Automatic LCR Meter 7330

Instruction/Service Manual

Part No. 9H7330

This instrument has been manufactured by:
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ILLUSTRATIONS

Automatic LCR Meter 7330

1. SAFETY

1.1 General

This equipment has been designed to meet the requirements of EN61010 'Safety requirements for electrical equipment for measurement, control & laboratory use', and has left the factory in a safe condition.

The following definitions in EN61010-1 apply to this manual:

OPERATOR	Person operating equipment for its intended purpose. **Note: The OPERATOR should have received training appropriate for this purpose.**
RESPONSIBLE BODY	Individual or group responsible for the use and maintenance of equipment and for ensuring that operators are adequately trained.

The RESPONSIBLE BODY must ensure that this equipment is used only within its specified operating conditions. These include environmental, electrical, installation and operating conditions.

This equipment is intended for use by suitably trained and competent persons only.

This equipment can cause hazards if not used in accordance with these instructions. Read them carefully and follow them in all respects.

This instrument is not intended for use in atmospheres which are explosive, corrosive or adversely polluted (e.g. containing conductive or excessive dust). It is intended for indoor use only.

If it is likely that protection against a hazard has been impaired, e.g. there is mechanical damage, do not continue to use the equipment. In this situation, the instrument must be made inoperative and secured against any unintentional operation. The manufacturer should then be contacted at the address given at the front of the manual to obtain the appropriate procedure to follow.

Do not use the equipment if it is damaged. In such circumstances the equipment must be made inoperative and secured against any unintentional operation.

WAYNE KERR ELECTRONICS LTD and the associated sales organizations accept no responsibility for personal or material damage, nor for any consequential damage that results from irresponsible or unspecified operation, or any misuse, of this instrument.

1.2 A.C. Power Supply

Power cable and connector requirements vary between countries. Always use a cable that conforms to local regulations, terminated in an IEC320 connector at the instrument end.

If it is necessary to fit a suitable AC power plug to the power cable, the user must observe the following colour codes:

WIRE	EUROPEAN	N. AMERICAN
LIVE	BROWN	BLACK
NEUTRAL	BLUE	WHITE
EARTH	GREEN/YELLOW	GREEN

The user must also ensure that the protective earth lead would be the last to break should the cable be subject to excessive strain.

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

If the power cable electrical connection to the AC power plug is through screw terminals then, to ensure reliable connections, any solder tinning of the cable wires must be removed before fitting the plug.

Before switching on the equipment, ensure that it is set to the voltage of the local AC power supply.

WARNING!

Any interruption of the protective earth conductor inside or outside the equipment or disconnection of the protective earth terminal is likely to make the equipment dangerous. Intentional interruption is prohibited.

1.3 Adjustment, Replacement of Parts, Maintenance and Repair

When the equipment is connected to the local AC power supply, internal terminals may be live and the opening of the covers or removal of parts (except those to which access can be gained by hand) is likely to expose live parts.

WARNING!

The equipment must be disconnected from all voltage sources before it is opened for any adjustment, replacement, maintenance, or repair.

Capacitors inside the equipment may still be charged even if the equipment has been disconnected from all voltage sources.

Any adjustment, maintenance, or repair of the opened equipment under voltage must be carried out by a skilled person who is aware of the hazards involved.

Servicing personnel should be trained against unexpected hazards.

Ensure that only fuses with the required rated current and of the specified type are used for replacement. The use of makeshift fuses and short-circuiting of fuse holders is prohibited.

1.4 Static Electricity

The unit supplied uses static sensitive devices and service personnel should be alerted to components which require handling precautions to avoid damage by static electrical discharge.

Before handling circuit board assemblies containing these components, personnel should observe the following precautions:

1) The work surface should be a conductive grounded mat.

2) Soldering irons must be grounded and tools must be in contact with a conductive surface to ground when not in use.

3) Any person handling static sensitive parts must wear a wrist strap which provides a leaky path to ground, impedance not greater than 1MΩ.

4) Components or circuit-board assemblies must be stored in or on conductive foam or mat while work is in progress.

5) New components should be kept in the suppliers packaging until required for use.

2. SCHEDULE OF EQUIPMENT

The instrument has been carefully packed to prevent damage in transit.

The complete equipment comprises:-

Description	WK Part Number	Qty
Automatic LCR Meter 7330	1EV7330	1
Instruction/Service Manual	9H7330	1
Detachable AC Power Cord	HC22V2	1

Accessories	WK Part Number
Kelvin Clip Leads	5-385-5724
Component Fixture 1006	1EV1006

Note: In the event of damage in transit or shortage in delivery, separate notices in writing should be given to both the carriers and Wayne Kerr Electronics Limited, within three days of receipt of the goods, followed by a complete claim within five days. All goods which are the subject of any claim for damage in transit or shortage in delivery should be preserved intact as delivered for a period of seven days after making the claim, pending inspection or instructions from Wayne Kerr Electronics Ltd., or an agent of this company.

3. INSTALLATION

3.1 Supply Voltage

Normally, instruments are supplied to suit local power supplies: 230V, 50Hz or 115V, 60Hz. A label on the rear of the instrument shows the settings made at the time of despatch. The front-panel fuse ratings are:

230V AC operation	160mA-T
115V AC operation	315mA-T

If the voltage or frequency settings are changed, corresponding changes must be made to the label and to the fuse fitted. The power lead supplied with the instrument normally has the appropriate plug, to suit local AC supplies, moulded on. If for any reason the plug has to be replaced, the connections should be as follows:

WIRE	EUROPEAN	N. AMERICAN
LIVE	BROWN	BLACK
NEUTRAL	BLUE	WHITE
EARTH	GREEN/YELLOW	GREEN

If the plug is fused, a 3A fuse should be fitted. The power on/off switch is on the front panel. The instrument is not suitable for battery operation.

3.1.1 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. 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.

3.1.2 Changing the Mains Voltage Setting

Perform the following to change the mains voltage setting:

1) Remove the power connector from the rear and turn the instrument base uppermost.
2) Remove two screws from each side of the base cover and remove it.
3) Attached to the transformer is a two-position slide switch with a reversible cover plate. Remove the plate, set the switch to the required position and re-fit the plate, to show the new voltage selected.
4) Refit the base cover with the ventilation slots towards the front of the instrument.
5) Change the fuse to the rating listed in section 3.1.

Note:

On some instruments, the change-over switch is not fitted. To change the mains voltage setting on these models, perform the following:

Wire the two sections of the split primary in series for 230V AC operation.

Wire the two sections of the split primary in parallel for 115V AC operation.

CAUTION!

It is ESSENTIAL that the relative sense of the two sections is correct. Failure to observe this will cause the supply to blow.

3.1.3 Changing the Mains Frequency Setting

Perform the following to change the mains frequency setting:

1) Remove the power connector from the rear of the instrument and remove the top cover (two screws each side).

2) Remove the ribbon-cable connection from PL06 on the main PCB (this is the narrower ribbon-cable from the front panel). This will expose the two connection points of LK1 on the board. The mains frequency setting is selected as follows:

60Hz Operation	LK1 Link Fitted
50Hz Operation	LK1 Link Not Fitted

3) Replace the ribbon-cable connector and re-fit the top cover.

4. GENERAL INFORMATION

4.1 Introduction

4.1.1 Purpose

The Automatic LCR Meter 7330 is designed for use in GPIB-controlled systems to provide accurate measurement and sorting of inductors, capacitors and resistors. It is largely immune to the presence of supply-borne noise and is exceptionally well protected against damage or malfunction from the connection of charged capacitors. Although intended primarily for operation with component handling and binning equipment, the 7330 can be used as a stand-alone instrument for automatic measurement of the major and minor terms of components to laboratory standards.

4.1.2 Test Frequencies

Three alternative test frequencies are provided, with push-button selection. Measured values of L, C and R, and the Q factor of inductors or dissipation factor D of capacitors, are shown on a five-digit LED display with LED indication of the appropriate units for direct readout. The 7330 selects the more usual presentation of results (equivalent series or parallel terms) according to the impedance value measured, but users can select the alternative presentation if required.

4.1.3 Transistor and Diode Measurements

To provide for dependable measurements of transistor and diode junction capacitances, a drive signal level of only 250mV rms, from a 100Ω source, is used.

4.1.4 Bias Voltage

Provision is made for the application of a bias voltage for polarizing electrolytic capacitors while they are measured.

4.1.5 Range Switching

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

4.1.6 Binning of Components

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

4.1.7 Remote Control

GPIB to IEEE 488 Standard allows the 7330 to be remote-controlled on all functions and provides for the connection of handlers, binning systems and printers.

4.1.8 Terminals

Four-terminal connection for all measurements virtually eliminates the effect of test lead impedances, while the availability of a fifth connection - guard - can be used to simplify in-situ measurements by neutralizing the effect of unwanted shunt impedances.

4.1.9 Kelvin Clip Leads

Kelvin Clip leads are available as an accessory for accurate low-impedance measurements under laboratory conditions.

4.1.10 Component Fixture 1006

Component Fixture 1006 is available as an accessory for use with the 7330. It has spring-loaded jaws providing four-terminal connections to components with radial or axial leads. The spacing between the two pairs of jaws can be adjusted to suit components of all normal sizes.

4.2 Specifications

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.

SAFETY
Designed to meet the requirements of EN61010-1.

EMC	
This instrument is CE marked demonstrating compliance to EU directive 89/336/EEC (EMC Directive) as amended by 93/68/EEC (CE Marking Directive). It has been designed to comply with EN50081-1:1992 for emissions and EN50082-1:1992 for immunity.	
RF IMMUNITY (AS TESTED TO IEC 801-3)	When the instrument is being used in a 3V/m field, a permissible loss of performance of typically 3% may be reasonably expected. The instrument is considered as satisfying Performance Criterion A of EN50082-1 under these conditions.

OVERALL DIMENSIONS	
WIDTH	483mm (19in)
HEIGHT (inc feet)	136mm (5.4in)
DEPTH	452mm (17.8in)
WEIGHT	9.5kg (21lb)

MAINS INPUT	
INPUT VOLTAGE	115VAC ±10% or 230VAC ±10% (selectable)
FREQUENCY	50/60Hz (selectable)
INPUT POWER	25VA max
INPUT FUSE RATING	115V Operation 315mA 'T' type 230V Operation 160mA 'T' type The input fuse is located in the fuseholder on the front panel above the input power switch.

ENVIRONMENTAL CONDITIONS		
TEMPERATURE RANGE:		
Storage	-20°C to +60°C	-4°F to + 140°F
Operating	0°C to +50°C	+32°F to +122°F
Full Accuracy	+10°C to +30°C	+50°F to +86°F
ALTITUDE	Up to 2000m	
RELATIVE HUMIDITY	Up to 80% non-condensing	
INSTALLATION CATEGORY	II (in accordance with IEC664)	
POLLUTION DEGREE	2 (in accordance with IEC664)	

PERFORMANCE	
MEASUREMENT FUNCTIONS	L, C, R, Q, D percentage deviation and auto component mode.
MEASUREMENT FREQUENCIES	100Hz, 1kHz, 10kHz (50Hz operation) 120Hz, 1.02kHz, 10.2kHz (60Hz operation) Accuracy ±0.1%
MEASUREMENT LEVEL	250mV ±15mV from 100Ω
MEASUREMENT SPEED	Typically 650ms
DISPLAY	5-digit LED with decimal point plus individual LEDs for units/multipliers
CONNECTION	4-terminal via four BNC connectors. Optional: Kelvin clip-leads. Optional: Component Fixture 1006.
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 POLARIZATION	Internal 2V DC supply, manually selected. Inhibited on L, R and Auto.
TRIMMING	Automatic compensation.
BINNING	8 bins with rectangular limits. 8 bins with absolute limits. Reject and minor term reject bins.
IEEE INTERFACE (GPIB)	Automatic output of measurement data. 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	Between any pair of terminals, or any terminal and ground, protection against damage due to connection of charged

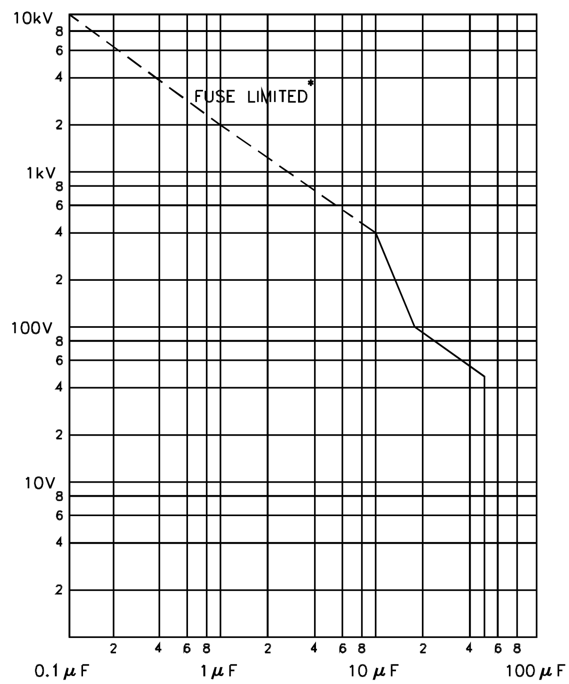
capacitors is provided, subject to the following:

a) Measurement leads to be same type and minimum length as the optional WK Kelvin clip-leads (750mm - but can be longer).

b) Between red and ground, protection limited to 500V, 2mF. Other terminals to ground, same as protection between terminals (see item c).

c) Graph full line shows protection; dotted line shows approximate levels at which internal protection fuses will blow.

d) Protection as defined above, assumes capacitor is connected for not more than 2 seconds (as would apply with a handler system), even if the fuses blow.



* see item c

Fig 4–1 Protection Graph

ACCURACY			
Beyond the ranges shown, accuracy degrades linearly (see Fig 4–2 Accuracy 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 - 16µF	±0.1% ±0.01pF	±0.5% ±0.5pF
Resolution	0.001pF		
Max Display	990mF		
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 - 16H	±0.1% ±0.01µH	±0.5% ±0.5µH
Resolution	1nH		
Max Display	9900H		
DISSIPATION (D)		CAL	UNCAL
3.2nF - 1600µF		±0.001 $(1+D^2)$	
160pF - 160µF		±0.001 $(1+D^2)$	±0.005 $(1+D^2)$
16pF - 1.6µF		±0.001 $(1+D^2)$	±0.005 $(1+D^2)$
Resolution		0.0001	
Max Display		9900	
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)%
Resolution		0.0001	
Max Display		9900	

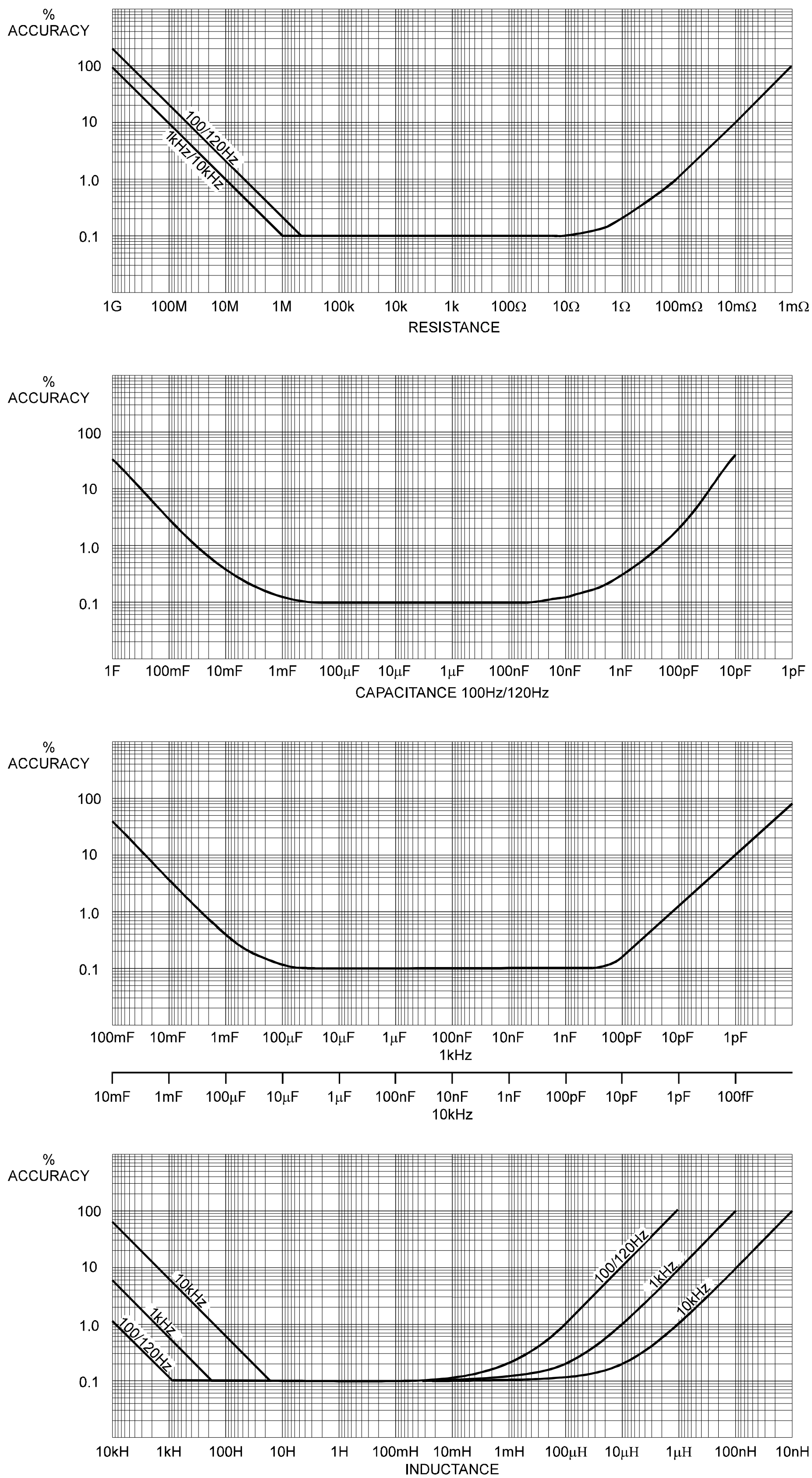


Fig 4–2 Accuracy Graphs

5. USER INSTRUCTIONS

5.1 Ventilation

The instrument must be located so that the ventilation holes in the bottom cover and in the rear panel are not obstructed in any manner.

5.2 Measurement Connections

Available as options are Kelvin clip-leads and Component Fixture 1006. Both items have colour-coded connectors which must always be connected to the corresponding panel sockets (see section 5.4). Both types provide four-terminal connections and the spring-loaded jaws of the fixture accept axial or radial leads; spacing between the two sets of leads is adjustable to suit most sizes of component.

5.3 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.

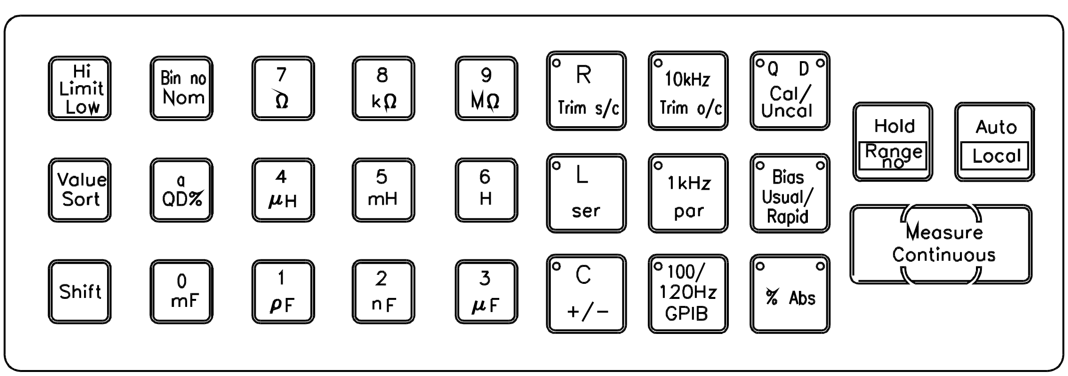


Fig 5–1 Keypad

5.4 Trimming.

For most measurements, no trimming operations are necessary. The very small corrections applied by the 7330 are held in a non-volatile store 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 7330 should be set up with the test fixture or measurement leads arranged as they will be used for a measurement.

For all trimming operations, it is essential that the leads connected are those to be used for subsequent measurements. Also, all leads must be colour-coded so that all four BNC connectors are always made to the same four panel sockets. From left to right, these are:

Brown	I'	(Voltage sense low)
Red	I	(Drive return)
Orange	E	(Drive source)
Yellow	E'	(Voltage sense high)

For correct four-terminal operations (trimming and measurement), I' must be connected to I at the component measurement point; likewise, E' must be connected to E.

For Trim s/c a solid, heavy conductor should be connected between the two pairs of measurement connections. For Trim o/c make no connection between the two pairs of connections, but ensure that I' is connected to I, and E' is connected to E. It is not necessary to reset both trim values. Trim s/c is applicable only to low impedances and Trim o/c to high impedances.

Press Shift and Trim s/c or o/c as appropriate. It takes several seconds for the 7330 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 5–5) and that for trim o/c equal to range 6. This capability may be useful for establishing an offset for specialized applications. It also means that for normal use an operator must ensure that, when trimming, only the appropriate short or open circuit 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.

5.4.1 Using the Optional Kelvin Clip-Leads for Trimming

Each Kelvin-clip lead provides one pair of like sense and drive connections (e.g., I' and I - one at each jaw). So, when the jaws are closed (or clipped to a component wire), I' is connected to I on one clip, and E' is connected to E on the other. These connections must exist for correct four-terminal operations - trimming and measurement.

5.5 Unknown Component Tests.

Assuming the instrument has the initial settings (see section 5.3), perform the following:

1) Connect the component between the measurement leads.

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 1000Ω) or Parallel (above 1000Ω). Further information on this is described in section 6.2.

4) If the component is an inductor and the Q factor is required, refer to section 5.8.1.

5) If the component is a capacitor and the dissipation factor (D) is required, refer to section 5.9. Information on polarizing capacitors is described in section 5.9.3.

6) Remove the component and substitute the next unknown component.

5.6 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 1000Ω change-over point between Series and Parallel readout. Further information on this is described in section 6.2.
- Text references to 100Hz, 1kHz and 10kHz, for 50Hz operation, apply to 60Hz operation as 120Hz, 1.02kHz and 10.2kHz, respectively.

5.7 Resistance Measurement.

Assuming the instrument has the Initial Settings (see section 5.3), perform the following:

1) Select R and connect the resistor between the measurement leads.

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.

5.8 Inductance Measurement.

Assuming the Instrument has the Initial Settings (see section 5.3), perform the following:

1) Select L and connect the inductor between the measurement leads.
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.

5.8.1 Measurement of Q Factor & Loss Resistance

With the inductor connected 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: $$R = \frac{\omega L}{Q}$$

Parallel: $$R = \omega L Q$$

where $\omega = 2\pi \times \text{frequency}$

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 dc passed, the measured Q value will be subject to variations, and these can be substantial.

5.8.2 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 section 5.4).

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 hf choke tested at af) 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 noise 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.

5.8.3 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 magnetization (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 dc is present at the measurement connections. If this is unacceptable, use a series blocking capacitor of not less than 100µF (C1 in Fig 5–2).

The effective value of all iron-cored inductors can vary widely with the magnetization and, therefore, with the level of the test signal. Ideally, they should be measured at the frequency of use, with the same ac and dc 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 minimize the effect of the dc supply components on the measured value. The circuit arrangement for energizing inductors, as shown in Fig 5–2 achieves this.

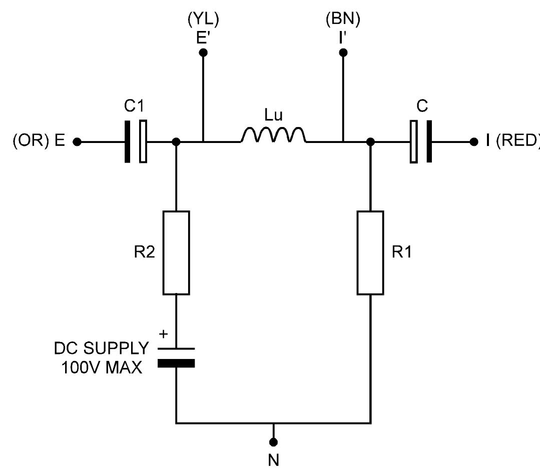


Fig 5–2 Circuit Arrangement for Energizing Inductors

WARNING!

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 dc supply.

The direct current through the inductor is also passed by resistors R1 and R2, which must have an adequate power rating. However, 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:

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

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 5–3) to read R2.

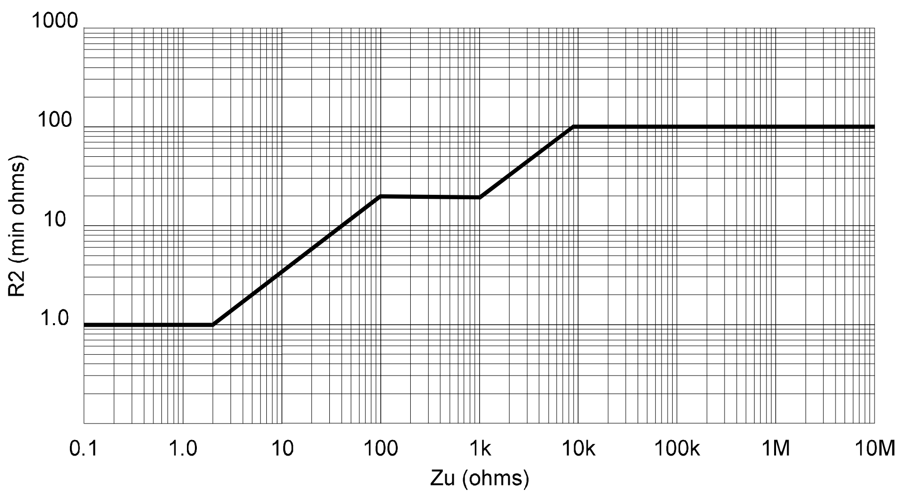


Fig 5–3 Minimum Shunt Load Impedance for 1% Loss of Accuracy

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

5.9 CAPACITANCE MEASUREMENT.

Assuming the instrument has the Initial Settings (see section 5.3), perform the following:

1) Select C and connect the capacitor between the measurement leads.
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.

5.9.1 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: $R = \frac{D}{\omega C}$

Parallel: $R = \frac{1}{\omega C D}$

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

5.9.2 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. Position the leads and measurement clips or fixture exactly as they will be used for the measurement but with no component connected. (Ensuring that I' is linked to I and, separately, E' is linked to E (see section 5.4). Press Shift and Trim o/c. The 7330 will reset the stored correction figure for stray impedance and this will be deducted automatically from all subsequent measurements.

5.9.3 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 E (Orange) connecting lead. 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, use the circuit shown in Fig 5–4. Cu is the capacitor under test. C1 should be >100 µF and of a working voltage to suit the voltage of the dc supply.

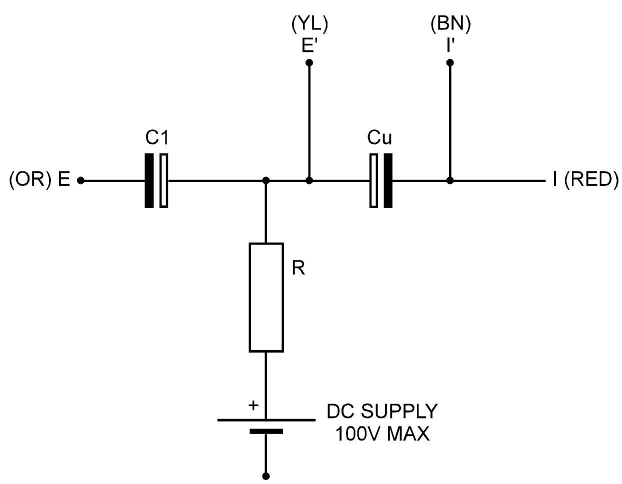


Fig 5–4 Bias Circuit for Capacitors

WARNING!

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).

5.9.4 Charged Capacitor Protection

Refer to the protection text and graph given in section 4.2 'Specifications - PERFORMANCE - PROTECTION'.

5.9.5 Semiconductor Junction Capacitance

Because of the small value of the test voltage and the availability of 2V bias, the 7330 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 I (red) connecting lead).
3) Note the value and substitute the next component to be checked, again taking care to obtain reverse bias.

5.10 Deviation Readout.

As an alternative to reading resistance, inductance or capacitance as an absolute value, the 7330 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
   Press: 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
   Press: 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 7330 cannot provide % deviation readout on Q and D values. The nominal value for % deviation readout is the same as that used for binning.

5.11 Continuous/Single-Shot Measurements.

In normal use, the 7330 makes a new measurement, and updates the display, at intervals of approximately 650ms. 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:

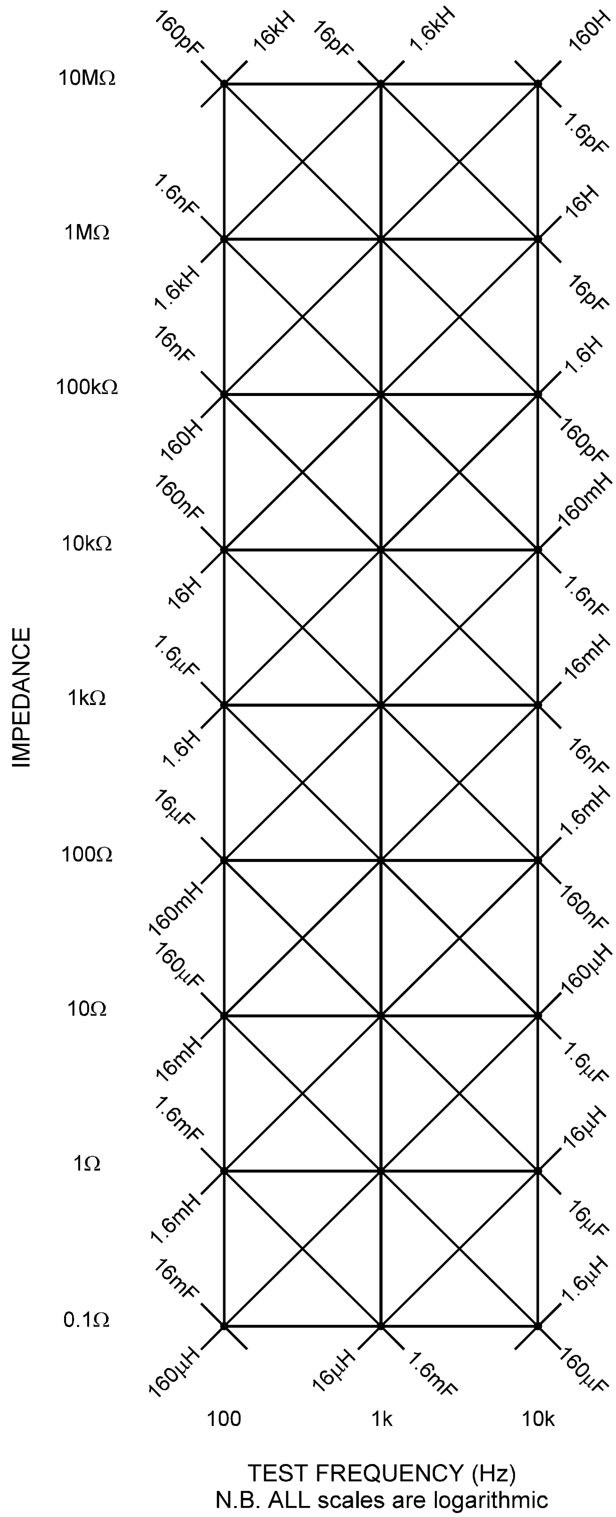
Flashing:	Continuous
Off:	Single-shot

5.12 Range Selection

Normally the 7330 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 section 5.13). However, it is also possible to pre-select a particular range. The key sequence to achieve this is:

1) Shift
2) Range no
3) Any key 0-6, according to the range required.

Coverage of the seven ranges is shown in Fig 5–5. 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.



Range	Vs (mV)	Eu (mV)	Es (mV)	Au	As
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

↑ Eu > Es
↓ Eu < Es

Eu and Es are based on reactive impedances and are therefore maximum values

Fig 5–5 Impedance Chart

5.13 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 not be held for all subsequent tests (value or Sort). The Hold function is indicated by the LED illuminating by the Hold key. To turn to autoranging, re-press Hold.

5.14 Display Characteristics

5.14.1 General

All values displayed by the 7330 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:

o.r.

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 is selected is unsuitable, or because the range Hold has been used inappropriately.

5.14.2 Negative Reactance

If C is selected with an inductor connected, or L with a capacitor connected, the 7330 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 5–5.

5.15 Binning

5.15.1 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 section 5.16).

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):

The % Mode

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.[1] 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.

The Abs Mode

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 Low. 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.[1] 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 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 operational 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 OH (Hi). However, in the Sort mode, the limit entered in Bin 0 is applied as an acceptable[2] maximum for D (when the defined operation is capacitance) while it is applied as an acceptable[2] 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 7330 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.

During sorting, normally, the selected bin number is displayed. Pressing R, L or C will change display to show, instead, the major term value.

---

[1] 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.

[2] Bin 0 is for minor term rejects. 'Acceptable' in this context means that components are NOT classified into Bin 0.

5.15.2 Keying Errors

These can be grouped into two classes:

1) A valid command (i.e., one that the 7330 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 in section 5.15.5.

2) An invalid command - one that is not logical or for some other reason is not acceptable by the 7330. 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 in section 5.15.6.

5.15.3 Sorting by % Deviation.

5.15.3.1 General

1) Press: value
Select: % (on the %/Abs white key)
Press: Shift
Press: 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[3] 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)

[3] 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 (Low)

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 thru 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 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 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 before 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 number in which the value lies.

5.15.3.2 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 (Low)

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%).

5.15.3.3 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 (Low)

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 (Low)

(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, 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%).

5.15.4 Sorting by Absolute value

5.15.4.1 General

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[4] 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 (Low)

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

8) If further categories are required, using different Hi and/or Low limits, repeat steps 2-7 inclusive, substituting Bin 2, Bin 3, etc. as required and the appropriate maximum (Hi) and minimum (Low) 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 1l. For inductors and capacitors, press:

---

[4] 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 1 Low value in memory. Where the units keyed in at step 4 are of a different type, the bin 1 Low value will be cleared. If, however, the units are of the same type, and the value keyed in for bin 1 Hi is smaller than the existing bin 1 Low value, the 7330 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 (Low) and enter the new low limit before entering the high limit. A similar procedure applies if the sequence Hi/Low is attempted in the reverse order.

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 (refer to section 5.8.1) 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 (see section 5.9.1) 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.

5.15.4.2 Example - Inductors (by Abs value)

From a quantity of 1mH inductors it is required to select those whose value lies between 800 µH and 1.4 mH. 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. Refer to note in section 5.15.4.1.

3) Key in 1 · 4

4) Press: Shift
mH

5) Press: Shift
Limit (Low)

6) Key in 8 0 0

7) Press: Shift
µH

8) Press: Bin no
0
Limit (Hi)

9) Key in 5

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 800 µH and 1.4 mH), or

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

5.15.5 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 keystroke has been made and has been accepted by the instrument. (An unacceptable command produces an error message - see section 5.15.6.) Also described are situations where the instrument shows no response to a command.

1) If Auto cannot be selected, check that Abs is selected on the %/Abs key.

2) If %/Abs cannot be selected as required, press value. (The %/Abs changeover is not available in the Sort mode.) Then select %/Abs as required.

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

4) 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.

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

6) 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 section 5.15.6). 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, Low), re-enter the number and then press Shift and the correct units.

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

8) For users familiar with the binning sequence, the setting-up time can be reduced by toggling the Usual/Rapid key to shorten the duration of any displayed message.

5.15.6 Displayed Messages.

Auto.r	Auto-ranging in progress. The 7330 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 7330 has sorted the component.
bin ‘n’H	The higher limit of bin ‘n’
bin ‘n’L	The lower limit of bin ‘n’
CAL	Normal measurement accuracy and speed.
cLEAr Abs	*All* bin memories for absolute mode have been cleared *except* the bin 1 limit just entered.
cLEAr PErc	*All* bin memories for percentage deviation have been cleared, *except* the nominal just entered.
c not l	Limit required is capacitance, not inductance.
c not r	Limit required is capacitance, not resistance.
Error	The last key instruction did not make sense and has been ignored.
Hold.r	Overload when range Hold has been selected.
LOCAL	GPIB control not in use.
l not c	Limit required is inductance, not capacitance.
l not r	Limit required is inductance, not resistance.
nEEd bin ‘n’H (or L)	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., Low value proposed exceeds existing Hi value). Also shown if same value attempted for Hi and Low. Use correct units or recall appropriate Limit (Hi or Low) 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 keystroke is ignored.
O.C.	Open-circuit trim in progress.
o.d.r.	Outside % display range. Magnitude >99.99%.
o.r.	Outside range. Beyond the 7330 computation capability (e.g., if L or R is selected, in the Parallel mode, at 1kHz, with no component connected).
rESEt	Non-volatile memory has been corrupted. Re-trim and repeat bin set-ups.
r not c	Limit required is resistance, not capacitance.

r not l	Limit required is resistance, not 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 present too large for Trim s/c or too small for Trim o/c. Check connections.
UNCAL	Fast measurement speed. Low accuracy.

5.16 GPIB Operation

Use the following steps for GPIB operation.

1) Select Sort mode.
2) Select single-shot mode (LED on Measure/Continuous key extinguished). See section 5.11.
3) Enter GPIB address 99. This brings the Handler into operation and inhibits normal operation of the GPIB facility.

5.17 High Speed Operation

A fast mode enables the 7330 to achieve a measurement cycle in 200-350ms (dependent upon range) at 1kHz and at 10kHz with a basic accuracy of 0.5%.

5.17.1 Selection

1) Press: Shift
   Cal/Uncal
2) Utilizing GPIB Interface (address lower than 30 selected), use GPIB command UNCAL.

5.17.2 De-selection

1) Press: Shift
   Cal/Uncal
2) Utilizing GPIB Interface, use GPIB command CAL.

6. GENERAL THEORY OF OPERATION

6.1 Handler Interface.

The GPIB (IEEE-488) Interface port can be used to interface to component handlers, making use of the binning features of the 7330 and, when required, the high speed operation (see section 5.17). The Handler Interface enables the 7330 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:

In this text 'low' refers to a TTL logic level between 0 and 0.8 V and 'high' is a TTL level between 2.4 and 5V.

6.1.1 Operation

1) Select 'Sort' mode
2) Select single-shot mode (LED on Measure/Continuous key extinguished - see section 5.11)
3) Enter GPIB address 99. This brings the Handler into operation and inhibits normal operation of the GPIB facility.

6.1.2 Interface Details

The functions of the Interface lines are defined below:

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	$\overline{\text{BIN 1}}$	Going low indicates a result in bin 1
3	$\overline{\text{BIN 2}}$	Going low indicates a result in bin 2
4	$\overline{\text{BIN 3}}$	Going low indicates a result in bin 3
13	$\overline{\text{BIN 4}}$	Going low indicates a result in bin 4
14	$\overline{\text{BIN 5}}$	Going low indicates a result in bin 5
15	$\overline{\text{BIN 6}}$	Going low indicates a result in bin 6
16	$\overline{\text{BIN 7}}$	Going low indicates a result in either bin 7, 8 or 9.
24	GND	Electrical Ground

Fig 6–1 Interface Lines

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:

- Null
- Ready for Trigger
- Busy
- Not Busy

6.1.2.1 Null State

The Null state is defined as:

$\overline{\text{BUSY}}$ low	(i.e., machine is busy)
$\overline{\text{BDA}}$ high	(i.e., no data available)
All $\overline{\text{BIN}}$ lines high	(i.e., no bins selected)

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

- The machine is not in Sort mode.
- The machine is not in Single shot mode.
- The machine is Trimming.

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

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

6.1.2.2 Ready for Trigger

In this state:

$\overline{\text{BUSY}}$ is high	(i.e., not busy)
$\overline{\text{BDA}}$ is low	(i.e., bin data is valid)

All $\overline{\text{BIN}}$ lines will be unchanged. If the previous state was a null, then all $\overline{\text{BIN}}$ lines will be high, meaning no bin selected, although $\overline{\text{BDA}}$ 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 $\overline{\text{TRIGGER}}$ line.

When the machine receives a trigger, it will respond by entering the next state.

6.1.2.3 Busy

In this state:

$\overline{\text{BUSY}}$ is low	(i.e., the machine is busy)
$\overline{\text{BDA}}$ is low	(i.e., 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.

6.1.2.4 Not Busy

In this state:

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

In this state the machine has finished with the component under test, which may be removed and replaced by 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 four states has been completed without interruption, the 7330 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 (e.g., Hold.r).

6.1.3 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 measurement triggering the next, then a circuit such as that given below should be used.

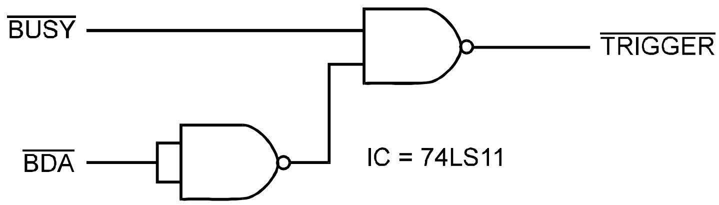


Fig 6–2 External Trigger Circuit

Note:

The 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 measurement and restart another.

6.1.4 Output Drive Levels.

Low state: <0.5V at 48mA

High state: BIN 0 to BIN 7 >2.4V at -5.2 mA.

6.2 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 7330 determines automatically which form is the more generally useful (series for impedances below 1000Ω, parallel above 1000Ω). 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 a circuit are shown in Fig 6–3 below:

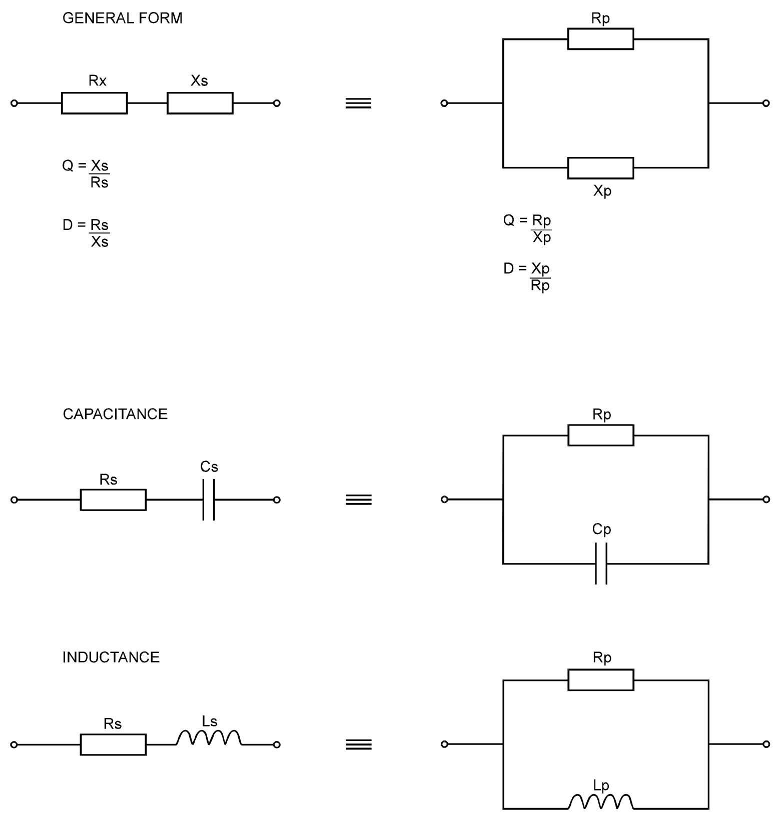


Fig 6–3 Series/Parallel Equivalent Circuits

The computations made by the 7330 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.

6.3 High Speed Operation

A fast mode enables the 7330 to achieve a measurement cycle in 200-300ms (dependent upon range) at 1kHz and at 10kHz with a basic accuracy of 0.5%.

6.3.1 Selection

1) Press: Shift
   Cal/Uncal

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

6.3.2 De-selection

1) Press: Shift
   Cal/Uncal

2) Utilizing GPIB Interface, use GPIB command CAL.

6.4 GENERAL PURPOSE INTERFACE BUS (GPIB).

6.4.1 IEEE Std 488-1978

The 7330 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 7330 is to be incorporated successfully into a system.

Addresses 0 to 30 inclusive are for the full remote control mode. Addresses 31 to 98 cover the data output only mode. Address 99 is the bin handler interface. To change address, press Shift followed by GPIB. The current address will then be displayed. Use the keypad to overwrite with the new address required, which will be retained until a further change is made. After 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.

6.4.2 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
TE0	Extended Talker - no capability
L4	Basic Listener - no Listen Only, Unaddressed if MTA
LE0	Extended Listener - no capability
SR1	Service Request
RL1	Remote/Local Function - complete capability
PP0	Parallel Poll - no capability
DC1	Device Clear - complete capability
DT1	Device Trigger - complete capability
C0	Controller - no capability

6.4.2.1 Command Format

The IEEE bus control codes (section 6.4.2.8) contain 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 shown below:

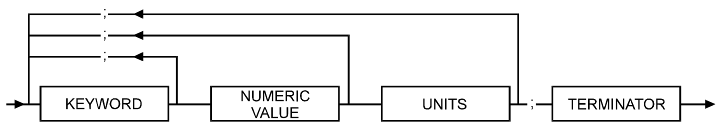


Fig 6–4 GPIB Command Syntax

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 1k ohms;L0 900 oh;SORT;

terminated as in a, b, c, or d shown above.

6.4.2.2 Command Errors

Command errors will be encoded in the status byte (see section 6.4.2.9). 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.

6.4.2.3 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.

6.4.2.4 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 below.

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

6.4.2.5 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, GPIB, 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 30, the Talk Only mode will be selected as indicated by t.o. in the display window.

6.4.2.6 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
105.13kohm  100Hz  Par
105.12kohm  100Hz  Par
105.12kohm  100Hz  Par
    11.8pF  100Hz  Par
    13.3pF  100Hz  Par
     8.1pF  100Hz  Par
    13.7pF  100Hz  Par
```

6.4.2.7 Programming

When using the 7330 on the GPIB, it is necessary to take some basic precautions when the command string to the 7330 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 7330 has completed the measurement successfully.

Section 6.4.2.10 contains some sample programs for control of the 7330 from typical GPIB controllers.

6.4.2.8 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	millifarads
MH	mHenrys	millihenrys
MO	Mohms	Megohms
NO	Nominal	
NF	nFarads	nanofarads
OH	ohms	
O/	O/C trim	open circuit trim
PA	Parallel	
PF	pFarads	picofarads
Q	Q value	
R	Resistance	

Minimum Abbreviation	Full Expression	Remarks
RA	range	= Shift, Range no
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	microfarads
UH	uHenrys	microhenrys
UNC	Uncalibrated	
V	Value	
%	%	no toggle

6.4.2.9 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
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

Display	Error Code (Decimal)	Description
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

6.4.2.10 Sample Programs for Control of 7330 from Typical IEEE Controllers.

Program 1

```
5 REM CONTROL OF LCR METER 7330 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 7330 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 O 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,"0"
S810 GOIF,NOGO,S830
S820 SLET, N2="BIN 3 ENTRY MISSING"
S830 SCOMP, N3,"P"
S840 GOIF,NOGO,S860
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 SOIF,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,"^"
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 7330 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
```

6.5 SYSTEM DESCRIPTION.

6.5.1 Microprocessor Control

All functions of the system 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

6.5.2 Basic Measurement

Refer to Fig 6–5; 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 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.

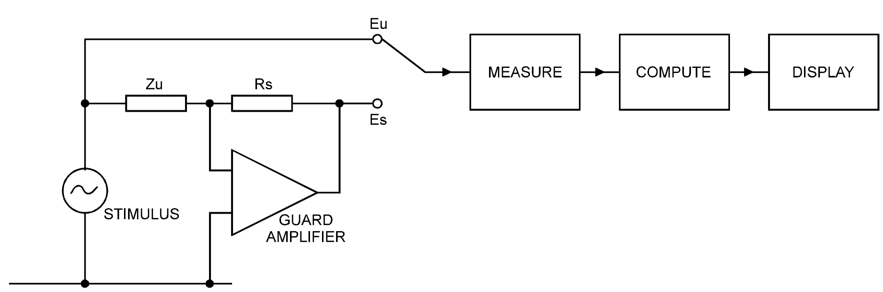


Fig 6–5 Basic Measurement

6.5.3 Overall System

A block diagram of the complete system (excluding power supplies) is shown in Fig 6–6 Block Diagram; refer also to the Main PCB circuit diagram - digital and analogue sections. In Fig 6–6 the microprocessor is shown at the right-hand end of the 8-bit data bus. Near to it is the 16.32MHz square-wave source IC101, from which all clock and measure frequencies are derived. A square-wave at the selected test frequency is produced by the final divider, IC112 and 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.

From the values of Eu, Es and the standard resistor, the value of the unknown can be computed.

To achieve the specified impedance coverage, ranging is used. The Impedance Chart (Fig 5–5) shows the coverage applicable at each of the three test frequencies.

Ranging is provided by the precision attenuator associated with IC138 and IC139. The phase information in Eu and Es is extracted by the phase-sensitive detector IC144. By multiplying the unknown ac 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 ac voltage from the phase-sensitive detector is integrated (on C145) for 20ms (in the 50Hz version) together with dc 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, IC110.

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.

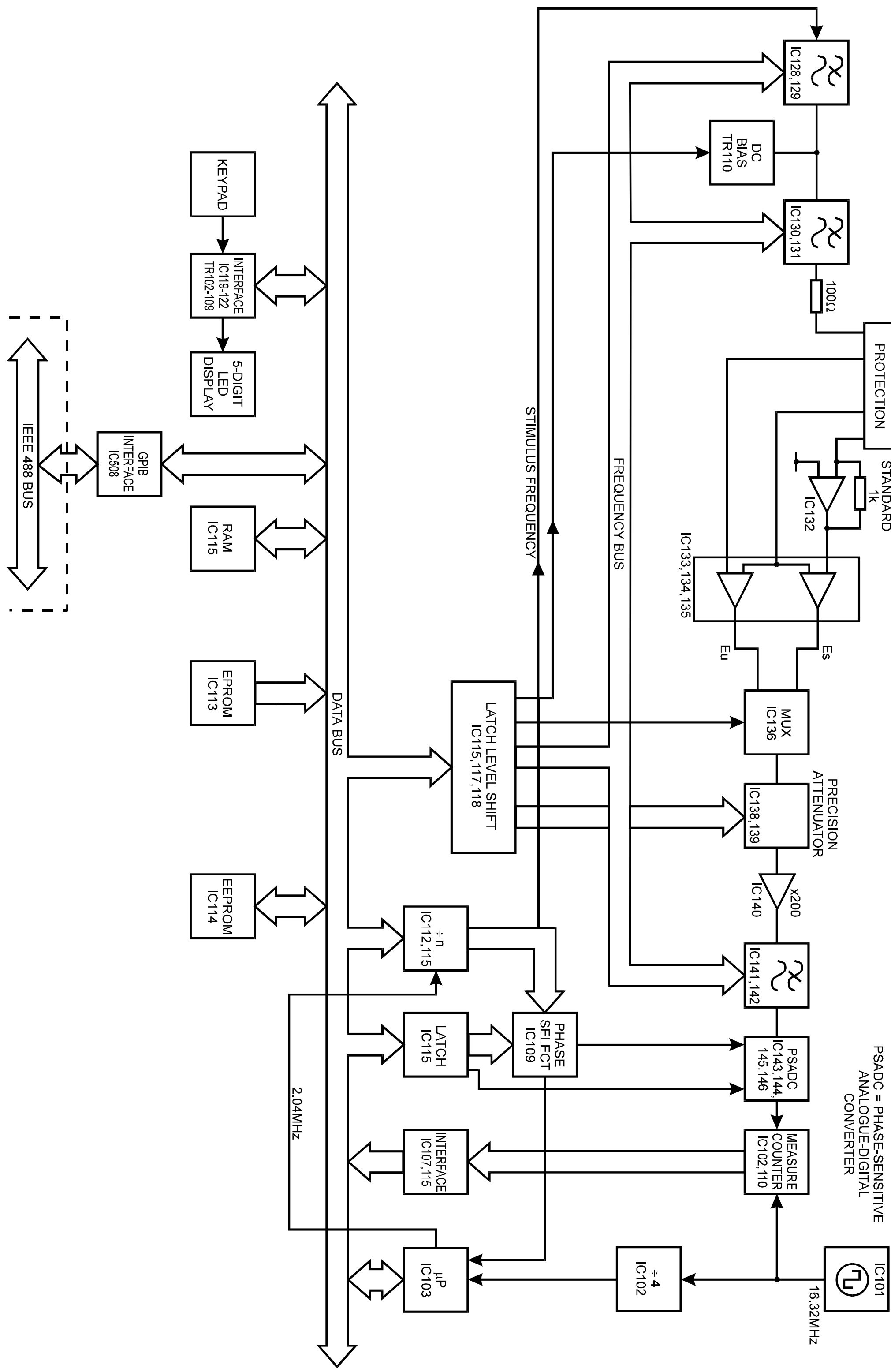


Fig 6–6 Block Diagram

6.5.4 Digital Circuits

Refer to the Main PCB circuit diagram - digital section; the 16.32MHz 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 takes 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

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

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

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 re-synchronizing 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 synchronization provided by IC111 (pins 2-6).

When the voltage on C145 (Main PCB circuit diagram - analogue section) 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 (Main PCB circuit diagram - digital section) 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 ac 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 ready 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.

The digits of the matrix are scanned by IC120, producing a binary count at SL0, 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 RL0 - RL7. IC120 debounces the switch operations which are notified to the microprocessor by asserting interrupt RST6.5 (pin 8).

6.5.5 Analog Circuits

The square wave at measure frequency is level shifted and cleaned by IC127a, b and c. 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 polarizing 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 ground 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 (pin 2) 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.

6.5.6 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.

6.5.7 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).

6.5.8 GPIB Board

Refer to the GPIB board circuit diagram; this circuit interfaces between the IEEE 488 bus and the microprocessor bus, with the IC506 handing the 488 bus protocol.

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

During a read to or write from the GPIB, the register addresses RS0 to RS2 are de-multiplexed 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 GPIB (i.e., $\overline{\text{CS7}}$ high) cause 02 of the GPIB to follow the $\overline{\text{RD}}$ or $\overline{\text{WR}}$ through IC503.

When the microprocessor reads from or writes to the GPIB, a wait state is introduced by IC511, READY is set low for one cycle of CLOCK OUT, to allow adequate set-up times before 02 going low strobes the data into GPIB during a write.

The GPIB 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.

The regulated voltage at PL502 pin 7 is coupled by a link on PL502 to pin 8, which allows testing of the regulator IC501 in isolation.

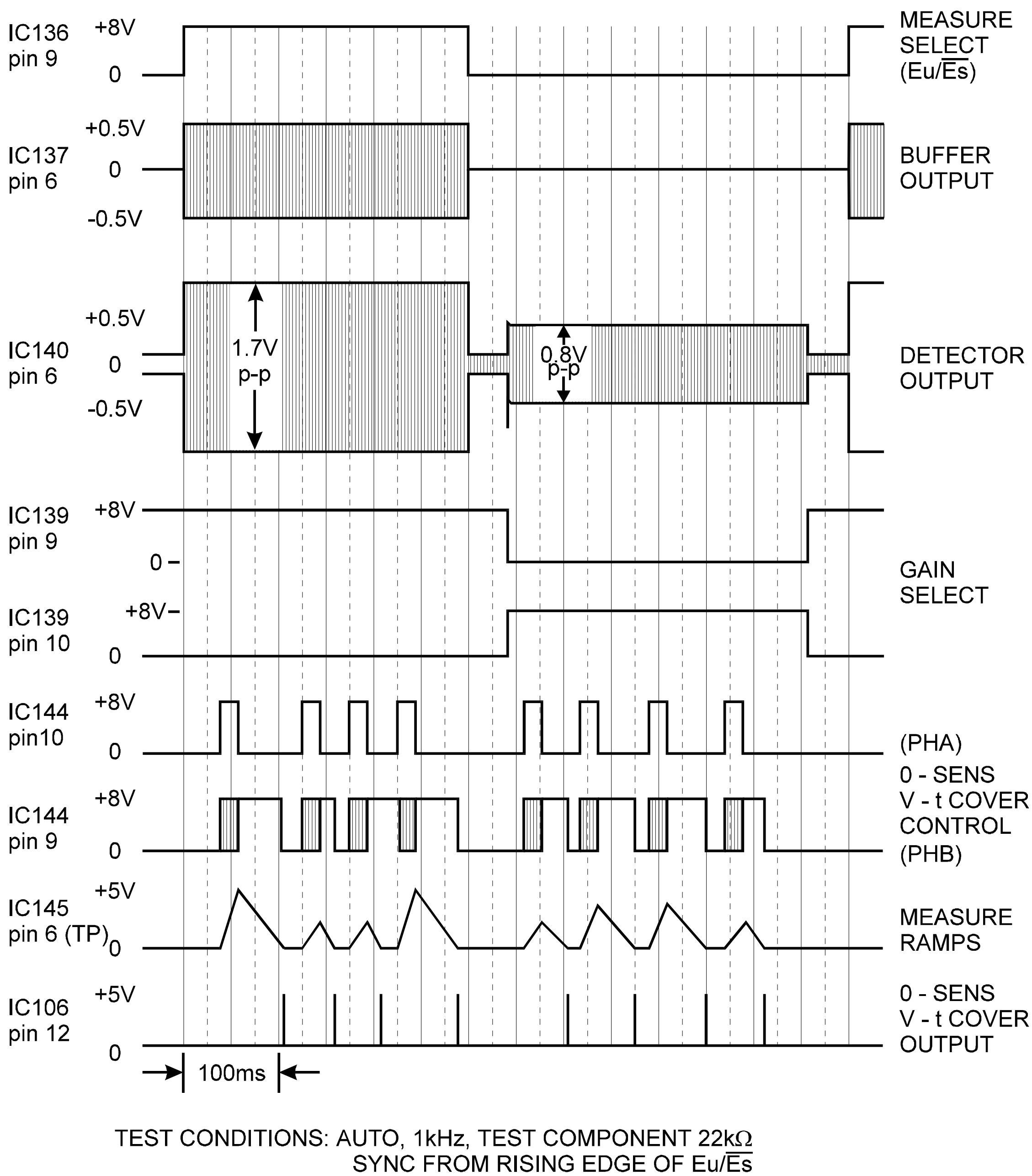


Fig 6–7 Timing Waveforms

7. MAINTENANCE

7.1 Cleaning

The body of the equipment can be cleaned with a damp lint-free cloth. Should it be required, weak detergents can be used. No water must enter the equipment. If the insides of the unit become clogged with dust, a service will be required. Do not attempt to wash down internal parts.

7.2 Safety Checks

Each year the equipment should be given a simple safety check.

7.2.1 Equipment required

25A earth bond tester (e.g. Megger PAT 2)

Insulation tester @ 500V DC (e.g. Megger BM 7)

7.2.2 Tests

Inspect the unit for dents or missing parts which might pose a threat to the unit's safe operation. Look for any signs of overheating or loosening of parts.

Earth bond. Ensure that 25A DC can flow from the exposed metal parts of the unit to the protective conductor (earth) in the mains cable (ignoring the resistance of the cable) with an impedance of less than 100mΩ.

Insulation test. Connect the Live and Neutral of the mains cable together and test the insulation between this point and the earth at 500V dc values greater than 1MΩ are acceptable.

7.3 Power Supply and Performance Checks

7.3.1 Test Equipment Required

1) Variac 500VA, 50/60Hz, Range 0 to 240V

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

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

4) Oscilloscope or distortion meter

5) Capacitors:

Capacitors:	1.50nF	±1%	Purity standard. Sealed polystyrene tanδ <0.0001 at 10kHz
	150pF	±1%	C values known to 0.01% at all three frequencies (100/120Hz, 1kHz, 10kHz). tanδ 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) Trimming tool

8) Extension leads

7.3.2 Dismantling

1) Disconnect the instrument from the AC supply.

2) Remove the two screws on each side of the instrument associated with the top cover and remove the cover.

3) Accessibility for checking and fault-finding is such that the boards need not be removed unless access is required to the copper side. In such instances, disconnect the associated leads and remove the board fixing screws. It will be necessary to make up extension leads for the power supply and display/keyboard connections. Also, provide temporary links on SK05 (see the Protection Circuit diagram) from pins 1 to 3 and - separately - from pins 9 to 11. Finally, the main board will not operate without the GPIB board connected. The ribbon to the latter should not be extended, so the board should also be removed.

7.3.3 Power Supply Checks

1) Remove the power supply isolation links from SK108 (refer to the Main Board Layout Diagram in section 9).

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

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

3) Set the Variac as follows:

115-volt operation:	103V
230-volt operation:	216V

Connect the Variac to the 7330 and switch on.

4) With the voltmeter on its 0-20V dc 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 AC supply, remove the three resistors from SK108 and refit the isolation links.

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

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

7) Change the voltmeter to its 0-20V dc range and check that the voltage across C111 (annotated on Main Board Layout Diagram) lies between 7.8V and 8.6V.

7.3.4 Source Sine Wave

1) Connect the voltmeter (0-1V ac 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.

7.3.5 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 other extinguished.

2) Connect the frequency counter to PL105 (annotated on Main Board Layout Diagram):

Lo to pin 3

Hi to pin 1

The reading should be:

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

3) Disconnect the counter.

7.3.6 Bias

1) With the voltmeter remaining on pins 3 and 1 of PL105, switch it to the 0-20V dc range. The dc voltage should be less than 20mV.
2) On the keypad, select C and Bias.
3) Check that the voltmeter now reads between 1.9 and 2.4V dc (PL105 pin 1 positive). Disconnect the voltmeter. Switch off and disconnect the Variac.

7.3.7 Reassembling

1) Disconnect the AC supply, remove the temporary links (if added) from SK05, and screw the boards in position.
2) Remake all connections to the boards. Check that the 40-pin DIL connections to the GPIB board are made correctly.
3) Check that the top cover is correctly orientated (the unused ground tag towards the rear) and refit the four screws.

7.3.8 Performance Checks

The following checks are made with the top cover removed for access to phase trims on the main board.

1) Connect the 7330 to the AC supply (230V or 115V, as appropriate) and observe the display at the moment of switch-on. It should show 7330.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 (see Main Board Layout Diagram, '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 operation) <u>or</u> -1172±20 (60Hz operation)

6) Remove purity standard. Press Shift, Trim o/c, C and 100/120Hz. 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) Connect a stout short-circuit across the measurement terminals.
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 four digits: known value ±20.

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

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

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

20) Select R and 10kHz. Should show four 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 four digits: known value ±11.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

44) Select 1kHz. Should show four digits: known value ±11.

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

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

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

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

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

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

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

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

53) Remove 150pF, connect 1.5nF. Press Shift, Hold 6. Select 100Hz. Should show four digits: known value ±35.

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

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

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

57) Remove 1.5nF, connect 15nF. Press Shift, Hold 6. Should show four digits: known value ±17.

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

59) Select C. Press shift, Hold, 5. Should show four 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 7330 and external items. It is likely that the nature of a malfunction will indicate the area of a fault. The table below is provided to assist users in checking interconnecting cables.

Pin No	Code	Function (active low)
1	D101	8 bit data bus Carries command messages from controller (ATN low) or output data from device (ATN high)
2	D102	
3	D103	
4	D104	
13	D105	
14	D106	
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

7.3.9 Troubleshooting

Troubleshoot the 7330 using the troubleshooting charts below:

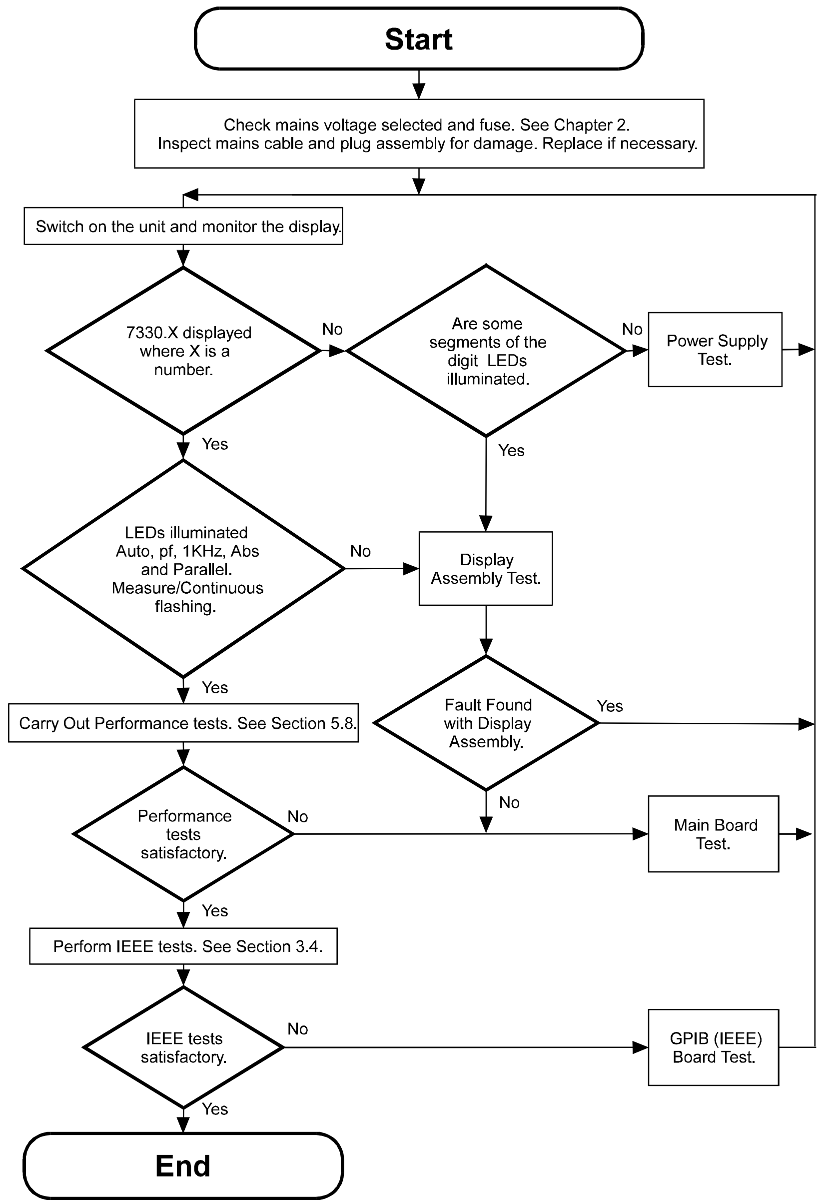


Fig 7–8 Troubleshooting Chart (Start)

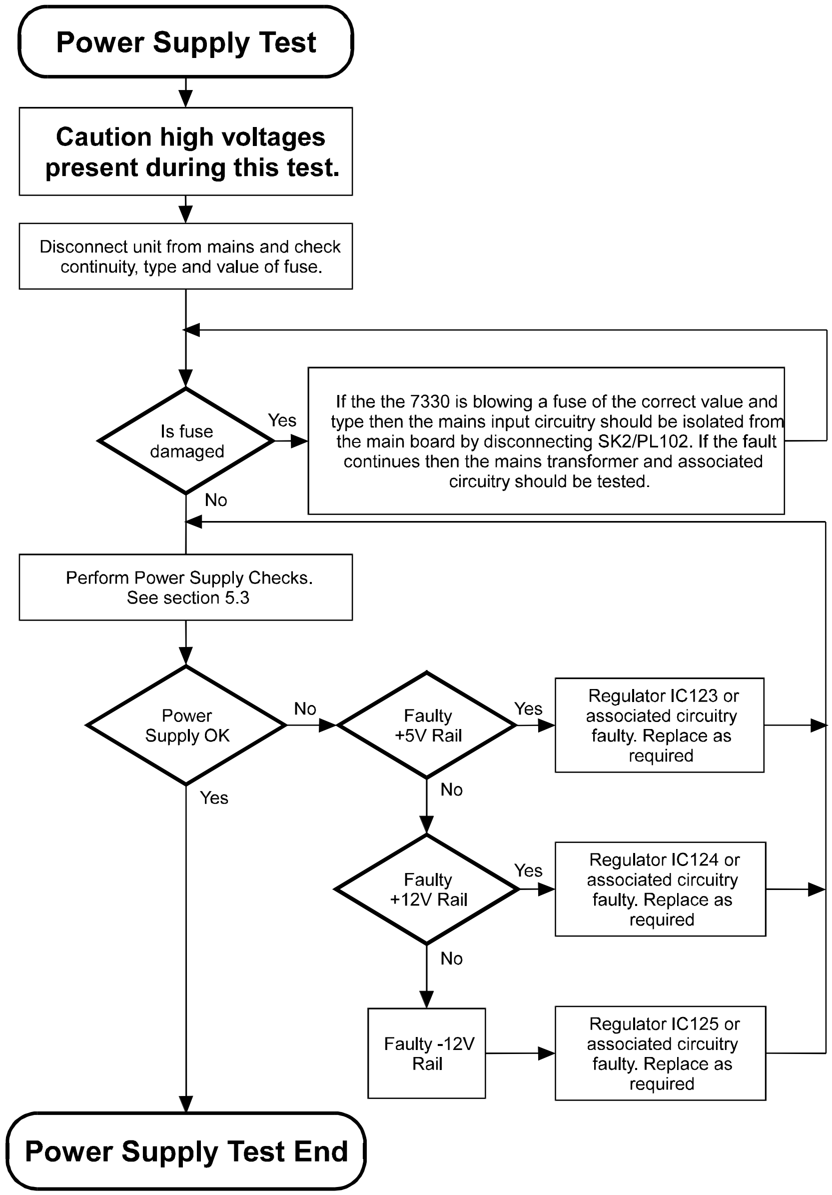


Fig 7–9 Troubleshooting Chart (Power Supply Test)

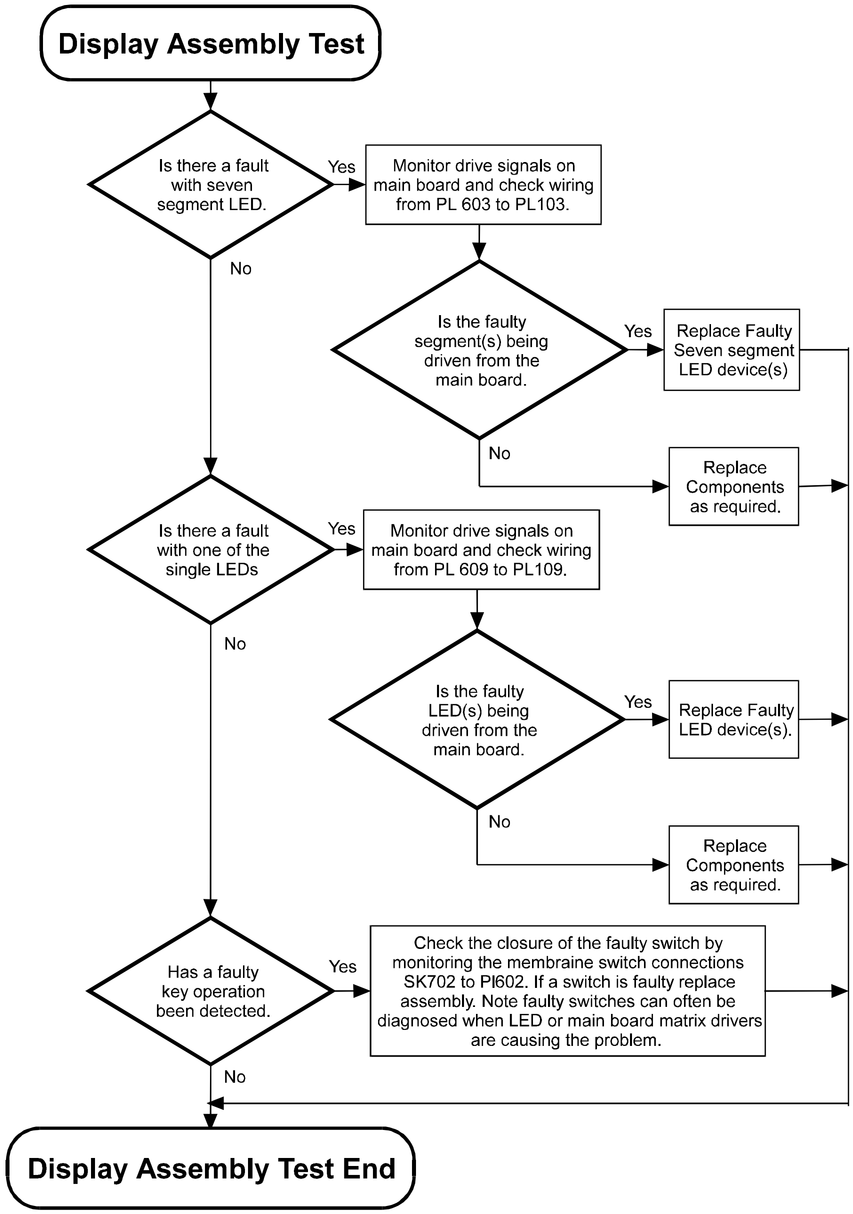


Fig 7–10 Troubleshooting Chart (Display Assembly Test)

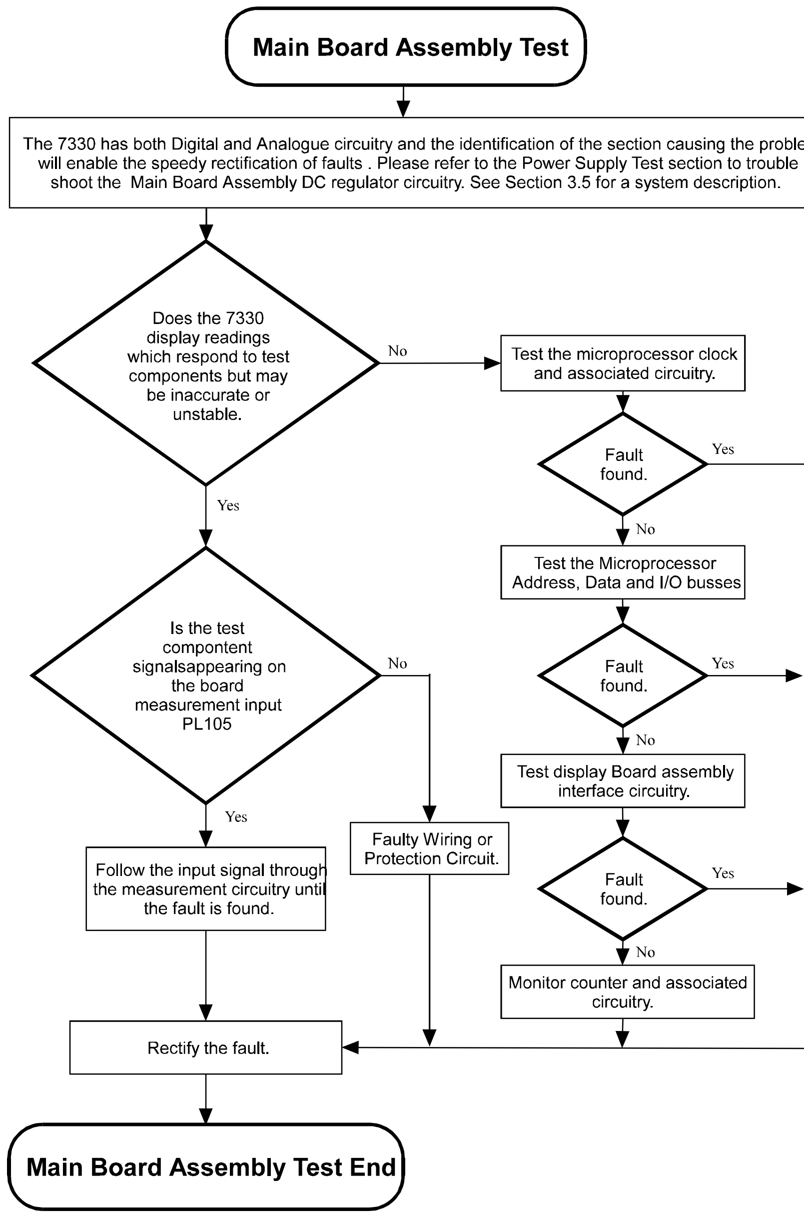


Fig 7–11 Troubleshooting Chart (Main Board Assembly Test)

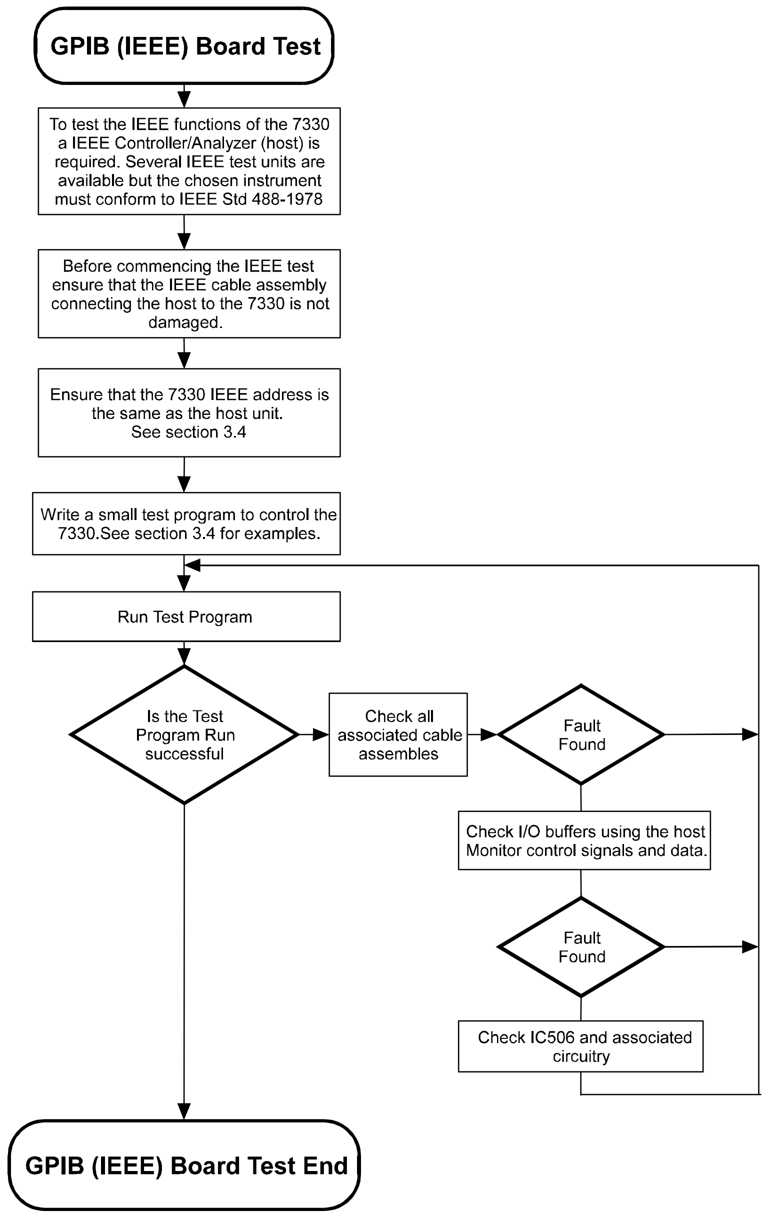


Fig 7–12 Troubleshooting Chart (GPIB (IEEE) Board Test)

8. COMPONENT SCHEDULES

RESISTORS

Ref	Value	Tol. (%)	Rating	Type	Supplier and 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

Ref	Value	Tol. (%)	Rating	Type	Supplier and Type No.
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
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

Ref	Value	Tol. (%)	Rating	Type	Supplier and Type No.
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
R1010	100R	5		Film	Mullard SFR25
R1011	1k0	1	100ppm	Metal Film	Allen Bradley FC55
R1012	470R	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

Ref	Value	Tol. (%)	Rating	Type	Supplier and Type No.
C1	220n		10V	Ceramic Disc	ITT/STC 811T
C101	2 m2	-10 +50	63V	Electrolytic	Mullard 030-38228
C102	4700 m		16V	Electrolytic	Mullard 03315472
C103	1000 m		25V	Electrolytic	Mullard 03216102
C104	1000 m		25V	Electrolytic	Mullard 03216102
C105	10 m		25V	Electrolytic	Mullard 01516109
C106	Not fitted				
C107	100 m		25V	Electrolytic	Mullard 01636101
C108	100 m		25V	Electrolytic	Mullard 01636101
C109	47 m		25V	Electrolytic	Mullard 01616479
C110	47 m		25V	Electrolytic	Mullard 01616479
C111	470 m		25V	Electrolytic	Mullard 03216471
C112	470 m		25V	Electrolytic	Mullard 03216471
C113	10 m		25V	Electrolytic	Mullard 01516109
C114	470p	2½	160V	Polystyrene	LCR FSC
C115	10 m		25V	Electrolytic	Mullard 01516109
C116	10 m		25V	Electrolytic	Mullard 01516109
C117	22n	2½	160V	Polystyrene	LCR FSC
C118	220p	2	63V	Polystyrene	Suflex PPS
C119	10 m		25V	Electrolytic	Mullard 01516109
C120	22n	2½	160V	Polystyrene	LCR FSC
C121	220p	2	63V	Polystyrene	Suflex PPS
C122	Not fitted				
C123	4 m7	5	100V	Polyester	Wima MKS-4
C124	1n	2½	160V	Polystyrene	LCR FSC
C125	4 m7	5	100V	Polyester	Wima MKS-4
C126	4 m7	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	20	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

Ref	Value	Tol. (%)	Rating	Type	Supplier and Type No.
C138	47n		40V	Ceramic Disc	ITT Transcap TD16/K3
C139	56p AOT	2½	160V	Polystyrene	LCR FSC
C140	6 m8	5	63V	Polyester	Wima MKS-4
C141	220n	5	100V	Polyester	Wima MKS-4
C142	8n2	2½	30V	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	100 m		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
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	10 m		25V	Electrolytic	Mullard 01516109
C164	10 m		25V	Electrolytic	Mullard 01516109
C165	10 m		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

Ref	Value	Tol. (%)	Rating	Type	Supplier and Type No.
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	47 m		25V	Electrolytic	Mullard 01616479
C184	47 m		25V	Electrolytic	Mullard 01616479
C185	47 m		25V	Electrolytic	Mullard 01616479
C186	56p	2½	160V	Polystyrene	LCR FSC
C187	100p	10	500V	Ceramic Disc	ITT CD08/N3300
C501	2200 m		16V	Electrolytic	Dubilier CEA 220016
C502	10 m	-10 +50	25V	Electrolytic	Mullard 03036109
C503	10 m		25V	Electrolytic	Mullard 03036109
C504	100n		63V	Ceramic	Siemens B37449
C505	100n		63V	Ceramic	Siemens B37449
C506	100n		63V	Ceramic	Siemens B37449
C507	100n		63V	Ceramic	Siemens B37449
C508	100n		63V	Ceramic	Siemens B37449
C509	100n		63V	Ceramic	Siemens B37449
C510	100n		63V	Ceramic	Siemens B37449
C511	100n		63V	Ceramic	Siemens B37449
C512	100n		63V	Ceramic	Siemens B37449
C515	2200 m		16V	Electrolytic	Dubilier CEA 220016

INTEGRATED CIRCUITS

Ref	Description	Supplier and Type No.
IC101	Oscillator 16.32 MHz ±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, 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

Ref	Description	Supplier and Type No.
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		Texas SN 74LS 10N
IC504		Texas SN 74LS 04N
IC505		Texas SN 74LS 75N
IC506		Motorola MC68488P
IC507		Motorola MC3448AP
IC508		Motorola MC3448AP
IC509		Motorola MC3448AP
IC510		Motorola MC3448AP
IC511		Texas SN 74LS 74N

DIODES

Ref	Description	Supplier and Type No.
D01		Mullard 1N4006
D02		Mullard 1N4006
D102		Mullard 1N4006
D103		Mullard 1N4006
D104	Bridge Rectifier	Internat'l Rectifier 1KAB10E
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 1N4148
D113		Mullard 1N4148
D114		Mullard 1N4006
D115		Mullard 1N4006
D116		Mullard 1N4006
D117		Mullard 1N4006
D118	4.7V	Mullard BZX79-C4V7

Ref	Description	Supplier and Type No.
D501		Mullard 1N4006
D502		Internat'l Rectifier 1N4148
D601-627	LED	IMO 5129 RD
D631-635	Display LED, 7 segment	Hewlett Packard 5082-7750

TRANSISTORS

Ref	Description	Supplier and Type No.
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

Ref	Description	Supplier and Type No.
FS01-04	1.6 A Quick blow 20x5mm	Little Fuse EA
FS1	Fuse 160 mA-T (230V)	Beswick TDC 212
FS1	Fuse 315 mA-T (115V)	Beswick TDC 212
GD01-GD03	Gas discharge tube	Cerberus UC90Q
L101	Inductor 3 µH3	Sigma SC10
L102	Inductor 3 µH3	Sigma SC10
Toroid	2643804502 (43 Mat'l)	Fair-Rite
LK101	Link	B.T. Cu wire 1/0.7
PL1	Power Inlet, Filtered	Belling-Lee L2131C/6/5
PL3	Crimp connector bullet male	Takbro/Majortek FVDGM 1,25-5
PL101	40-way connector DIP Plug	R Nugent IDP C406-TG
PL102	Connector Elect. Wafer	Molex 3003 10-08-1061 6-way
PL105	Plug (Modified MKS)	WKR 5-524-5460
PL106	Connector Elect. Header	Spectra-Strip 800-583 2 x 13-way
PL108	Programmable Header	Aries 8-680-191T
PL109	Wafer 3-way 0.1"	Panduit ML55100-03-C
PL306	(Part of Membrane Keypad)	
PL502	Connector MKS 3750-1-0-2020	Stocko
PL602	12-way (rt. angle) Wafer, Series	4094 Molex 22-05-1122
PL606	26-way Connector	R Nugent IDH-26PK1-SR3-TG

Ref	Description	Supplier and Type No.
PL609	3-way MKS	Stocko 3733-1-0-303
SK01-SK04	BNC Insulated	Belling-Lee LXD4-0503-22-00-5N
SK2	6-way Connector	Molex 10-01-1064
SK4	Receptacle, insulated, red	Stocko RSVP7543 F6,3-1
SK5	(Part of Connection Fixture)	
SK101	40-pin DIL Socket	R Nugent ICN-406-S4-TG
SK106	15-way Connector Housing E5051	Molex 22-01-1153
SK108	IC Socket DIL 8 pin	R Nugent ICN-083-S3T
SK109	3-way Connector Housing	Molex 22-01-1033
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	Panduit CE100F 24-3-C
SK502	20-way Connector	Stocko MKF 17380-1-0-2020L
SK503	24-way Connector	Amphenol 57-20240/2
SK609	3-way Connector	Stocko MKF17363-1-0-303
SK903	15-way Connector Housing E5051	Molex 22-01-1153
SW1	Power Rocker Switch	Arrow Hart 2600-11E
SW2	Slide Switch	Stackpole S5022CD03-0
T1	Power Transformer	WKR 4-524-5474
TC501	40-way connector	R Nugent IDL C40-1-T
Front Panel PCB Assy		WK Part Code 5-530-7111
Main PCB Assy		WK Part Code 5-524-5496
Kelvin Clip Leads (Mk II-1605)		WK Part Code 5-385-5724

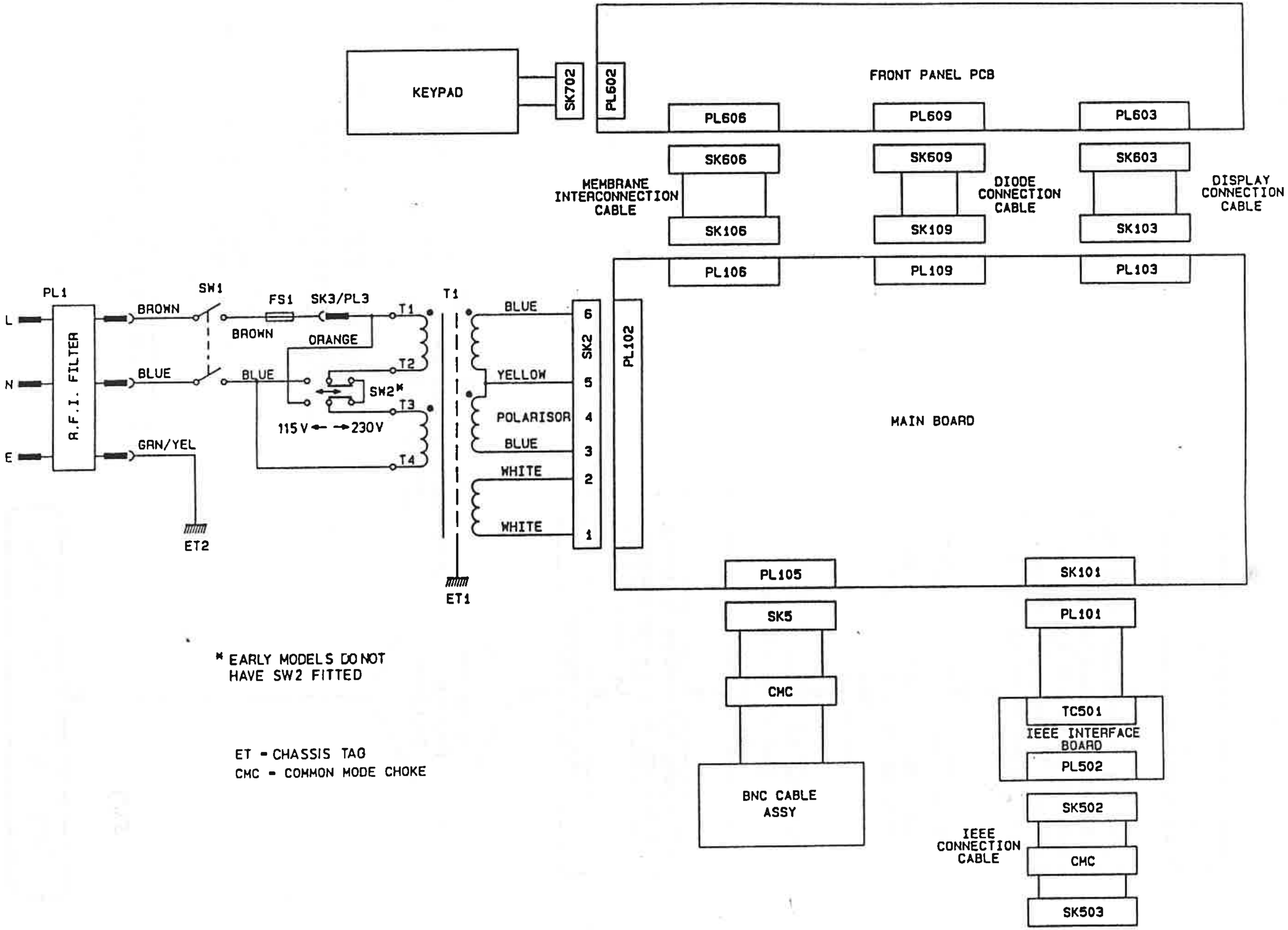
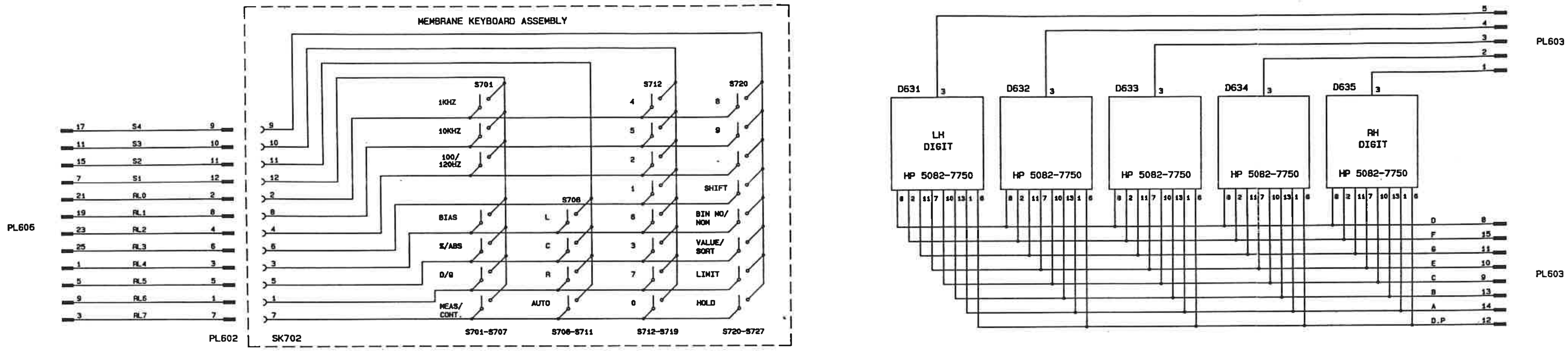
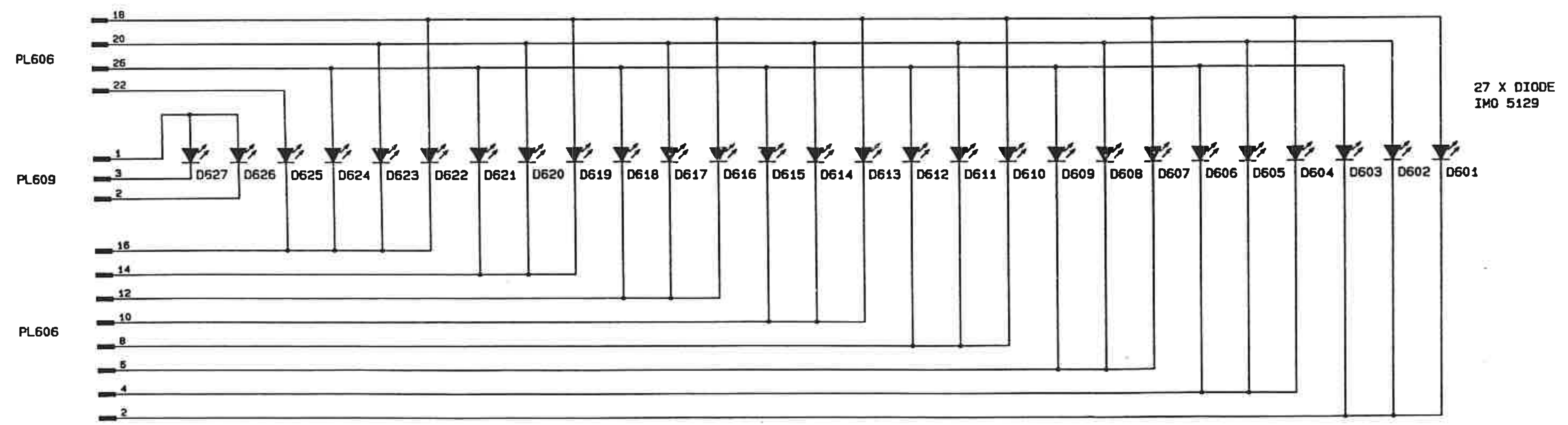


Figure 5-3. Interconnection Diagram (DW2/27402/P2)





D601 1kHz
D602 mF
D603 H
D604 10kHz
D605 µF
D606 mH
D607 100/120Hz
D608 nF
D609 µH
D610 HOLD
D611 pF
D612 MOhms
D613 AUTO
D614 BIAS
D615 kOhms
D616 R
D617 % (NEXT TO mF)
D618 Ohms
D619 C
D620 D
D621 PARALLEL
D622 L
D623 Q
D624 SERIES
D625 MEASURE/CONTINUOUS
D626 ABSOLUTE
D627 % (NEXT TO ABSOLUTE)

Figure 5-4. Keypad/Display Circuit Diagram (DW1/27109/P1)

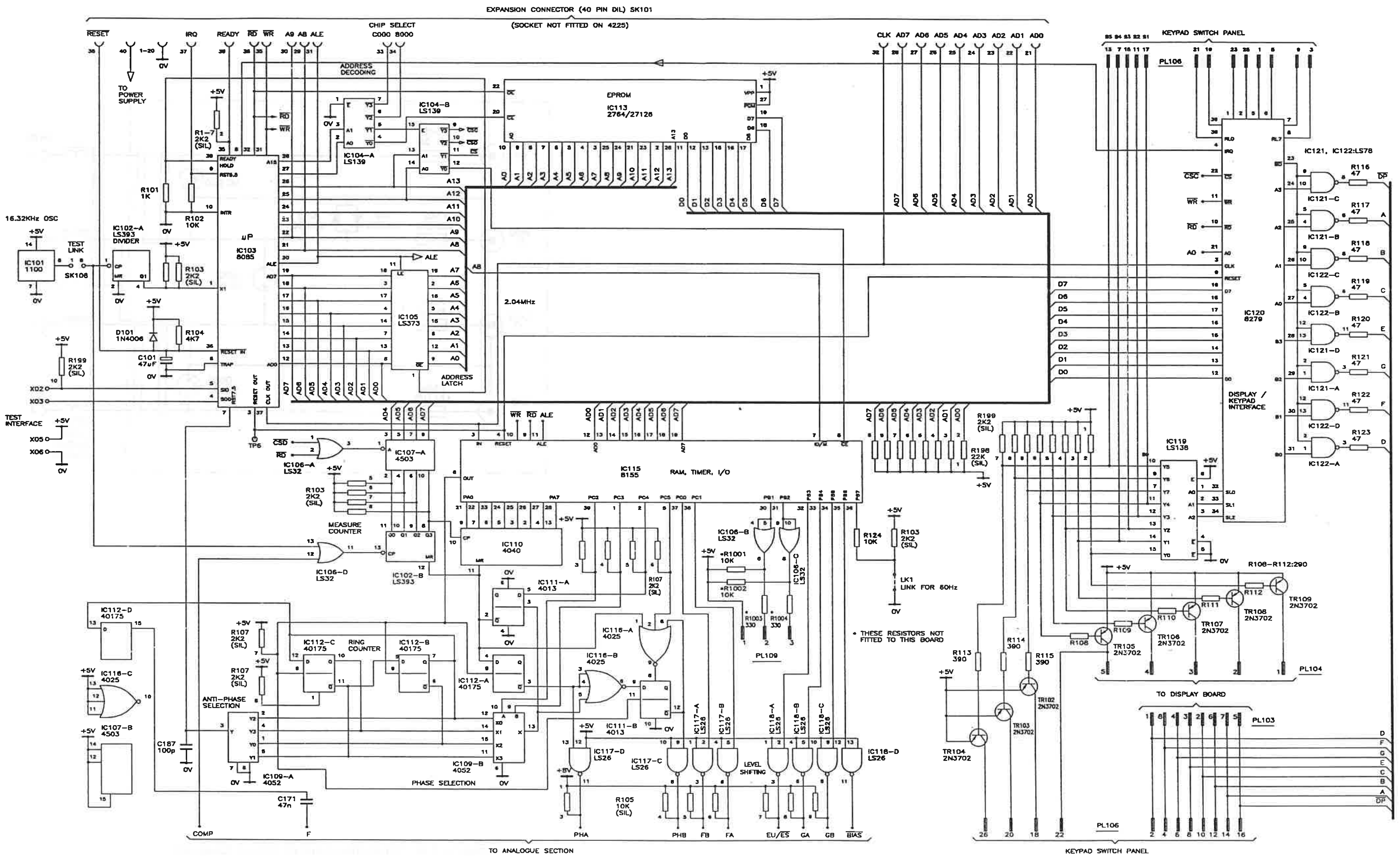


Figure 5-5. Digital Circuit Diagram (DW1/25495/Sht1/P3)

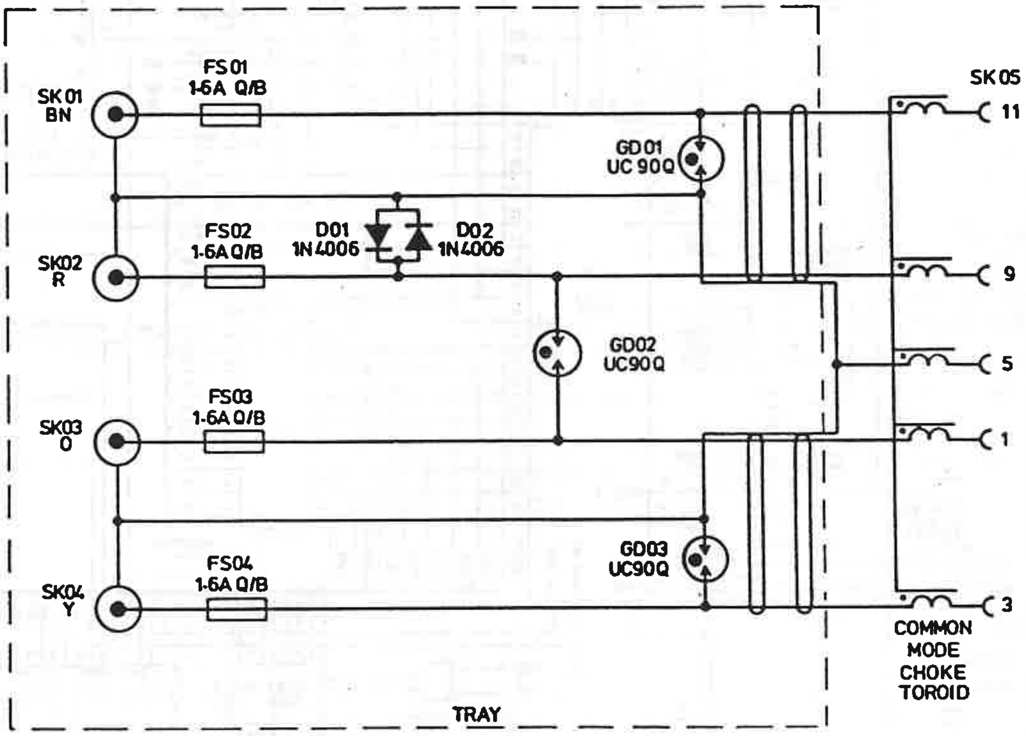


Figure 5-6. Protection Circuit, Circuit Diagram

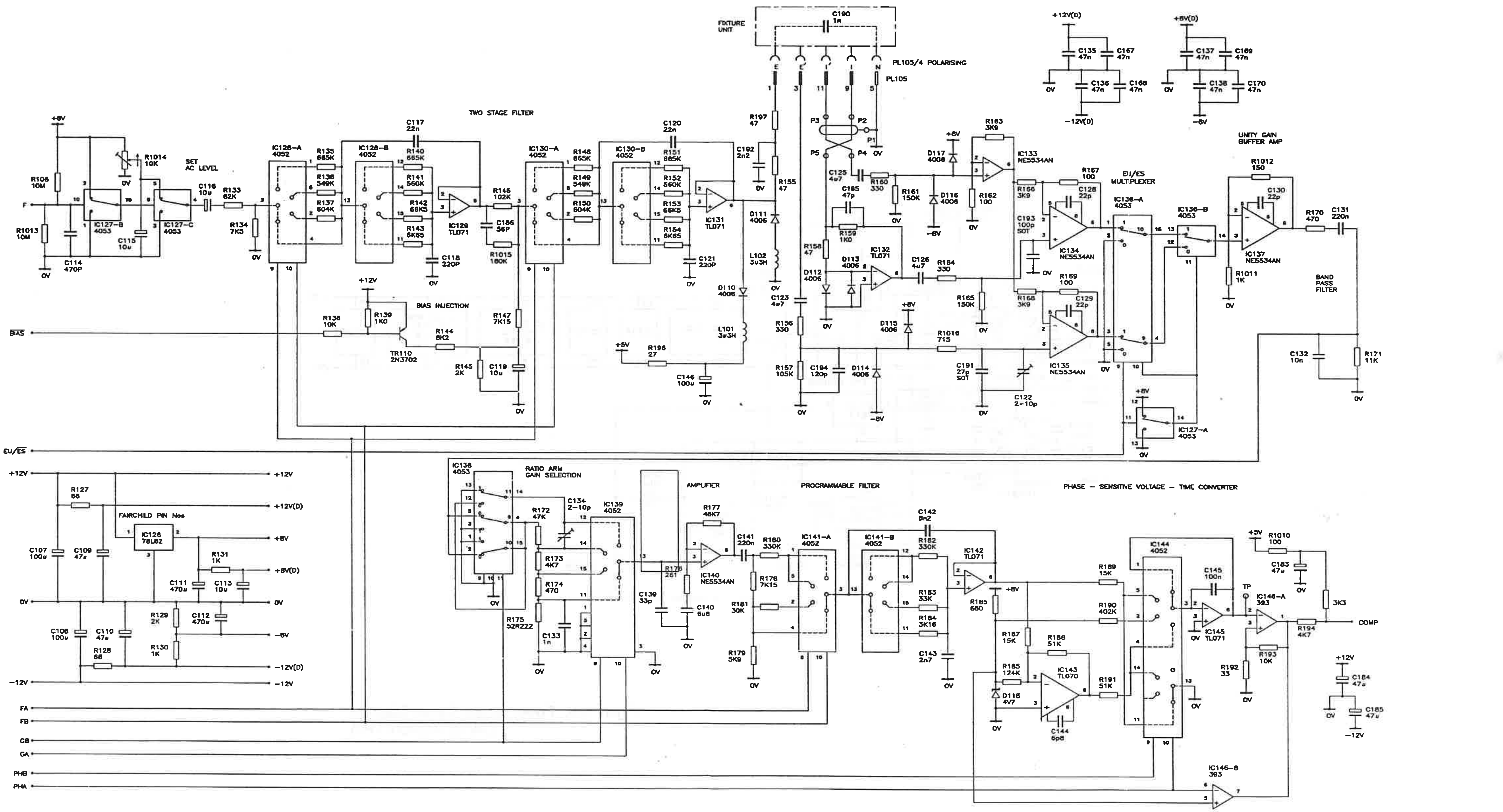


Figure 5-7. Analog Circuit Diagram
(DW1/25495/Sht2/P3)

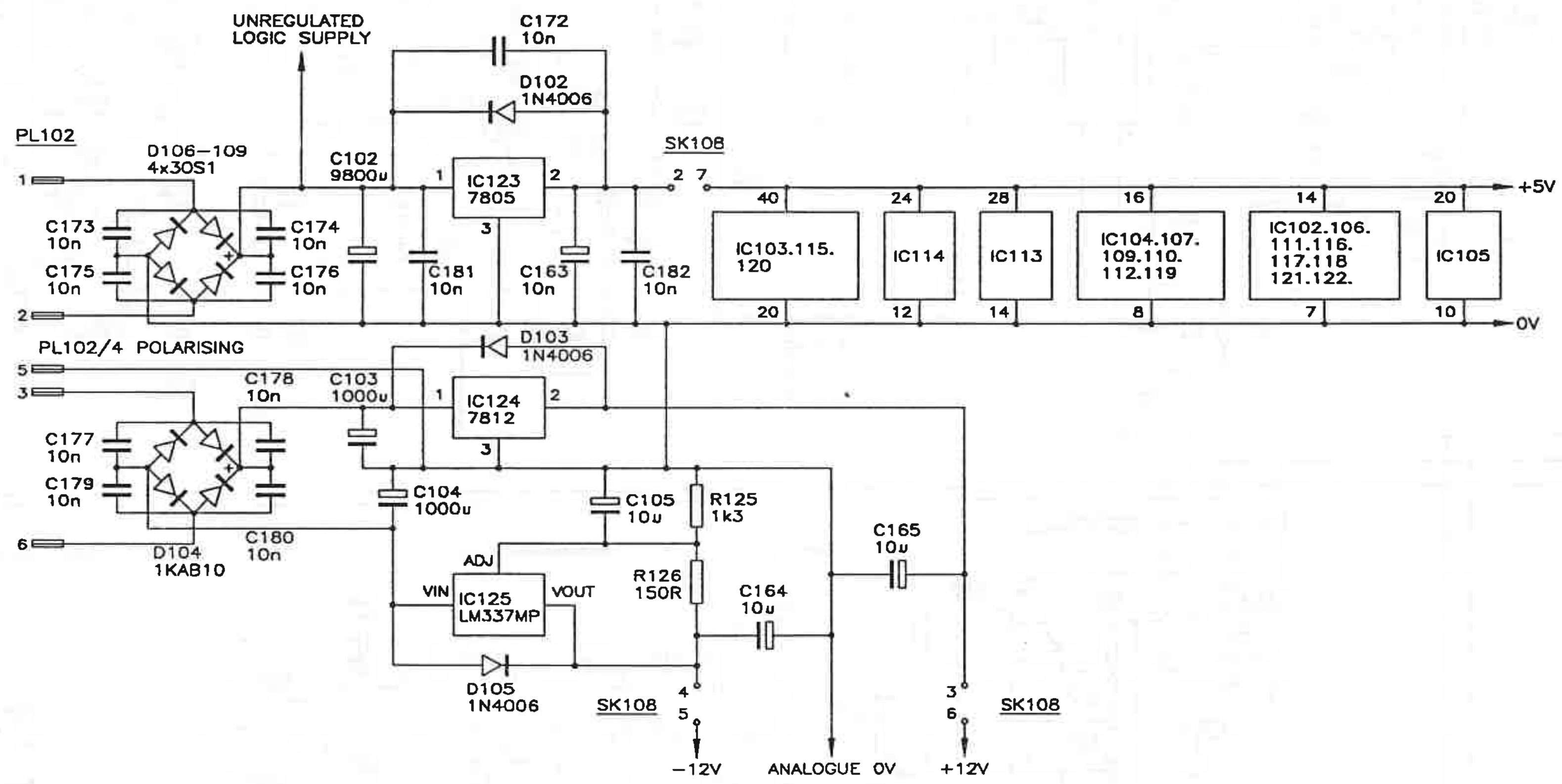


Figure 5-8. Power Supply Circuit Diagram (DW1/25495/Sht3/P2)

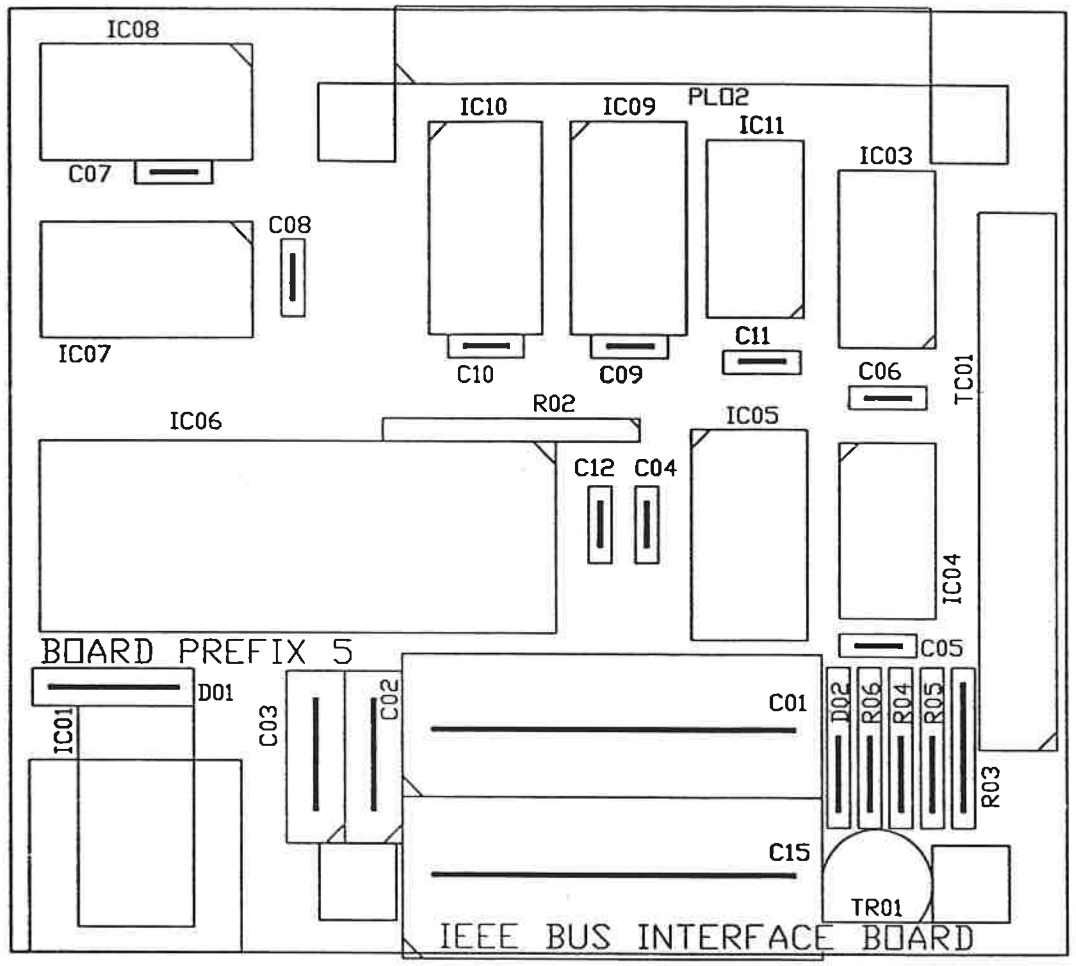


Figure 5-9. GPIB (IEEE) PCB Layout

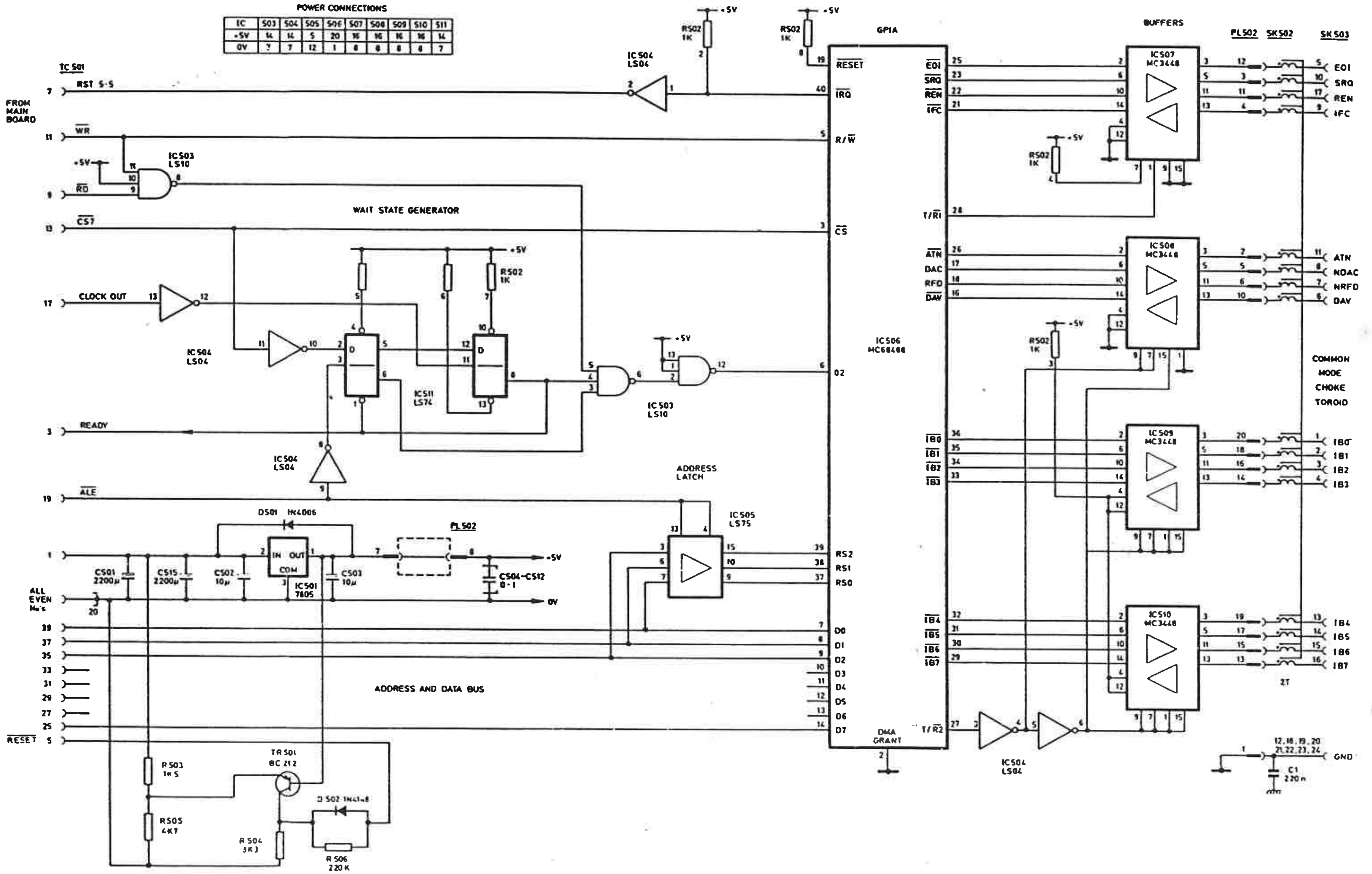


Figure 5-10. GPIB (IEEE) Circuit Diagram (DW2/25466/P3)

10. SUPPORT AND SERVICES

10.1 Guarantee

The equipment supplied by Wayne Kerr Electronics Limited is guaranteed against defective material and faulty manufacture for a period of twelve months from the date of despatch. In the case of material or components employed in the equipment but not manufactured by us, we allow the customer the period of any guarantee extended to us.

The equipment has been carefully inspected and submitted to comprehensive tests at the factory prior to dispatch. If, within the guarantee period, any defect is discovered in the equipment in respect of material or workmanship and reasonably within our control, we undertake to make good the defect at our own expense subject to our standard conditions of sale. In exceptional circumstances and at the discretion of the Service Manager, a charge for labour and carriage costs incurred may be made.

Our responsibility is in all cases limited to the cost of making good the defect in the equipment itself. The guarantee does not extend to third parties, nor does it apply to defects caused by abnormal conditions of working, accident, misuse, neglect or wear and tear.

10.2 Maintenance

In the event of difficulty, or apparent circuit malfunction, it is advisable to telephone (or fax) the Service Department or your local Sales Engineer or Agent (if overseas) for advice before attempting repairs.

For repairs and maintenance it is recommended that the complete instrument be returned to one of the following:

UK

Wayne Kerr Electronics Ltd
Durban Road,
BOGNOR REGIS,
West Sussex,
P022 9RL,
United Kingdom.

Tel: 01243-825811
Fax: 01243-824698
Telex: 86420 Wayren G

USA

Wayne Kerr Inc.,
11 Sixth Road,
Woburn,
Massachusetts 01801,
United States of America.

Tel: (781) 9388390
Fax: (781) 9339523

Germany

Wayne Kerr
Dieselstrasse 21,
63533 MAINHAUSEN,
Germany

Tel: (61) 8226024
Fax: (61) 8227905

Italy

Advance Italia SRL,
via F.IIi Cernuschi 22,
22055 Merate (COMO),
Italy

Tel: (39) 9907612
Fax: (39) 599213

When returning the instrument please ensure adequate care is taken with packing and arrange insurance cover against transit damage or loss. If possible re-use the original packing box.