.

OVERALL SYSTEM

A block diagram of the complete system (excluding power supplies) is shown in Fig. 11, the digital circuit diagram in Fig. 21, and the analog circuit diagram in Fig 22. On Fig. 11, the microprocessor is shown at the right-hand end of the 8-bit data bus. Near to it is the 16.32 MHz square-wave source IC1, from which all clock and measure frequencies are derived. A square-wave at the selected test frequency is produced by the final divider, IC112 & IC115, and then passed through the two active filter stages of IC128,129 and IC130,131. The resulting sinusoidal stimulus of 250mV rms is applied via the source resistor of 100Ω to the unknown, Zu.

The current through the unknown is converted by the virtual ground amplifier IC132 to a voltage across the standard 1kΩ resistor. The voltages across the unknown and standard, Eu and Es, are then extracted by differential amplifiers IC133-IC135. These two voltages are measured sequentially by the phase-sensitive analog/digital converter, IC143-IC146.

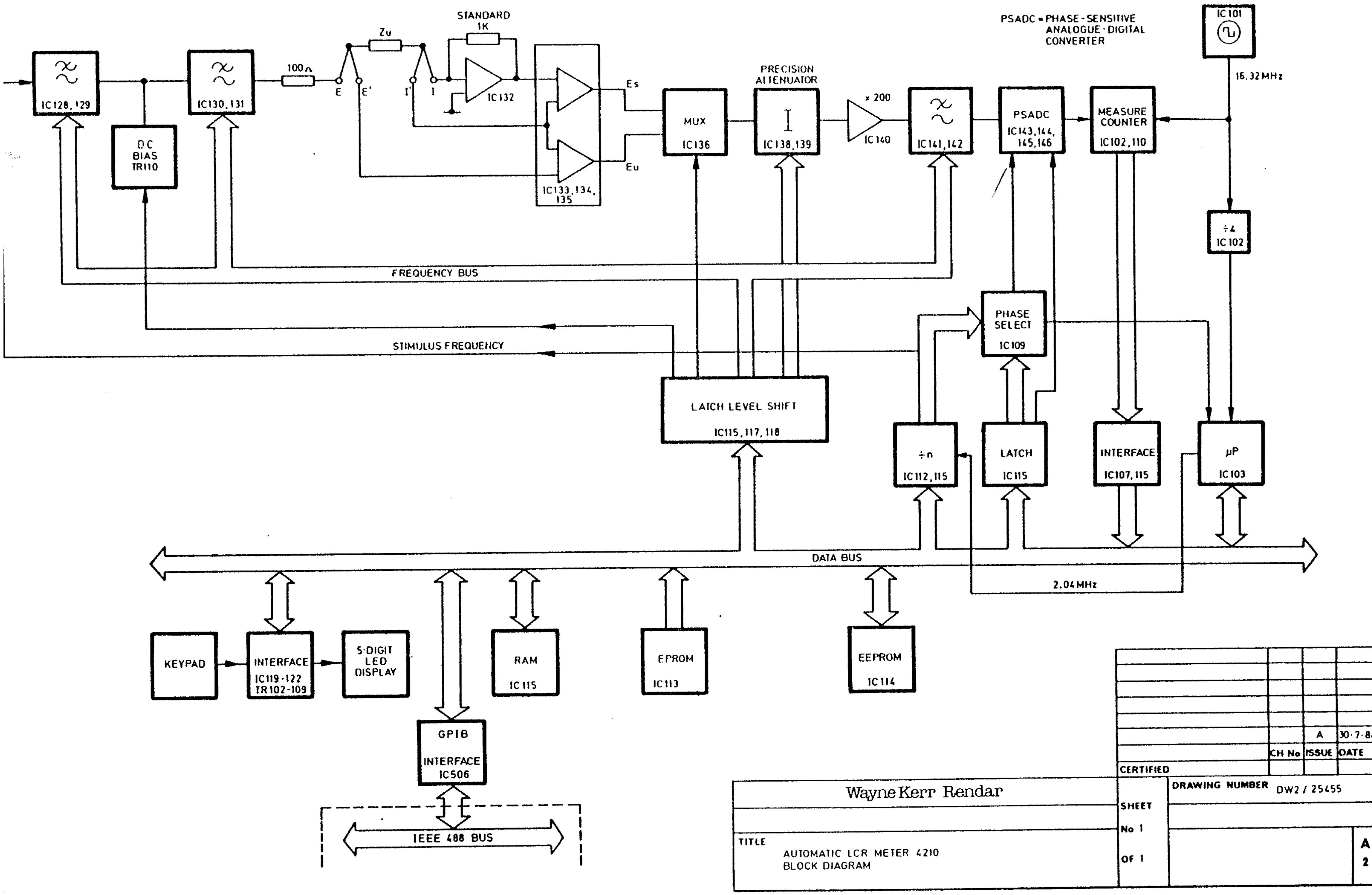


Fig. 11 Block Diagram

To achieve the specified impedance coverage, ranging is used. The Impedance Chart (Fig. 7) shows the coverage applicable at each of the three test frequencies.

Ranging is provided by the precision attenuator associated with IC138, 139. The phase information in Eu and Es is extracted by the phase-sensitive detector IC144. By multiplying the unknown a.c. voltage with a square-wave which is coherent with the stimulus, an output proportional to the in-phase component of the unknown voltage is obtained. A total of four such measurements, for each of which the phase of the square-wave is advanced by 90°, resolves the unknown voltage into orthogonal components. Anti-phase components are added, consequently reducing noise.

The a.c. voltage from the phase-sensitive detector is integrated (on C145) for 20ms (in the 50Hz version) together with d.c. offset from IC143, which ensures that the final result is always of the same sign. The value of the voltage is obtained by timing the discharge of the capacitor with measure counter IC102,110.

Digital values produced by the measure counter are read by the microprocessor, IC103, and from these the unknown impedance is calculated. The value of the term requested is then sent to the display.

DIGITAL CIRCUITS (Fig. 21)

The 16.32 MHz clock signal from IC101 is divided by 4 in IC102 and by 2 in the microprocessor, IC103, to give 2.04MHz for the system at CLK OUT (pin 37). The microprocessor is reset at switch-on by TR501, D502, R503-506 - a circuit on the GPIB board which continuously monitors the +5V microprocessor supply and generates a 'reset' whenever the supply falls below a set threshold. R506 together with C101 on the main board provide a time delay on the reset pin upon power-up.

The operating program is stored in EPROM IC113. The EEPROM IC114 provides non-volatile storage of trimming data, binning limits and IEEE 488 device address

During writes to IC114, which take up to 10ms, the microprocessor waits in a polling loop.

At switch-on, the integrity of the data in IC114 is checked against a signature also stored in IC114. If an error is detected, the message rESEt is displayed while all data is reset to default values.

Decoding of the four highest addresses, to produce chip selects, is by IC104.

The memory map is:

0000	- 3FFF	Main software (IC113)
4000	- 40FF	Read/Write memory (IC115)
4100	- 4103	Timer/Counter, I/O (IC115)
5000	- 57FF	Non Volatile Memory (IC114)
6000		LSB Measure Counter (IC107)
7000	- 7001	Display/Keypad encoder (IC120)
8000	- 8007	GPIB Interface Adaptor

TIMER OUT on pin 6 of IC115 is programmed to produce four times the stimulus frequency :

400Hz	4000Hz	40.00kHz	(50Hz models)
480Hz	4080Hz	40.80kHz	(60Hz models)

Two sections of IC112 are interconnected to form a ring counter, the four outputs of which (pins 6,7,10,11) are at 1/4 the input frequency and in 90° phase increments. One of the phases always stimulates the measure chain through C171.

IC109 is programmed via IC115 (PC2, pin 39 and PC3, pin 1) to produce at pins 3 and 13 the four phases in sequence. Differential phase delays introduced by IC109 are removed by resynchronising with 4f in IC111 (pins 8-12).

The action of PC5 on IC115 (pin 5) going low allows PHB to change at measure frequency rate, which continues for the integrate period. This period is measured by the microprocessor which is interrupted once per cycle through its RST 7.5 input (pin 7).

At the end of the integrate period, PC5 (IC115 pin 5) will go high and PC4 (pin 2) will go low: this sets PHB high and enables the ripple-through measure counter (IC102, 110) with synchronisation provided by IC111 (pins 2-6).

When the voltage on C145 (Fig. 22) has been reduced to zero by the current flowing from R191, the output of comparator IC146a (COMP) will go low, inhibiting the clock from IC101 (Fig. 21) to the measure counter (IC102 pin 13).

The state of the counter may now be read by the microprocessor through tristate buffer IC107 and I/O port IC115 port A (pins 21-28). The last part of the measurement sequence is to reset the integrator via PHA, and the measure counter via PC4 and IC111, ready for the next conversion.

Other I/O lines on IC115 control the analog filters FA,FB ; the ratio-arm gain settings GA,GB ; the a.c. voltages to be measured Eu/$\overline{\text{Es}}$; and bias on/off $\overline{\text{BIAS}}$.

On IC115, PB7 (pin 36) is an input which, at switch-on, is read by the microprocessor to determine whether a 50Hz or 60Hz version is required.

Information to be displayed is sent to IC120. The five digits of the display and the status LEDs in the keypad form a matrix of 8 x 8 (see Figs. 19 and 18).

The digits of the matrix are scanned by IC120, producing a binary count at SLØ,SL1,SL2 which is decoded to 1 of 8 by IC119. Thus the anodes of each digit are driven for 1/8th of the time by TR102-TR109.

Synchronous with the selection of each set of anodes, the segments to be illuminated are selected by IC120 through IC121,122. Resistors R116 to R123 limit the current in the segments.

The 1 of 8 scan also scans the keypad matrix, key depression being determined by reading RLØ - RL7. IC20 debounces the switch operations which are notified to the microprocessor by asserting interrupt RST6.5 (pin 8).

ANALOG CIRCUITS (Fig. 22)

The square wave at measure frequency is level shifted and cleaned by IC127a and b. There then follow two identical stages of filtering (IC128/129 and IC130/131) with control lines FA,FB selecting the appropriate one of four frequency positions:

100Hz 120Hz 1kHz/1.02kHz 10kHz/10.2kHz

Bias voltage (for polarising capacitors) is injected at IC130 pin 3 when TR110 is turned on by $\overline{\text{BIAS}}$ going low. The bias voltage is derived from the +12V supply by potential divider R144/145.

Any excess positive voltage applied to the E terminal (by, for example, connection of pre-charged capacitors) is absorbed by R196 and C146 through D110. Any excess negative voltage is caught by D111.

E and I are the terminals carrying the drive signal to the unknown: E' and I' provide sense connections to complete the four-terminal arrangement.

Virtual earth amplifier IC132 via Standard resistor R159, feeds a current to the I terminal exactly cancelling the current at this terminal from the Unknown component.

Differential amplifiers IC134 and IC135 have (pin2) a common reference derived from the I' terminal. The non-inverting input to IC134, from the virtual ground amplifier, is a measure of the Standard voltage, Es. Input to IC135 is a measure of the Unknown voltage, Eu.

Es and Eu in sequence are passed to the measuring chain by Eu/$\overline{\text{Es}}$ controlling the multiplexer IC136.

IC137 is a buffer amplifier of unity gain.

R170,171, C131,132 perform some band-pass filtering.

Ratio arm gain selection is by IC138 and 139. Capacitor C134 provides phase adjustments at 10kHz and at gain x200. IC140 provides gain.

IC141,142 is a programmable filter to remove distortion. The short-term stability of D118 is used to provide a reference voltage for the analog to digital conversion. IC146b holds off the measure counter until ramp-down.

AUTORANGING

If a measurement is made on the wrong range, an overload of the A-D converter may occur. Under these conditions, the measure counter either will not start or it will overflow. The microprocessor will detect these conditions and select range 3 if range Hold is not selected. Whenever an overload occurs, the current measurement is aborted and a new one started. From the measurement on range 3, the best range is selected.

INTERRUPTS

Whenever a key is depressed, the microprocessor is interrupted and the current measurement is aborted. After implementing the key function, a new measurement is made (except during bin setting).

GPIB BOARD (Fig. 23)

This circuit interfaces between the IEEE 488 bus and the microprocessor bus, with IC506 handling the 488 bus protocol.

IC507 to 510 are tristateable drivers which convey signals between the IEEE 488 bus and the GPIA IC506.

During a read to or write from the GPIA, the register addresses RS0 to RS2 are demultiplexed from the address and data bus by the $\overline{\text{ALE}}$ strobe clocking the address latch IC505.

Reads to or writes from any locations other than the GPIA (i.e. CS7 high) cause Ø2 of the GPIA to follow the $\overline{\text{RD}}$ or $\overline{\text{WR}}$ through IC503.

When the microprocessor reads from or writes to the GPIA, a wait state is introduced by IC511, READY is set low for one cycle of CLOCK OUT, to allow adequate set up times before Ø2 going low strobes the data into GPIA during a write.

The GPIA is configured by software to produce an interrupt under certain 488 bus conditions. The interrupt is conveyed by IC504 to RST 5.5 on the microprocessor.

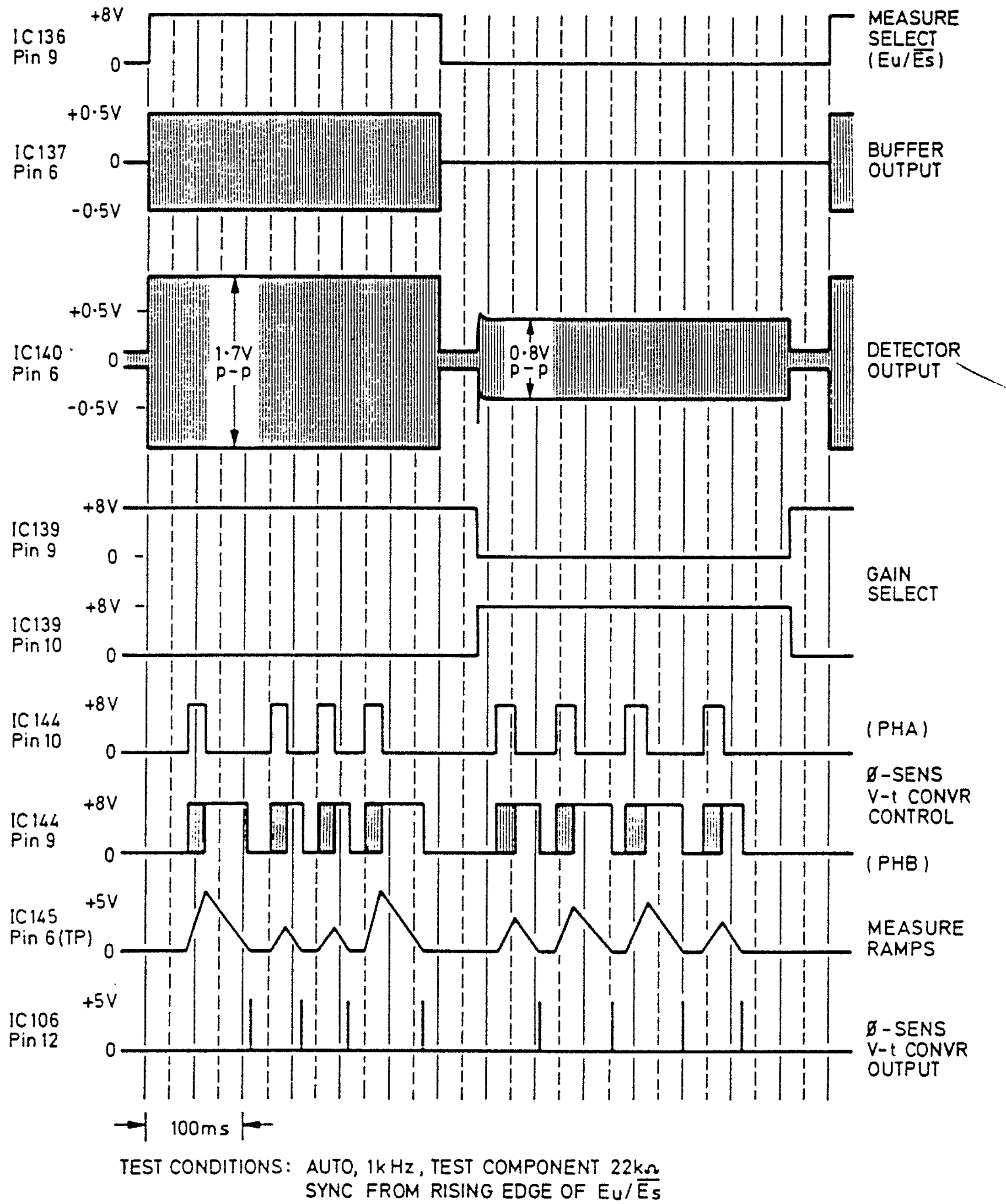


Fig. 12 Timing Waveforms

MAINTENANCE

TEST EQUIPMENT REQUIRED

1 Variac

2 AC/DC Voltmeter 0-20V dc, 0-1Vrms ac
Accuracy 0.1% at fsd
Resolution 0.1mV

3 Frequency counter to measure 1kHz to accuracy of 10 ppm

4 Oscilloscope or distortion meter

5 Capacitors:

1.50nF	±1%	Purity standard. Sealed polystyrene tan δ <0.0001 at 10kHz
150pF	±1%	C values known to 0.01% at all three frequencies (100/120Hz, 1kHz, 10kHz). tan δ values known to ±0.0004 at 10kHz and to ±0.0001 at 100Hz and 1kHz.
1.50nF	±1%	
15.0nF	±1%	

6 Resistors:

0.95Ω	±1%	Low inductance (<0.1μH) bulk film resistors, values known to ±0.01% at 1kHz
9.50Ω	±1%	
95.0Ω	±1%	
950.0Ω	±1%	
10.5kΩ	±1%	
3.1Ω	8W	(1 off)
120Ω	2W	(2 off)

7 Screening bars (see Fig. 13)

8 Power Supply extension lead (see Fig. 14)

9 Keypad extension lead (see Fig. 15)

10 Trimming tool

DISMANTLING

1 Disconnect the instrument from the a.c. supply.

2 Carefully invert the unit, allowing the connection pillars to rest on a soft pad, remove 9 screws from the base-plate and lift it away. Replace 1 screw to hold the earthing tag (near the mains transformer) in position.

3 Raise the main pcb slightly by its longer side and remove two screws to release the measurement connector fixture.

4 From the main pcb, remove the keypad interconnection cable and the power supply connector.

5 Fit the base-plate, the T-shaped and plain screening bars in position (see Figures 13 and 16). Connect plain bar to ground.

6 Use the extension leads (test items 8 and 9) to reconnect the power supply circuit and keypad to the pcb. With the main board beside the case, the connection to the GPIB board should remain in position. Also check that the LED Display board is properly connected to the main pcb.

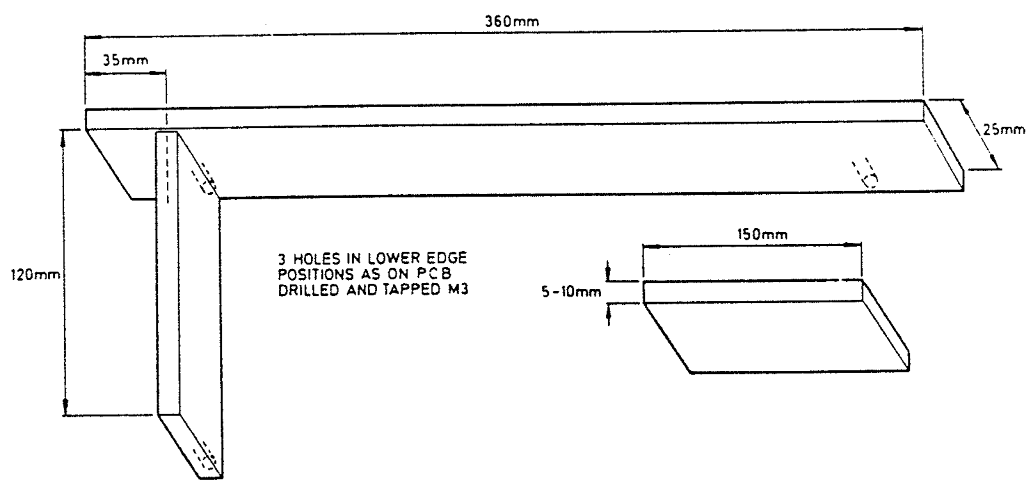


Fig. 13 (Above)
Screening bars

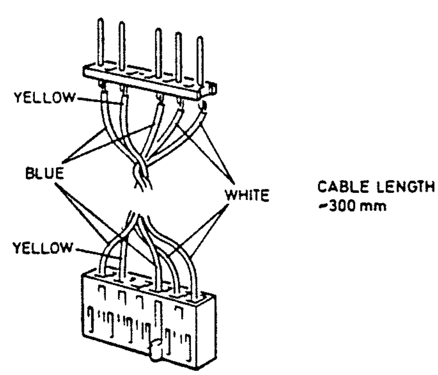


Fig. 14 (Right)
Power Supply
Extension Lead

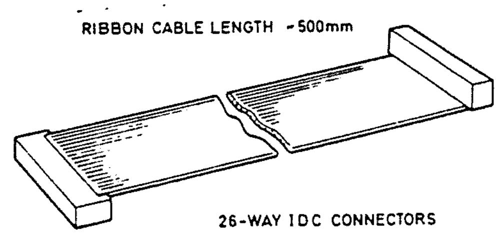


Fig. 15 Keypad
Extension Lead

POWER SUPPLY CHECKS

1 Remove the power supply isolation links from SK108 (see Fig.16).

2 From a convenient ground point on the pcb, connect resistors to SK108 as follows:

pin 2	3.1Ω	8W
pin 3	120 Ω	2W
pin 4	120 Ω	2W

3 Set the Variac as follows:

115-volt instruments:	103V
240-volt instruments:	216V

Connect the Variac to the 4210 and switch on.

4 With the voltmeter on its 0-20V d.c. range, voltages measured at SK108 should lie within these limits:

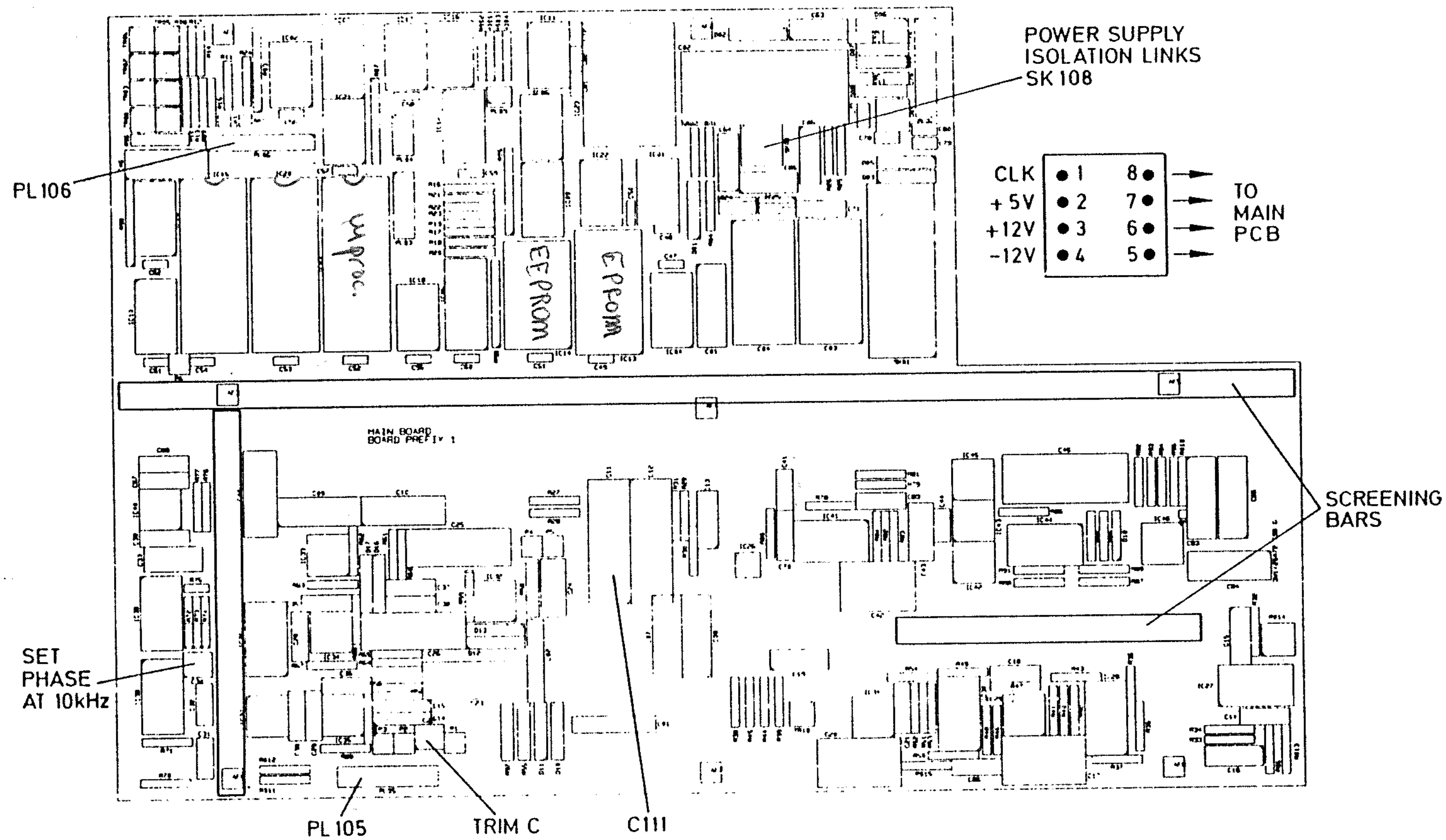
pin 2 :	+4.75	to	+5.25V
pin 3 :	+11.40	to	+12.60V
pin 4 :	-11.20	to	-12.90V

5 Switch off the a.c. supply, remove the three resistors from SK108 and re-fit the isolation links.

6 Switch on the supply. Change the voltmeter to its 0-1V a.c. range. At SK108, check that voltages do not exceed the values given:

pin 2 :	5.0mV	rms	max
pin 3 :	0.5mV	"	"
pin 4 :	0.5mV	"	"

7 Change the voltmeter to its 0-20V d.c. range and check that the voltage across C11 (annotated on Fig. 16) lies between 7.8V and 8.6V.



NOTE: COMPONENT REFERENCE NUMBERS ON PCB OMIT PREFIX '1'.

Fig. 16 Main PCB Layout

SOURCE SINE WAVE

1 Connect the voltmeter (0-1V a.c. range) to PL105 pins 3 and 1. Adjust R1014 for a reading of 250mV ±1mV.

2 Connect the oscilloscope (or distortion meter) to PL105:

Lo to pin 3
Hi to pin 1

Distortion on the sine wave should be less than 10%. Disconnect the oscilloscope.

MEASURE FREQUENCY

1 Check that the instrument is in the normal switch-on condition, i.e. 1kHz, Auto, pF, Parallel, with Measure/Continuous LED flashing, and all others extinguished.

2 Connect the frequency counter to PL105 (annotated in Fig.16):

Lo to pin 3
Hi to pin 1

The reading should be:

1kHz	±0.01%	(50Hz instruments)
1.02kHz	±0.01%	(60Hz instruments)

Disconnect the counter.

BIAS

1 With the voltmeter remaining on pins 3 and 1 of PL105, switch it to the 0-20V d.c. range. The d.c. voltage should be less than 20mV.

2 On the 4210 keypad, select C and Bias.

3 Check that the voltmeter now reads between 1.9 and 2.4V d.c. (PL105 pin 1 positive). Disconnect the voltmeter. Switch off and disconnect the Variac

RE-ASSEMBLING

1 Disconnect the a.c. supply, also the extension leads from the power supply circuit and the keypad.

2 Remove the screening bars and the screw holding an earthing tag to the case (near the power transformer). Separate the base-plate from the main pcb.

3 While lowering the board into position, check that the 5-digit LED Display board locates correctly in the slots, and remains properly connected to the pcb.

4 Re-make the connections to the power supply and keypad. Check that the connections to the GPIB board are made correctly.

5 Ensure that the earthing solder tag is in position, and re-fit the measurement connector fixture (2 screws).

6 Check that the base-plate is correctly orientated (the hole for C34 access towards the front) and re-fit all nine screws.

PERFORMANCE CHECKS

1 Connect the 4210 to the a.c. supply (240V or 115V, according to model) and observe the display at the moment of switch-on. It should show 4210.X, where X is a digit.

2 After the initial display, the only LEDs illuminated should be Auto, pF, 1kHz, Abs, Parallel, with Measure/Continuous flashing.

3 Select C and 10kHz. Connect the 1.5nF purity standard. The display should show between 1.4800nF and 1.5200nF.

4 Select D. Using the trimming tool, adjust C34 (accessible through a hole in the instrument base plate : see Fig. 16, "Set Phase at 10kHz" for location) for a reading of 0.0000 or 0.0001.

5 Select L and 100/120 Hz. Display should show:

-1689 ±20 (50Hz instruments)
-1172 ±20 (60Hz instruments)

6 Remove purity standard. Press Shift, Trim o/c, C and 100/120 Hz. Display should initially show O.C. and then between -2pF and +2pF.

7 Select 1kHz. Should show between -0.1pF and +0.1pF.

8 Select 10kHz. Should show between -0.01pF and +0.01pF.

9 Slide the two connection pillars together and connect a short-circuit (copper strip or stout wire : double-sided pcb is NOT suitable unless the two sides are connected together).

10 Press Shift, Trim s/c, R and 100/120Hz. Display should initially show S.C. and then between -0.001Ω and +0.001Ω .

11 Select L. Should show between -1μH and +1μH.

12 Select R and 1kHz. Should show between -0.001Ω and +0.001Ω .

13 Select L. Should show between -0.1μH and +0.1μH.

14 Select R and 10kHz. Should show between -0.001Ω and +0.001Ω .

15 Select L. Should show between -0.01μH and +0.01μH.

16 Remove the short-circuit and connect 0.95Ω. Select R and 100/120Hz. Press Shift, Hold, 1. (This pre-selects range 1). Should show 5 digits : known value ±20.

17 Select L. Should show between -2.6μH and +2.6μH.

18 Select R and 1kHz. Should show 4 digits : known value ±20.

19 Select L. Should show between -0.26μH and +0.26μH.

20 Select R and 10kHz. Should show 4 digits : known value ±20.

21 Select L. Should show between +0.119μH and +0.171μH.

22 Remove 0.95Ω, connect 9.5Ω. Select R and 100Hz. Should show 5 digits : known value ±11.

23 Select 1kHz. Should show 5 digits : known value ±11.

24 Select 10kHz. Should show 5 digits : known value ±11.

25 Press Shift, Hold, 2. (This pre-selects range 2). Select 100/120Hz. Should show 5 digits : known value ±11.

26 Select L. Should show between -17μH and +17μH.

27 Select R and 1kHz. Should show 4 digits : known value ±11.

28 Select L. Should show between -1.7μH and +1.7μH.

29 Select R and 10kHz. Should show 4 digits : known value ±11.

30 Select L. Should show between +0.03μH and +0.37μH.

31 Remove 9.5Ω , connect 95Ω . Select R and 100/120Hz. Should show 4 digits : known value ±11.

32 Select 1kHz. Should show 4 digits : known value ±11.

33 Select 10kHz. Should show 4 digits : known value ±11.

34 Press Shift, Hold, 3. (This pre-selects range 3). Select 100/120Hz. Should show 4 digits : known value ±11.

35 Select 1kHz. Should show 4 digits : known value ±11.

36 Select 10kHz. Should show 4 digits : known value ±11.

37 Remove 95Ω , connect 950Ω . Select 100/120Hz. Should show 4 digits : known value ±10.

38 Select 1kHz. Should show 4 digits : known value ±10.

39 Select 10kHz. Should show 4 digits : known value ±10.

40 Press Shift, Hold, 4. Select 100/120Hz. Should show 4 digits : known value ±10.

41 Select 1kHz. Should show 4 digits : known value ±10.

42 Select 10kHz. Should show 4 digits : known value ±10.

43 Remove 950Ω , connect 10.5kΩ. Select 100/120Hz. Should show 5 digits : known value ±11.

44 Select 1kHz, Should show 5 digits : known value ±11.

45 Select 10kHz. Should show 5 digits : known value ±11.

46 Press Shift, Hold, 5. Select 100/120Hz. Should show 5 digits : known value ±11.

47 Select 1kHz. Should show 5 digits : known value ±11.

48 Select 10kHz. Should show 5 digits : known value ±11.

49 Remove 10.5kΩ, connect 150pF. Select C. Press Shift, Hold, 6. Select 1kHz. Should show 5 digits : known value ±25.

50 Select D. Should show known D value ±0.001.

51 Select C and 10kHz. Should show 5 digits : known value ±16.

52 Press Shift, Hold, 5. Should show 5 digits : known value ±16.

53 Remove 150pF, connect 1.5nF. Press Shift, Hold, 6.

Select 100Hz. Should show 5 digits : known value ±35.

54 Select D. Should show known D value ±0.002.

55 Select C and 1kHz. Should show 5 digits : known value ±16.

56 Press Shift, Hold, 5. Should show 5 digits : known value ±16.

57 Remove 1.5nF, connect 15nF. Press Shift, Hold, 6.

Should show 5 digits : known value ±17.

58 Select D. Should show known D value ±0.001.

59 Select C. Press Shift, Hold, 5. Should show 5 digits : known value ±17.

60 Select D. Should show known D value ±0.001.

Performance checks cannot be specified for the GPIB as any malfunction may depend on the ancillary equipment or on some incompatibility between the 4210 and external items. It is likely that the nature of a mulfunction will indicate the area of a fault. The list (below) is provided to assist users in checking interconnecting cables.

Interface pin connections

Pin No.	Code	Function (active low)
1	D101	
2	D102	
3	D103	8 bit data bus
4	D104	
13	D105	Carries command messages from controller
14	D106	(ATN low) or output data from device (ATN high)
15	D107	
16	D108	
5	EOI	Indicates end of multiple byte data sequence
6	DAV	Data available and valid
7	NRFD	At least 1 listener 'not ready for data'
8	NDAC	At least 1 listener 'not done accepting data'
9	IFC	Clears interface system to known quiescent state
10	SRQ	Unaddressed device is requesting attention from controller
11	ATN	'Attention' Defines use of bus (see above)
17	REN	Sets any addressed device into 'remote' mode

CCMPONENTS LIST

RESISTORS

Ref	Value	Tol.(%)	Rating	Type	Supplier & Type No.
R101	1k	5		Film	Mullard SFR25
R102	10k	5		Film	Mullard SFR25
R103	2k2			SIL N/W	Hitech L109
R104	Not fitted				
R105	10k			SIL N/W	Hitech L109
R106	10M	10		Film	Mullard SFR25
R107	2k2			SIL N/W	Hitech L109
R108	390R	5		Film	Mullard SFR25
R109	390R	5		Film	Mullard SFR25
R110	390R	5		Film	Mullard SFR25
R111	390R	5		Film	Mullard SFR25
R112	390R	5		Film	Mullard SFR25
R113	390R	5		Film	Mullard SFR25
R114	390R	5		Film	Mullard SFR25
R115	390R	5		Film	Mullard SFR25
R116	47R	5		Film	Mullard SFR25
R117	47R	5		Film	Mullard SFR25
R118	47R	5		Film	Mullard SFR25
R119	47R	5		Film	Mullard SFR25
R120	47R	5		Film	Mullard SFR25
R121	47R	5		Film	Mullard SFR25
R122	47R	5		Film	Mullard SFR25
R123	47R	5		Film	Mullard SFR25
R124	10k	5		Film	Mullard SFR25
R125	1k3	1	100ppm	Metal Film	Allen Bradley FC55
R126	150R	1	100ppm	Metal Film	Allen Bradley FC55
R127	68R	5		Film	Mullard SFR25
R128	68R	5		Film	Mullard SFR25
R129	2k0	1	100ppm	Metal Film	Allen Bradley FC55
R130	1k0	1	100ppm	Metal Film	Allen Bradley FC55
R131	1k	5		Film	Mullard SFR25
R132	Not fitted				
R133	62k	1	100ppm	Metal Film	Allen Bradley FC55
R134	7k5	1	100ppm	Metal Film	Allen Bradley FC55
R135	665k	1	100ppm	Metal Film	Allen Bradley FC55
R136	549k	1	100ppm	Metal Film	Allen Bradley FC55
R137	60k4	1	100ppm	Metal Film	Allen Bradley FC55
R138	10k	5		Film	Mullard SFR25
R139	1k	5		Film	Mullard SFR25
R140	665k	1	100ppm	Metal Film	Allen Bradley FC55
R141	560k	1	100ppm	Metal Film	Allen Bradley FC55
R142	66k5	1	100ppm	Metal Film	Allen Bradley FC55
R143	6k65	1	100ppm	Metal Film	Allen Bradley FC55
R144	8k2	1	100ppm	Metal Film	Allen Bradley FC55
R145	2k0	1	100ppm	Metal Film	Allen Bradley FC55
R146	102k	1	100ppm	Metal Film	Allen Bradley FC55
R147	7k15	1	100ppm	Metal Film	Allen Bradley FC55
R148	665k	1	100ppm	Metal Film	Allen Bradley FC55
R149	549k	1	100ppm	Metal Film	Allen Bradley FC55
R150	60k4	1	100ppm	Metal Film	Allen Bradley FC55
R151	665k	1	100ppm	Metal Film	Allen Bradley FC55
R152	560k	1	100ppm	Metal Film	Allen Bradley FC55

Ref	Value	Tol.(%)	Rating	Type	Supplier & Type No.
R153	66k5	1	100ppm	Metal Film	Allen Bradley FC55
R154	6k65	1	100ppm	Metal Film	Allen Bradley FC55
R155	47R	2		Metal Oxide	Welwyn MR5
R156	47R	5		Film	Mullard SFR25
R157	150k	1	100ppm	Metal Film	Allen Bradley FC55
R158	47R	2		Metal Oxide	Welwyn MR5
R159	1k0	0.01	10ppm	Metal Film	Vishay V53C1
R160	47R	5		Film	Mullard SFR25
R161	150k	5		Film	Mullard SFR25
R162	100R	0.1	50ppm	Metal Film	Allen Bradley FC55
R163	3k9	0.1	50ppm	Metal Film	Allen Bradley FC55
R164	47R	5		Film	Mullard SFR25
R165	150k	1	100ppm	Metal Film	Allen Bradley FC55
R166	3k9	0.1	50ppm	Metal Film	Allen Bradley FC55
R167	100R	0.1	50ppm	Metal Film	Allen Bradley FC55
R168	3k9	0.1	50ppm	Metal Film	Allen Bradley FC55
R169	100R	0.1	50ppm	Metal Film	Allen Bradley FC55
R170	470R	5		Film	Mullard SFR25
R171	11k	1	100ppm	Metal Film	Allen Bradley FC55
R172	47k	0.01	10ppm	Metal Film	Vishay V53C1
R173	4k7	0.01	10ppm	Metal Film	Vishay V53C1
R174	470R	0.01	10ppm	Metal Film	Vishay V53C1
R175	52R222	0.01	10ppm	Metal Film	Vishay V53C1
R176	261R	1	100ppm	Metal Film	Allen Bradley FC55
R177	48k7	1	100ppm	Metal Film	Allen Bradley FC55
R178	7k15	1	100ppm	Metal Film	Allen Bradley FC55
R179	5k9	1	100ppm	Metal Film	Allen Bradley FC55
R180	330k	1	100ppm	Metal Film	Allen Bradley FC55
R181	30k	1	100ppm	Metal Film	Allen Bradley FC55
R182	330k	1	100ppm	Metal Film	Allen Bradley FC55
R183	33k	1	100ppm	Metal Film	Allen Bradley FC55
R184	3k16	1	100ppm	Metal Film	Allen Bradley FC55
R185	680R	5		Film	Mullard SFR25
R186	124k	1	100ppm	Metal Film	Allen Bradley FC55
R187	15k	1	100ppm	Metal Film	Allen Bradley FC55
R188	51k	1	100ppm	Metal Film	Allen Bradley FC55
R189	15k	1	100ppm	Metal Film	Allen Bradley FC55
R190	402k	1	100ppm	Metal Film	Allen Bradley FC55
R191	51k	1	100ppm	Metal Film	Allen Bradley FC55
R192	33R	5		Film	Mullard SFR25
R193	10k	5		Film	Mullard SFR25
R194	4k7	5		Film	Mullard SFR25
R195	3k3	5		Film	Mullard SFR25
R196	27R	2		Metal Oxide	Welwyn MR5
R197	47R	2		Metal Oxide	Welwyn MR5
R198	22k			SIL N/W	Hitech L109
R199	2k2			SIL N/W	Hitech L109
R502	1k0			SIL N/W	Hitech L109
R503	1k5	5		Film	Mullard SFR25
R504	3k3	5		Film	Mullard SFR25
R505	4k7	5		Film	Mullard SFR25
R506	220k	5		Film	Mullard SFR25
R1001	10k	5		Film	Mullard SFR25
R1002	10k	5		Film	Mullard SFR25
R1003	330R	5		Film	Mullard SFR25
R1004	330R	5		Film	Mullard SFR25

Ref	Value	Tol.(%)	Rating	Type	Supplier & Type No.
R1010	100R	5		Film	Mullard SFR25
R1011	1k0	1	100ppm	Metal Film	Allen Bradley FC55
R1012	560R	1	100ppm	Metal Film	Allen Bradley FC55
R1013	10M	10		Film	Mullard SFR25
R1014	10k	10		Cermet	Allen Bradley E2B103
R1015	180k	1	100ppm	Metal Film	Allen Bradley FC55
CAPACITORS					
C1	220n		10V	Ceramic Disc	STC TD16220N10Q
C101	2μ2		25V	Electrolytic	Mullard 030-38228
C102	4700μ		16V	Electrolytic	Mullard 03315472
C103	1000μ		25V	Electrolytic	Mullard 03216102
C104	1000μ		25V	Electrolytic	Mullard 03216102
C105	10μ		25V	Electrolytic	Mullard 01516109
C106	Not fitted				
C107	100μ		25V	Electrolytic	Mullard 01636101
C108	100μ		25V	Electrolytic	Mullard 01636101
C109	47μ		25V	Electrolytic	Mullard 01616479
C110	47μ		25V	Electrolytic	Mullard 01616479
C111	470μ		25V	Electrolytic	Mullard 03216471
C112	470μ		25V	Electrolytic	Mullard 03216471
C113	10μ		25V	Electrolytic	Mullard 01516109
C114	470p	2½	160V	Polystyrene	LCR FSC
C115	10μ		25V	Electrolytic	Mullard 01516109
C116	10μ		25V	Electrolytic	Mullard 01516109
C117	22n	2½	160V	Polystyrene	LCR FSC
C118	220p	2½	160V	Polystyrene	LCR FSC
C119	10μ		25V	Electrolytic	Mullard 01516109
C120	22n	2½	160V	Polystyrene	LCR FSC
C121	220p	2½	160V	Polystyrene	LCR FSC
C122	Not fitted				
C123	4μ7	5	100V	Polyester	Wima MKS-4
C124	1n	2	160V	Polystyrene	LCR FSC
C125	4μ7	5	100V	Polyester	Wima MKS-4
C126	4μ7	5	100V	Polyester	Wima MKS-4
C127	Not fitted				
C128	22p	1p	160V	Polystyrene	Suflex HS
C129	22p	1p	160V	Polystyrene	Suflex HS
C130	22p	1p	160V	Polystyrene	Suflex HS
C131	220n	5	100V	Polyester	Wima MKS-4
C132	10n	20n	100V	Polyester	Wima MKS-4
C133	1n	2½	160V	Polystyrene	LCR FSC
C134	2-10p		(8mm)	Var. Tetfer	Jackson Bros. 5750/VPC
C135	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C136	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C137	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C138	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C139	33p	1p	160V	Polystyrene	Suflex HS
C140	6μ8	5	63V	Polyester	Wima MKS-4
C141	220n	5	100V	Polyester	Wima MKS-4
C142	8n2	2½	160V	Polystyrene	LCR FSC
C143	2n7	2½	160V	Polystyrene	LCR FSC
C144	6p8	½p	500V	Ceramic Disc	ITT CD08/NPO
C145	100n	2	125V	Polystyrene	DRB 6007
C146	100μ		25V	Electrolytic	Mullard 01636101
C147	100n		63V	Ceramic Disc	Siemens B37449
C148	100n		63V	Ceramic Disc	Siemens B37449
C149	100n		63V	Ceramic Disc	Siemens B37449

Ref	Value	Tol.(%)	Rating	Type	Supplier & Type No.
C150	100n		63V	Ceramic Disc	Siemens B37449
C151	100n		63V	Ceramic Disc	Siemens B37449
C152	100n		63V	Ceramic Disc	Siemens B37449
C153	100n		63V	Ceramic Disc	Siemens B37449
C154	100n		63V	Ceramic Disc	Siemens B37449
C155	100n		63V	Ceramic Disc	Siemens B37449
C156	100n		63V	Ceramic Disc	Siemens B37449
C157	100n		63V	Ceramic Disc	Siemens B37449
C158	100n		63V	Ceramic Disc	Siemens B37449
C159	100n		63V	Ceramic Disc	Siemens B37449
C160	100n		63V	Ceramic Disc	Siemens B37449
C161	100n		63V	Ceramic Disc	Siemens B37449
C162	100n		63V	Ceramic Disc	Siemens B37449
C163	10μ		25V	Electrolytic	Mullard 01516109
C164	10μ		25V	Electrolytic	Mullard 01516109
C165	10μ		25V	Electrolytic	Mullard 01516109
C166	Not fitted				
C167	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C168	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C169	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C170	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C171	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C172	10n		40V	Ceramic Disc	ITT TD08K3
C173	10n		40V	Ceramic Disc	ITT TD08K3
C174	10n		40V	Ceramic Disc	ITT TD08K3
C175	10n		40V	Ceramic Disc	ITT TD08K3
C176	10n		40V	Ceramic Disc	ITT TD08K3
C177	10n		40V	Ceramic Disc	ITT TD08K3
C178	10n		40V	Ceramic Disc	ITT TD08K3
C179	10n		40V	Ceramic Disc	ITT TD08K3
C180	10n		40V	Ceramic Disc	ITT TD08K3
C181	10n		40V	Ceramic Disc	ITT TD08K3
C182	10n		40V	Ceramic Disc	ITT TD08K3
C183	47μ		25V	Electrolytic	Mullard 01616479
C184	47μ		25V	Electrolytic	Mullard 01616479
C185	47μ		25V	Electrolytic	Mullard 01616479
C186	56p	2½	160V	Polystyrene	LCR FSC
C187	100p	10	500V	Ceramic Disc	ITT CD08
C190	1n		500V	Ceramic Disc	ITT CD08/K2
C501	2200μ		16V	Electrolytic	Dubilier CEA 220016
C502	10μ	-10 +50	25V	Electrolytic	Mullard 03036109
C503	10μ		25V	Electrolytic	Mullard 03036109
C504	100μ		63V	Ceramic	Siemens B37449
C505	100μ		63V	Ceramic	Siemens B37449
C506	100μ		63V	Ceramic	Siemens B37449
C507	100μ		63V	Ceramic	Siemens B37449
C508	100μ		63V	Ceramic	Siemens B37449
C509	100μ		63V	Ceramic	Siemens B37449
C510	100μ		63V	Ceramic	Siemens B37449
C511	100μ		63V	Ceramic	Siemens B37449
C512	100μ		63V	Ceramic	Siemens B37449
C515	2200μ		16V	Electrolytic	Dubilier CEA 220016

INTEGRATED CIRCUITS

Ref	Description	Supplier & Type No.
IC101	Oscillator 16.32MHz ±0.01%	ITT DIL 1100C
IC102		Texas SN 74LS 393N
IC103		Intel P8085A
IC104		Texas SN 74LS 139N
IC105		Texas SN 74LS 373N
IC106		Texas SN 74LS 32N
IC107		Motorola MC14503BCP
IC108	Not fitted	
IC109		RCA or SGS only. CD4052BE
IC110		RCA CD4040BE
IC111		RCA CD4013BE
IC112		National CD40175BCN
IC113	DW4/25458	HN 4827128-G 45 Programmed
IC114		Xicor X2816AD-45
IC115		Intel P8155
IC116		RCA CD4025BE
IC117		Texas SN 74LS 26N
IC118		Texas SN 74LS 26N
IC119		Texas SN 74LS 138N
IC120		Intel P8279-5
IC121		Texas SN 74LS 38N
IC122		Texas SN 74LS 38N
IC123	Voltage Regulator	National LM78-05-CP
IC124	Voltage Regulator	National LM78-M12-CP
IC125	Voltage Regulator	National LM337 MP
IC126		Fairchild μA 78L82 AWC
IC127		RCA, National or SGS only. CD4053BE
IC128		RCA or SGS only. CD4052BE
IC129		Texas TL071CP
IC130		RCA, National or SGS only. CD4052BE
IC131		Texas TL071CP
IC132		Texas TL071CP
IC133		Signetics NE5534AN
IC134		Signetics NE5534AN
IC135		Signetics NE5534AN
IC136		RCA, National or SGS only. CD4053BE
IC137		Signetics NE5534AN
IC138		RCA, National or SGS only. CD4053BE
IC139		RCA or SGS only. CD4052BE
IC140		Signetics NE5534AN
IC141		RCA or SGS only. CD4052BE
IC142		Texas TL071CP
IC143		Texas TL070CP
IC144		RCA or SGS only. CD4052BE
IC145		Texas TL071CP
IC146		National LM393N
IC501		National LM78-05-CP
IC503		National DM74LS10N
IC504		National DM74LS04N
IC505		Texas SN74LS75N
IC506		Motorola MC68488P
IC507		Motorola MC3448AP
IC508		Motorola MC3448AP
IC509		Motorola MC3448AP
IC510		Motorola MC3448AP
IC511		Signetics 74LS74AN

DIODES

Ref	Description	Supplier & Type No.
D102		Mullard 1N4006
D103		Mullard 1N4006
D104	Bridge Rectifier	Internat'l Rectifier 1KAB10
D105		Mullard 1N4006
D106		Internat'l Rectifier 30S1
D107		Internat'l Rectifier 30S1
D108		Internat'l Rectifier 30S1
D109		Internat'l Rectifier 30S1
D110		Mullard 1N4006
D111		Mullard 1N4006
D112		Mullard 1N4006
D113		Mullard 1N4006
D114		Mullard 1N4006
D115		Mullard 1N4006
D116		Mullard 1N4006
D117		Mullard 1N4006
D118	4.7V	Mullard BZX79-C4V7
D201	Display LED, 7 segment	Hewlett-Packard 5082-7750
D202	Display LED, 7 segment	Hewlett-Packard 5082-7750
D203	Display LED, 7 segment	Hewlett-Packard 5082-7750
D204	Display LED, 7 segment	Hewlett-Packard 5082-7750
D205	Display LED, 7 segment	Hewlett-Packard 5082-7750
D501		Mullard 1N4006
D502		Internat'l Rectifier 1N4148

TRANSISTORS

TR101	Not fitted	
TR102		Texas 2N3702
TR103		Texas 2N3702
TR104		Texas 2N3702
TR105		Texas 2N3702
TR106		Texas 2N3702
TR107		Texas 2N3702
TR108		Texas 2N3702
TR109		Texas 2N3702
TR110		Texas 2N3702
TR501		Texas BC212

MISCELLANEOUS

FS1	Fuse Holder	Belling & Lee L2006A
F1	Fuse 160mA-T (230V)	Belling & Lee L2080A
F1	Fuse 315mA-T (115V)	Belling & Lee L2080A
L101	Inductor 3μH3	Sigma SC10
L102	Industor 3μH3	Sigma SC10
LK101	Link	B.T. Cu wire 1/0.7
PL1	CEE22 "Clip-in" Appl. Inlet	Rendar R470 30 000
PL102	Connector Elect. Wafer	Molex 3003 10-08-1061 6-way

Ref	Description	Supplier & Type No.
PL103	15-way Connector (Mod'fd Molex)	WKR 5-524-5493
PL104	" " "	" " "
PL105	Plug (Modified MKS)	WKR 5-524-5460
PL106	Connector Elect. Header	Spectra-Strip 800-583 2 x 13-way
PL107		
PL108	Programmable Header	Aries 8-680-191T
PL109	Wafer 3-way 6410	Molex 22-27-2030
PL306	(Part of Membrane Keypad)	
PL502	Connector MKS 3750-1-0-2020	Stocko
SK2	6-way Connector 7823	Molex 10-81 2063
SK3		
SK5	(Part of Connection Fixture)	
SK101	40-pin DIL Expansion Connector	Greenpar DL2 40S
SK108	IC Socket DIL 8 pin	R Nugent ICN-083-S3T
SK203	(Part of 5-Digit LED Display)	
SK204	PCB Connector, Rt. angle. 5-way	Molex 4455-A. 22-15-2056
SK309	3-way Housing 0.1" pitch	Molex 22-01-2035
SW1	Mains Rocker Switch	Arrow Hart 2600-11E
T1	Power Transformer	WKR 4-524-5474
-	Membrane Keypad (100Hz)	WKR 4-524-5478
-	Membrane Keypad (120Hz)	WKR 4-524-5462
-	Membrane Interconnection Cable	WKR 5-524-5487
-	Connection Fixture	WKR 5-524-5488
-	5-Digit LED Display	WKR 5-524-5477
-	Main Board (inc.PL 102/3/5/6)	WKR 5-524-5473

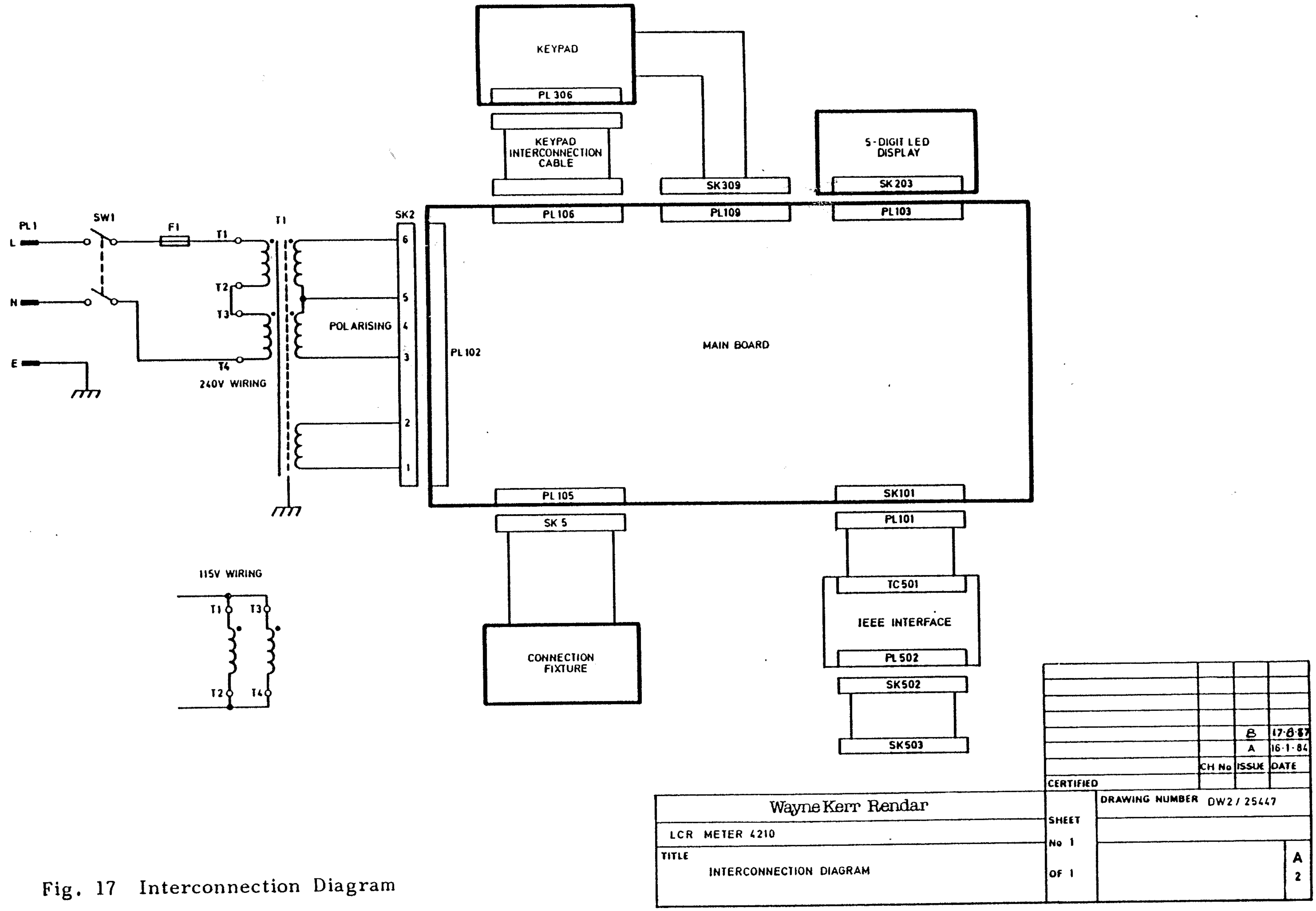


Fig. 17 Interconnection Diagram

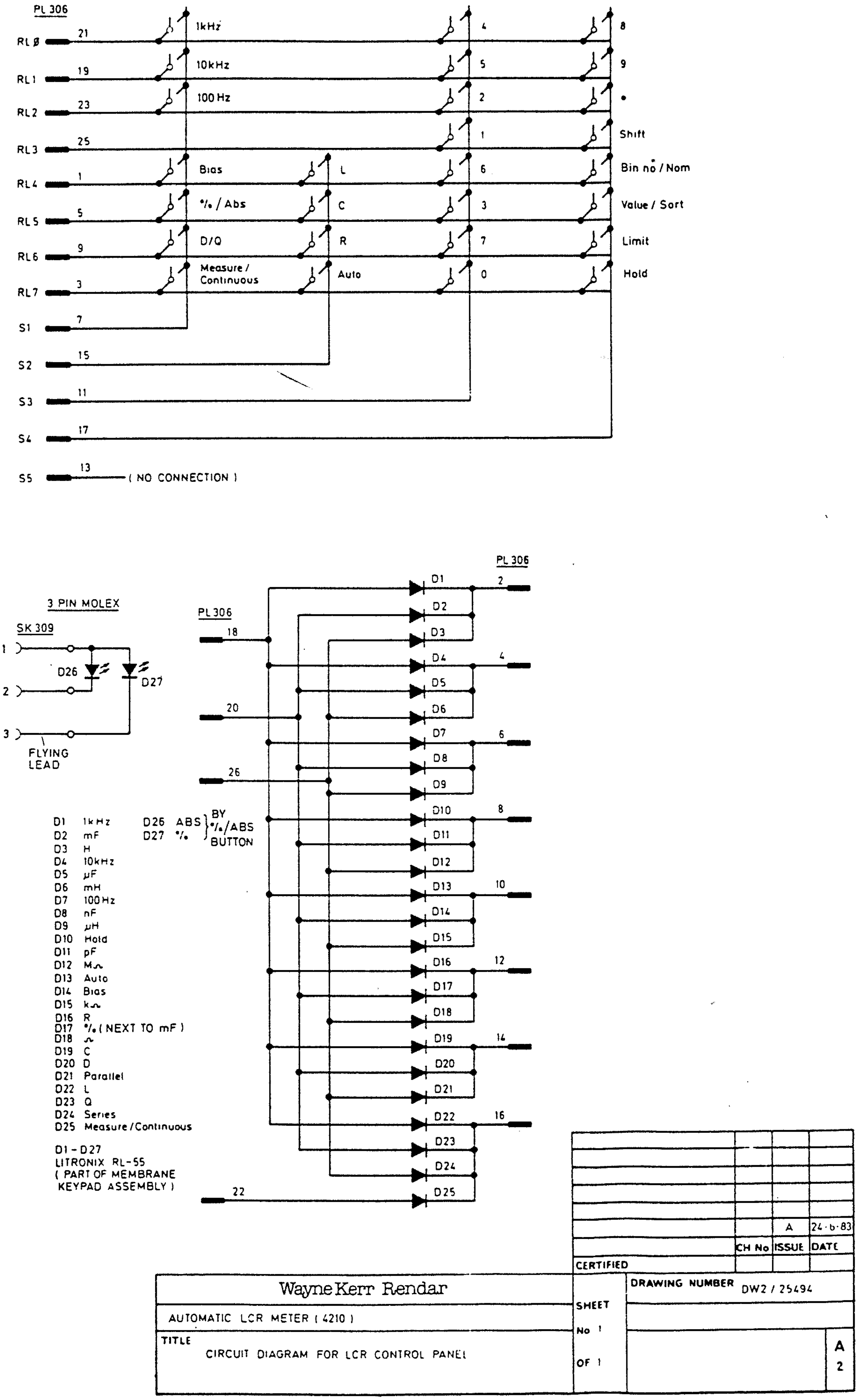


Fig. 18 Keypad Circuit Diagram

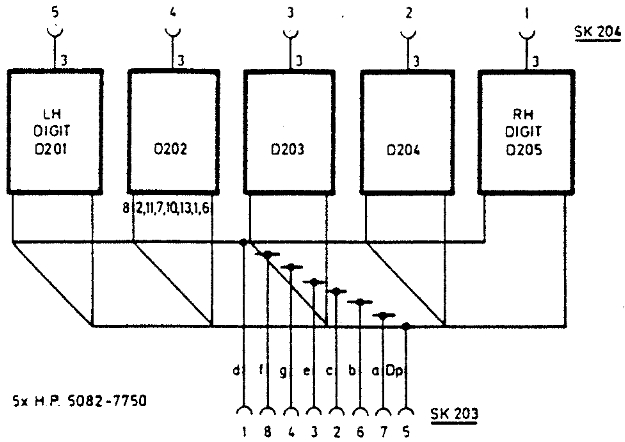


Fig. 19 5-digit LED Display Circuit Diagram

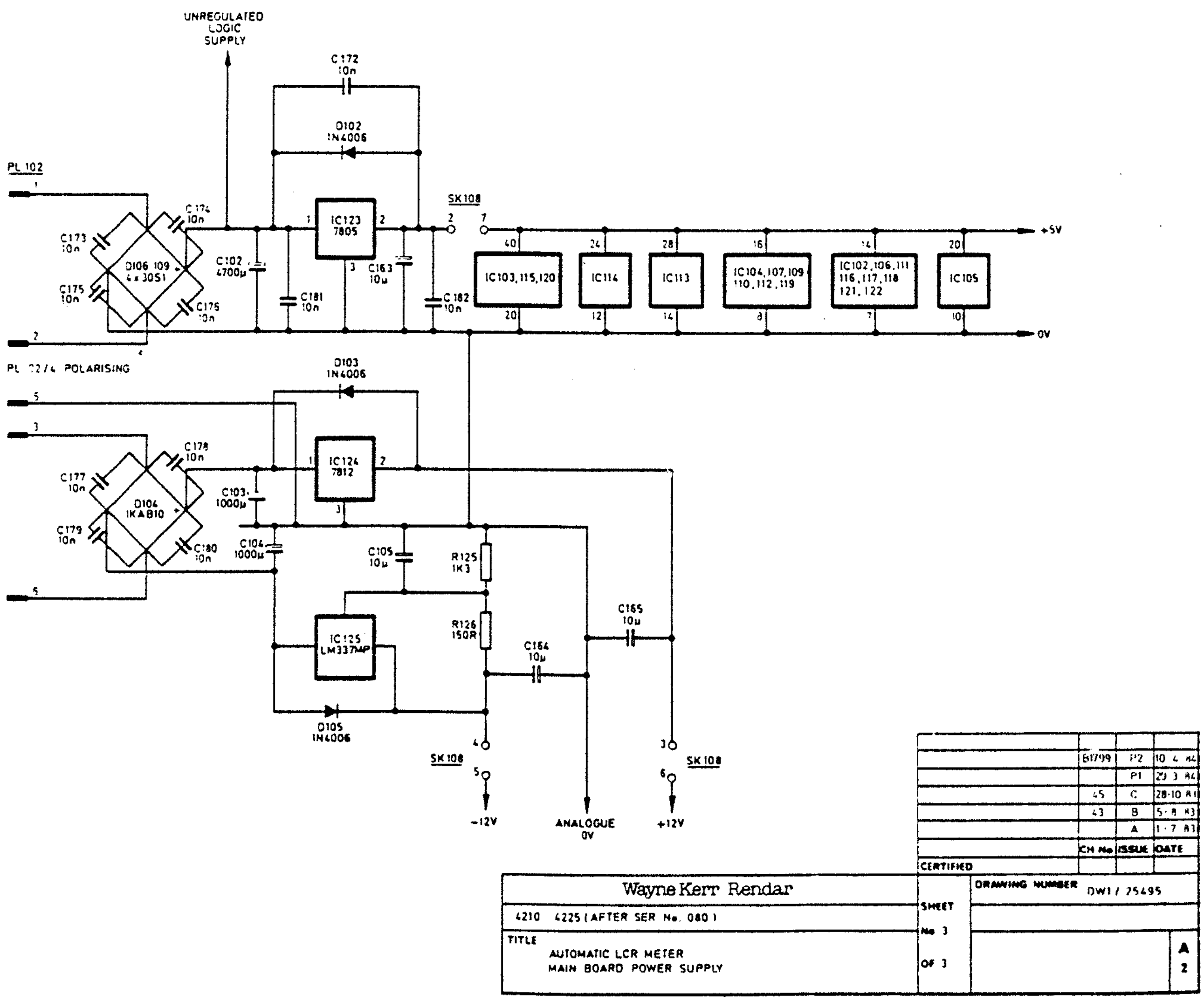


Fig. 20 Power Supply Circuit Diagram

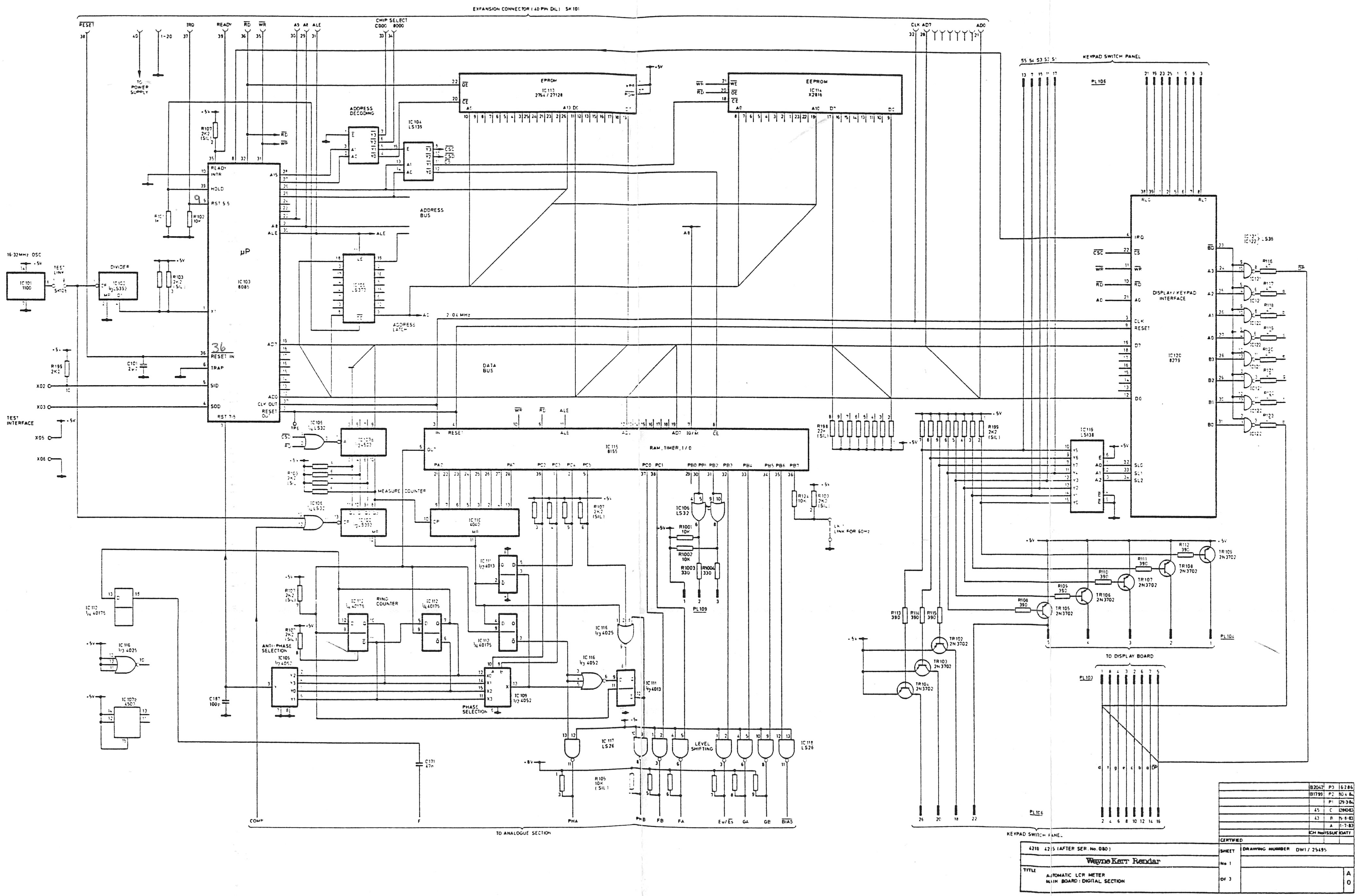


Fig. 21 Digital Circuit Diagram

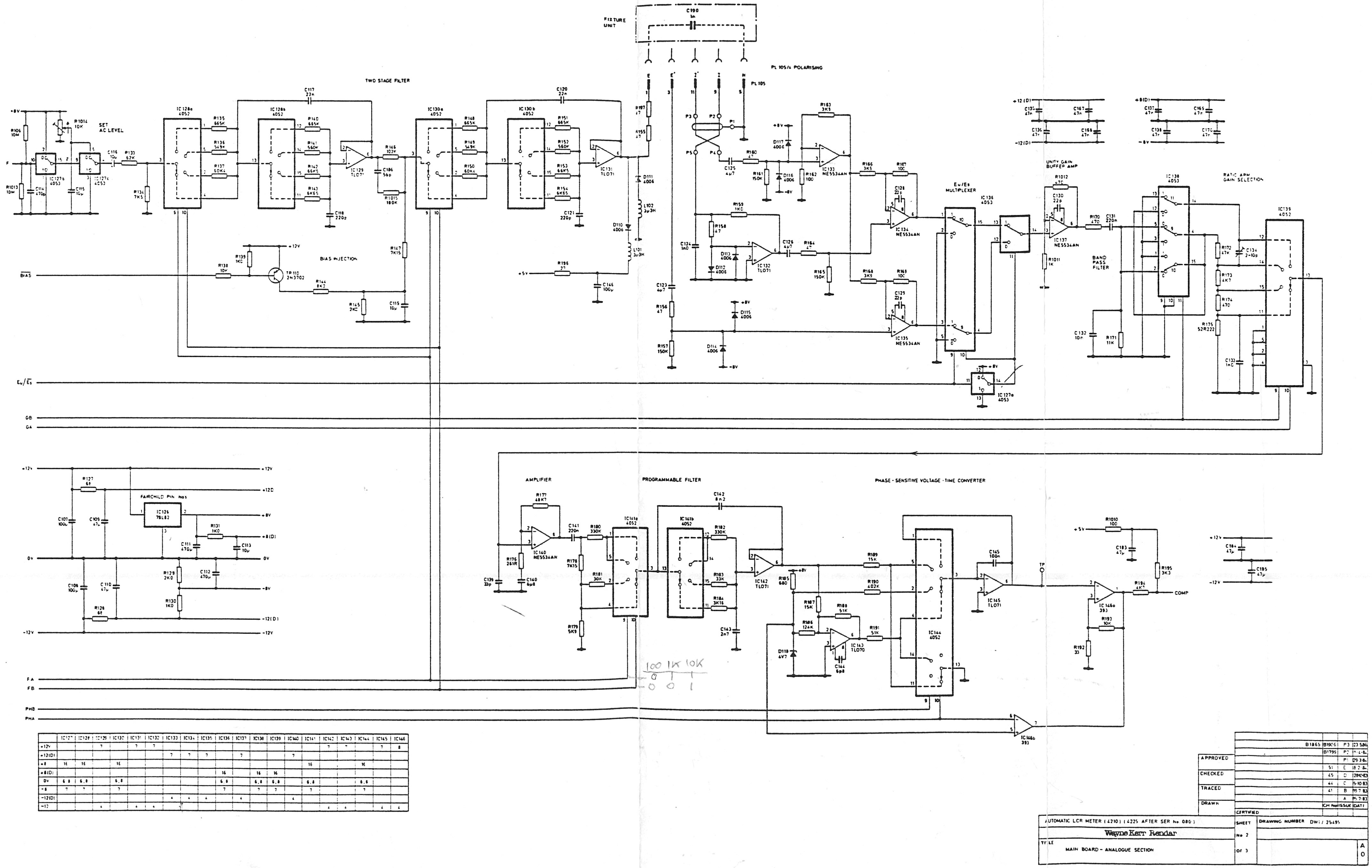


Fig. 22 Analog Circuit Diagram

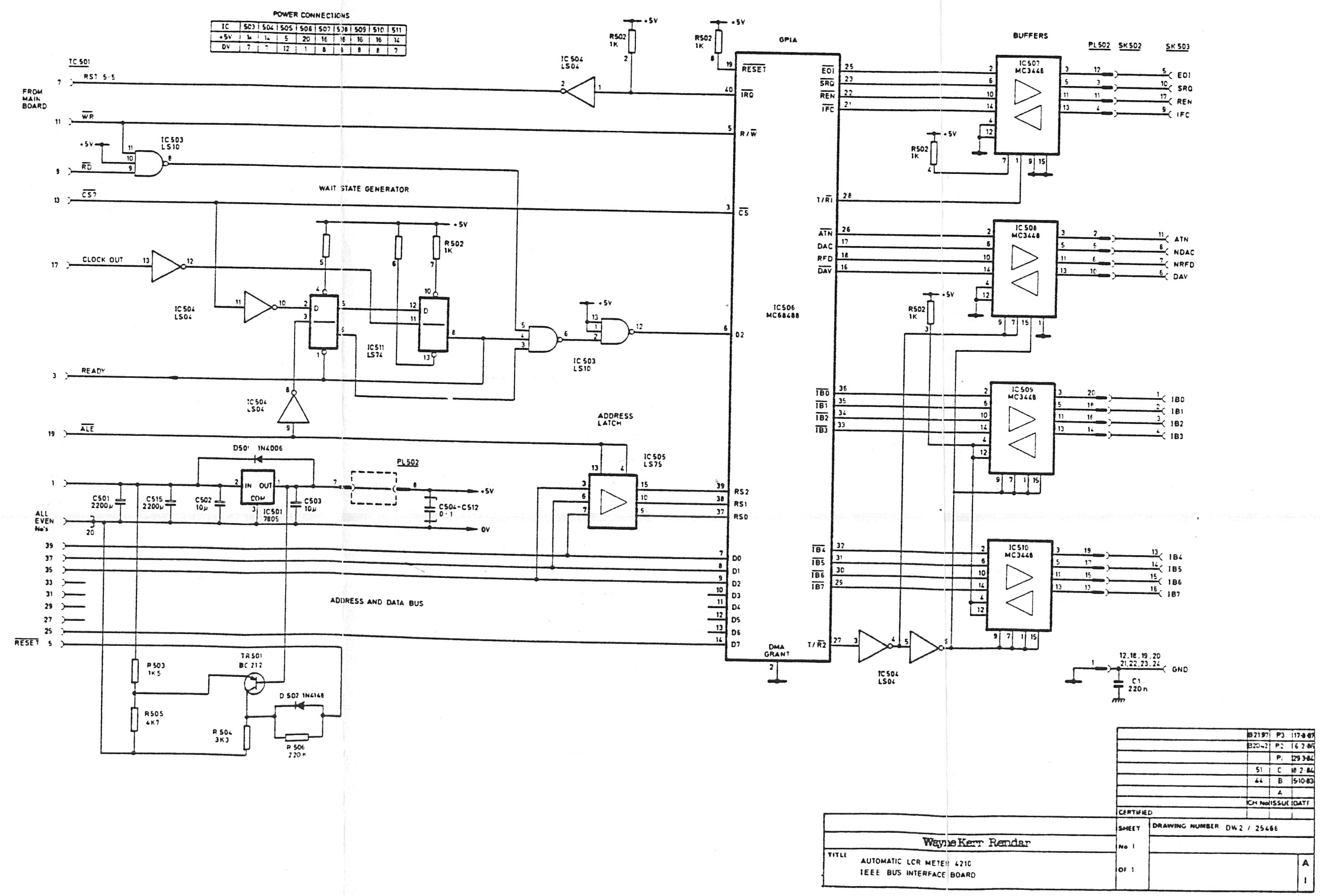


Fig. 23 GPIB Circuit Diagram

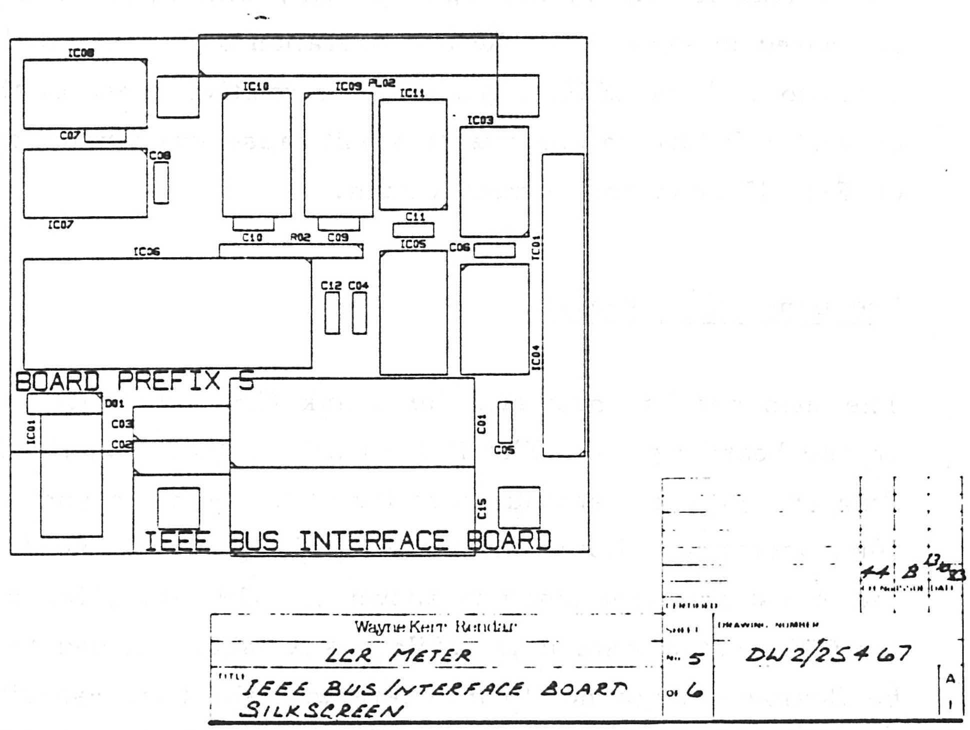


Fig. 24 GPIB PCB Layout

APPENDIX

50/60Hz and 240/115V OPERATION

Normally, instruments are supplied for 240V,50Hz operation, or 115V, 60Hz operation. Keypads show the lowest test frequency as 100Hz for 50Hz models : 120Hz for 60Hz models. It is possible to convert models to the alternative voltage and/or frequency.

Voltage change-over

Power transformer T1 has split primary windings. The two sections are wired in series for 240-volt operation and in parallel for 115-volt operation. It is ESSENTIAL that the relative sense of the two sections is correct : failure to observe this will cause irreparable damage. The dots on Fig. 17 show the correct wiring.

Frequency change-over

The main pcb has provision for a link (LK1) near R124 (annotated 'R24' on the board itself). The link (which is shown on the Digital Circuit Diagram, Fig. 21) should exist for 60Hz operation and be removed for 50Hz operation. Note that the keypad legend will need to be changed : the lowest test frequency is shown as 100Hz for 50Hz instruments while for 60Hz instruments it is 120Hz. Any labels affixed to the keypad must be flexible enough not to interfere with the touch-sensitive operation.

Safety

Voltage and/or frequency change-over must be undertaken only by qualified engineers and the instrument must be totally disconnected from the supply during the conversion. Access to the circuits is described in the section on Dismantling (page 70). It is the responsibility of the user to ensure that warning labels on the instrument are amended as necessary to meet local safety legislation, usually dependent upon National standards.

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