Marconi
Instruments

6960

RF POWER METER

Operating Manual

Operating Manual
H 6960
Vol.1

RF POWER METER

6960

Code Nos. 6960
6960-001

CONTENTS

PRELIMINARIES

CHAPTERS

HAZARD WARNING SYMBOLS

The following symbols appear on the equipment

Symbol	Type of Hazard	Reference in manual
⚠	Static sensitive device	Page (iv)
⚠	Dangerous voltages present	Page (iii)
⚠	Supply voltage	Chap.2, page 2

NOTES AND CAUTIONS

ELECTRICAL SAFETY PRECAUTIONS

This equipment is protected in accordance with IEC Safety Class 1. It has been designed and tested according to IEC Publication 348, 'Safety Requirements for Electronic Measuring Apparatus', and has been supplied in a safe condition. The following precautions must be observed by the user to ensure safe operation and to retain the equipment in a safe condition.

Defects and abnormal stresses

Whenever it is likely that protection has been impaired, for example as a result of damage caused by severe conditions of transport or storage, the equipment shall be made inoperative and be secured against any unintended operation.

Removal of covers

Removal of the covers is likely to expose live parts although reasonable precautions have been taken in the design of the equipment to shield such parts. The equipment shall be disconnected from the supply before carrying out any adjustment, replacement or maintenance and repair during which the equipment shall be opened. If any adjustment, maintenance or repair under voltage is inevitable it shall only be carried out by a skilled person who is aware of the hazard involved.

Note that capacitors inside the equipment may still be charged when the equipment has been disconnected from the supply. Before carrying out any work inside the equipment, capacitors connected to high voltage points should be discharged; to discharge mains filter capacitors, if fitted, short together the L (live) and N (neutral) pins of the mains plug.

Mains plug

The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. The protective action shall not be negated by the use of an extension lead without protective conductor. Any interruption of the protective conductor inside or outside the equipment is likely to make the equipment dangerous.

Primary fuses

Note that there is a supply fuse in both the live and neutral wires of the supply lead. If only one of these fuses should rupture,certain parts of the equipment could remain at supply potential.

To provide protection against breakdown of the supply lead, its connectors, and filter where fitted, an external supply fuse (e.g. fitted in the connecting plug) should be used in the live lead. The fuse should have a continuous rating not exceeding 6A.

Make sure that only fuses with the required rated current and of the specified type are used for replacement. The use of mended fuses and the short-circuiting of fuse holders shall be avoided.

CAUTION: STATIC SENSITIVE COMPONENTS

Components identified with the symbol ⚠ on the circuit diagrams and/or parts lists are static sensitive devices. The presence of such devices is also indicated in the equipment by yellow flags or labels bearing the same symbol. Certain handling precautions must be observed to prevent these components being permanently damaged by static charges or fast surges.

(1) If a printed board containing static sensitive components (as indicated by a warning disc or flag) is removed, it must be temporarily stored in a conductive plastic bag.

(2) If a static sensitive component is to be removed or replaced the following anti-static equipment must be used.

A work bench with an earthed conductive surface.

Metallic tools earthed either permanently or by repeated discharges.

A low-voltage earthed soldering iron.

An earthed wrist strap and a conductive earthed seat cover for the operator, whose outer clothing must not be of man-made fibre.

(3) As a general precaution, avoid touching the leads of a static sensitive component. When handling a new one, leave it in its conducting mount until it is required for use.

(4) If using a freezer aerosol in fault finding, take care not to spray programmable ICs as this may affect their contents.

WARNING: HANDLING HAZARDS

This equipment is formed from metal pressings and, although every endeavour has been made to remove sharp points and edges, care should be taken, particularly when servicing the equipment, to avoid minor cuts.

WARNING: TOXIC HAZARD

Many of the electronic components used in this equipment employ resins and other chemicals which give off toxic fumes on incineration. Appropriate precautions should therefore be taken in the disposal of these items. e.g. The non-volatile memory back-up battery contains lithium which will react with water if exposed.

Chapter 1

GENERAL INFORMATION

CONTENTS

FEATURES

1. The 6960 RF Power Meter provides accurate power measurement with speed and ease. All information is displayed on a 4 digit liquid crystal display. Correction factors and control operations are made via a dual function keypad. Each key is initially a function then becomes numeric.

2. Microprocessor control ensures simplicity and ease of use, at the same time enhancing the overall accuracy. Measurements can be made in 3 modes - Watts, dBm or dB Relative. In the latter mode offset values can be entered in dB's enabling direct power measurements to be made.

3. Non-volatile memory ensures that information stored can be recalled after power down or mains break and includes full instrument front panel settings from 9 stores.

4. RF Power measurements can be made over a 50dB dynamic range depending on the RF power sensor being used. Automatic sensor recognition and scaling is included. The frequency range of the 6910 RF power sensor is from 0.01 to 20GHz and measures over the power range -30dBm to +20dBm.

5. The 6960 features a built in RF power reference of 1mW at 50MHz, traceable to the National Physical Laboratory.

6. Resolution is automatic and chosen to give the fastest most significant display depending on the range where measurements are being made. On range 1, the most sensitive range, using the 6910 RF power sensor the resolution is 1dB but with user selection of a different averaging factor this can be increased to 0.001dB.

7. Autoranging is the standard power up condition of the 6960 but any specific range can be held so enabling the analog peaking meter to be used for circuit peaking adjustments.

8. Autozero information is stored digitally for each range thus reducing drift and zero carry-over errors normally encountered when the zero is performed by an analog circuit.

9. Autocal facility turns on the power reference automatically and for a period sufficient to set internal amplifier gain stages for an exact 1mW (0dBm) and then returns the instrument to the mode in which it was operating before AUTOCAL was initiated.

10. The 6960 possesses the unique ability for power accuracy linearity correction. This correction known as linearity factor and individual to each power sensor further enhances power accuracy.

11. Peak pulse power measurements can now be made and displayed directly in either watts or dBm, without the need to consult formula or nomographs to make the conversion.

12. Calibration Factors provided on the power sensor are entered numerically on the key pad to a resolution of 0.01%, providing another enhancement to power accuracy.

13. All the keyboard functions of 6960 can also be programmed by the general purpose interface bus (GPIB) if the option is fitted. This option also allows additional facilities to optimise its use in an automatic test system (ATE).

14. For full user confidence, self diagnostics take place at each power up and also internal routines for self test can be used as necessary.

15. For fast levelling applications or recording over the full sensor dynamic range two analog outputs are available on the rear panel.

Display Characteristics

16. The four digit seven bar alphanumeric display also shows at the appropriate time,or with selected function,the correct annunciator.

Fig.1

Liquid Crystal Display

Characteristic		Performance
17. Frequency Range	:	Dependent on RF Power Sensor
18. Internal Calibrator	:	50MHz, Type 'N'(f) Precision Connector 50 ohm
Uncertainty	:	±0.7%, traceable to National Standards.
19. Power Accuracy Watts Mode	:	±0.5%
dB Mode	:	±0.02dB
dB REL Mode	:	±0.02dB
20. Fast Levelling Output	:	±0.5% (Excludes Cal.Factor and Linearity Data). 1V per range.
21. Recorder Output	:	±1.0% dB mode: 1V/decade, 7V max Range 5 Watt mode: 5V linear
22. Blanking Output	:	Max Voltage 25V, Max Current 50mA, Open Collector, Short Circuit for blank
23. Zero Set	:	±1% of most sensitive range
24. Zero Carryover	:	±0.03% of f.s.d. (when zero on most sensitive range)
25. Noise	:	1% of f.s.d. for most sensitive range with an average factor greater than 19.
26. Response Time Range 1	:	1s, selectable.
Ranges 2-5	:	250ms (display update), selectable. 25ms using GPIB
27. Remote Programming	:	Compatible with IEEE 488-78. Fitted as standard in 6960-001 version. Optional as P/No.3964-600 All front panel functions remotely controlled.
28. Instrument Stores	:	9 stores of all front panel settings in non volatile memory with a 10 year battery back up.
29. General		
Temperature Range	:	Storage -40 to +70°C Operational 0°C to +50°C
Humidity	:	95% relative at 35°C
30. Radio frequency interference	:	Conforms to the requirements of EEC Directive 76/889 as to limits of r.f. interference.

31. Power requirements

Voltage	:	AC supply Voltage ranges (switchable) 105V - 120V +/- 10% 210V - 240V +/- 10%
Frequency	:	45 Hz - 440 Hz
Consumption	:	25 VA max

32. Weight and dimensions (over projections)

Height	:	108mm including feet 88mm without feet
Width	:	256mm including handle 216mm without handle
Depth	:	359mm overall
Weight	:	3.2 kg

33. VERSIONS: RF Power Meter with GPIB — Type 6960-001
RF Power Meter — Type 6960

ACCESSORIES

34. Supplied accessories

	Part No.
AC supply lead	43123-076Y
Instruction manual	H6960
2metre Power sensor cable	6950-039

35. Optional accessories

GPIB Module	3964-600
Rear Panel Sensor Input Assembly	6960-060
5 metre Power Sensor cable	6950-056
15 metre Power Sensor cable	6950-057
50 metre Power Sensor cable	6950-058
Rack mounting kit (double unit)	46883-536P
Blank frame kit for double unit rack mount	46883-537X
Rack mounting kit (single unit)	46883-638P
Stowage cover	54124-022L

RF SENSOR SPECIFICATIONS

35. Performance specifications for the RF sensor presently available are given below. Additional information will be available as the range of RF Sensors is expanded to suit user requirements.

36. <u>6910 RF Power Sensor</u>

Power Range	:	-30dBm (1uW) to +20dBm (100mW)
Maximum RF Input	:	+24.8dBm (300mW) CW Peak Power 15 W for 2uS
Frequency Range	:	10MHz to 18GHz, useable to 20GHz
VSWR	:	1.4 — 10 to 30MHz 1.18 — 30 to 50MHz 1.1 — .05 to 2GHz 1.18 — 2 to 12.4GHz 1.28 — 12.4 to 18GHz 1.4 typical 18 to 20GHz
Linearity Factor Accuracy:		±0.5% at 25°C
Calibration Factor	:	Provided with Sensor
Connector	:	Precision 'N' type (m) 50 ohm
Size	:	33.5mm diameter,87mm long (including connectors)
Weight	:	140g

Chapter 2

INSTALLATION

CONTENTS

UNPACKING AND REPACKING

1. Retain the packing materials and the packing instructions note (if included) in case it is necessary to reship the instrument.

2. If the instrument is to be returned for servicing attach a label indicating the service required, type or model number (on rear label), serial number and your return address. Pack the instrument in accordance with the general instructions below or with the more detailed information in the packing instruction note.

(1) Place a pad in the bottom of the container.

(2) Place pads in the front and rear ends of the container with the plywood load spreader(s) facing inwards.

(3) Put the polythene cover over the instrument and place it in the container with the front handles and rear projections (where applicable) against the plywood load spreaders.

(4) Place pads in the two sides of the container with cushioning facing inwards.

(5) Place the top pad in position.

(6) Wrap the container in waterproof paper and secure with adhesive tape.

(7) Mark the package FRAGILE to encourage careful handling.

Note......

If the original container or materials are not available, use a strong double-wall carton packed with a 7 to 10 cm layer of shock absorbing material around all sides of the instrument to hold it firmly. Protect the front panel controls with a plywood or cardboard load spreader; if the rear panel has guard plates or other projections a rear load spreader is also advisable.

MOUNTING ARRANGEMENTS

3. Excessive temperatures may affect the instruments performance; therefore, completely remove the plastic cover, if one is supplied over the case. Ensure that ventilation holes are not obstructed otherwise the maximum temperature specification is reduced resulting in imperfect operation. Avoid standing the instrument or associated detectors in the vicinity of large transformers or other possible magnetic fields or where X rays are present. If the source of such fields cannot be isolated Mumetal shields shoud be used to provide the necessary screening.

CONNECTING TO SUPPLY

4. Before connecting the instrument to the a.c. supply check the position of the voltage selector switch. The range selected can be seen on the side of the switch protection plate situated on the rear panel.

The instrument is normally dispatched selected to the 210-250V range. To select the 105-120V range remove the protection plate, switch ranges and change the value of the a.c. supply fuses to that shown below, reverse and refit the protection plate.

115V range 500mA-T (500mA time lag)
230V range 250mA-T (250mA time lag)

Fuses are 20mm x 5mm cartridge type.

(6) Wrap the container in waterproof paper and secure with adhesive tape.

(7) Mark the package FRAGILE to encourage careful handling.

Note......

If the original container or materials are not available, use a strong double-wall carton packed with a 7 to 10 cm layer of shock absorbing material around all sides of the instrument to hold it firmly. Protect the front panel controls with a plywood or cardboard load spreader; if the rear panel has guard plates or other projections a rear load spreader is also advisable.

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115V range 500mA-T (500mA time lag)
230V range 250mA-T (250mA time lag)

Fuses are 20mm x 5mm cartridge type.

5. The supplied a.c. supply cable is fitted at one end with a female plug which mates with the a.c. connector at the rear of the instrument. When fitting a supply plug ensure that conductors are connected as follows:-

Earth	-	Green/Yellow
Neutral	-	Blue
Live	-	Brown

Any interruption of the earth conductor is liable to make the equipment dangerous.

When attaching the mains lead to a non-soldered plug it is recommended that the tinned ends of the lead are first cut off owing to the danger of cold flow resulting in intermittent connections.

SAFETY TESTING

6. Where safety tests on the mains input circuit are required, the following procedures can be applied. These comply with BS 4743 and IEC Publication 348. Tests are to be carried out as follows and in the order given, under ambient conditions, to ensure that mains input circuit components and wiring (including earthing) are safe.

(1) Earth lead continuity test from any part of the metal frame to the bared end of the flexible lead for the earth pin of the user's mains plug. Preferable a heavy current (about 25 A) should be applied for not more than 5 seconds.

Test limit: not greater than 0.5 ohm.

(2) 500V d.c. insulation test from the mains circuit to earth.

Test limit: not less than 2M ohm.

GPIB INTERFACE (Part No.3964-600)

7. The GPIB interface is available as an optional accessory and can easily be fitted by the user as follows:-

(1) Switch the instrument off and disconnect from the supply.

(2) Remove and discard the rectangular cover plate from the top left hand side of the rear panel, also remove the instruments top cover. Insert the cable and p.c.b. through the rear panel such that the GPIB connector is on the left hand side. Using the two retaining screws from the cover plate, secure the GPIB assembly to the rear panel.

(3) Remove the top PCB AA02 and connect the interface plug to PL2 on AA02. Replace the PCB AA02 and secure with the six retaining screws.

(4) Add the supplied label to the rear panel to identify the GPIB connector and address switch as shown in Fig.1. Replace the top cover.

The instrument is now ready for GPIB operation.

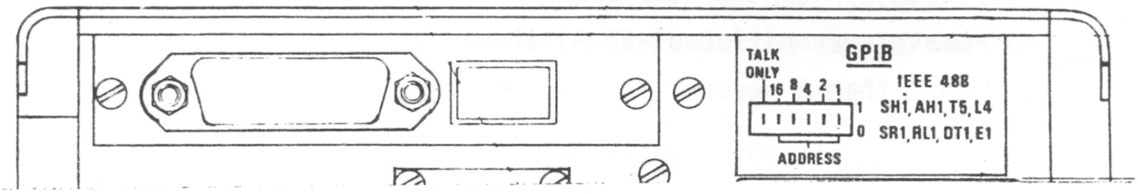


Fig.1 Fitting the GPIB interface

8. RACK MOUNTING ARRANGEMENTS

(1) For rack mounting the 6960 RF power meter on its own, a single unit rack mounting kit 46883-638P is available. This contains a pair of side angle plates wide enough to allow the instrument to sit centrally within the rack frmae.

(2) For rack mounting the RF power meter side by side with another similar instrument, a double unit rack mounting kit 46883-536P is available. This kit contains fixings for joining the two instruments together and for attaching the twinned unit to the rack (see Figs. 2 and 3).

(3) When the RF power meter is to be rack mounted on its own but provision retained for possible side by side mounting with another similar instrument, a blank frame unit 46883-537X is available. This is in addition to the double unit rack mounting kit and takes the place of the other instrument.

(4) Before assembling the double unit kit prepare the instrument(s) for rack mounting as follows:-

(a) Remove the rear securing screws, rear feet and rear frames and the top and bottom covers.

(b) Remove the four foot assemblies from the bottom cover.

(c) Remove the cap moulding from the tilt handle index and detach the handle and its fixings.

(5) Then assemble the kit as follows:-

(a) Place the two instruments (or instrument and blank frame unit) side by side and remove the plastic plugs and sleeve from the adjacent side frames.

(b) Locate the packing strip, short end forward, into the adjacent side frames and bring the two units together.

(c) Insert the two M4 x 30 mm hexagon head clamping screws through the adjacent frames and fit a nut, plain and crinkle washer, to each.

(d) Align the two units and tighten the two clamping screws.

(e) Attach the side angle plates to both outer frames with M5 x 10 mm self-threading screws. Align the angles with the front frames and tighten the fixing screws.

(f) Fit the rear frames and top and bottom covers to each unit.

(g) Secure the rear frames with M4 x 25 mm pan head screws, complete with washers, inserted into the side frames.

Notes......

1. For bench use the side angle plates need not be fitted and the self-adhesive pads, supplied loose, may be attached to each bottom cover.

2. Access to the twinned units can be gain by withdrawing the rear frames by about 10 mm. The covers may then be removed.

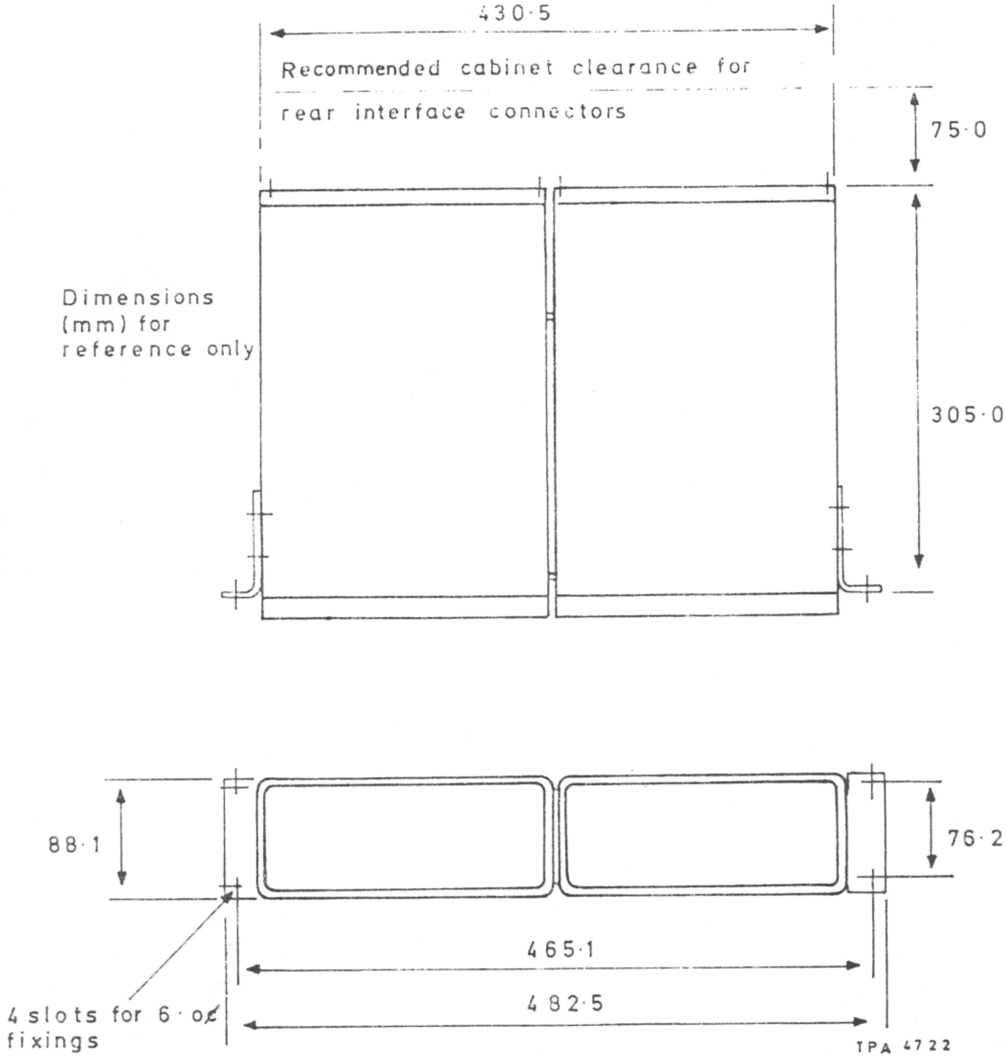


Fig. 2 Dimensions (in mm) of twinned rack mounting units

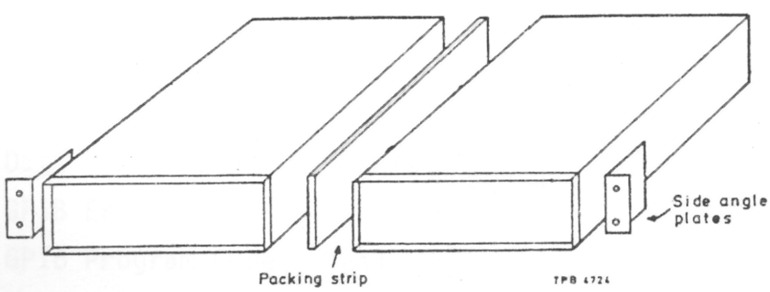


Fig. 3 Assembly of rack mounting kit

Chapter 3-1

OPERATION

CONTENTS

PREPARATION FOR USE

1. Providing the instrument is properly adjusted for a.c.supply voltage and is connected to an outlet socket with the correct fuses fitted, the instrument can be switched on.

2. A self test operation which checks the instruments memory is applied should the instrument fail the self test, an error code will be displayed.

3. A failure can be simulated by not connecting the RF Sensor via the appropriate sensor cable to the instrument. Error code Er 02 will be displayed. From table 1 this means 'No Sensor'. Other codes are given below:-

TABLE 1 DISPLAY ERROR CODES

01	Power-up fail
02	No RF Sensor
03	Auto-zero fail
04	Auto-cal fail
05	Manual entry error
12	Store/Recall error

4. Correct operation of the instrument with the RF Sensor connected is indicated by the self test routine sequentially displaying:-

6960	Instrument type number
ISOn	Issue No Software
ADR9	GPIB Address 9 (If GPIB Module P/No.3964-600 is fitted).

Once the self test is completed the instrument is ready for calibration prior to use.

5. An automatic zero operation is carried out by pressing the AUTOZERO key. During this function the display shows 5 bars which in turn are blanked, as each range is zero-ed.

6. The 6960 has an internal power reference of 1mW (0dBm) at 50 MHz. The power sensor should be connected to the type 'N' (f) output connector.

To obtain calibration to the internal power reference the AUTOCAL key is pressed. The reference is automatically turned on and the internal gain stages are set.

7. With the RF sensor head removed from the power reference, the instrument is ready for use.

FRONT PANEL CONTROLS

8. (1) SUPPLY

Applies a.c. supply voltage in both manual and remote control operation.

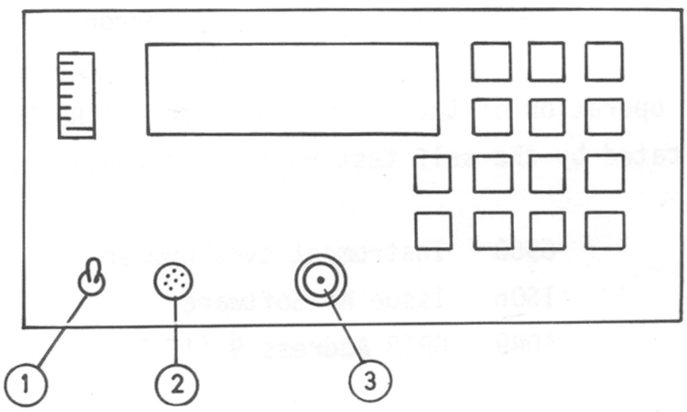


Fig.1

Front Panel Controls

(2) SENSOR INPUT. Accepts multipin connector from interconnecting 2m cable P/No.6950-039 linking RF sensor to the 6960.

(3) POWER REFERENCE. A type N(f) connector 50 ohm, accepts the RF sensor for calibration and provides an RF signal of 0dBm (1mW) at 50 MHz.

REAR PANEL CONTROLS

9. (1) GPIB Interface

This facility either factory fitted, in the standard 6960-001 version or available as an optional accessory, accepts the standard 24 way IEEE GPIB connector. An adaptor, Code No. 46883-408K is available for IEC 625 systems.

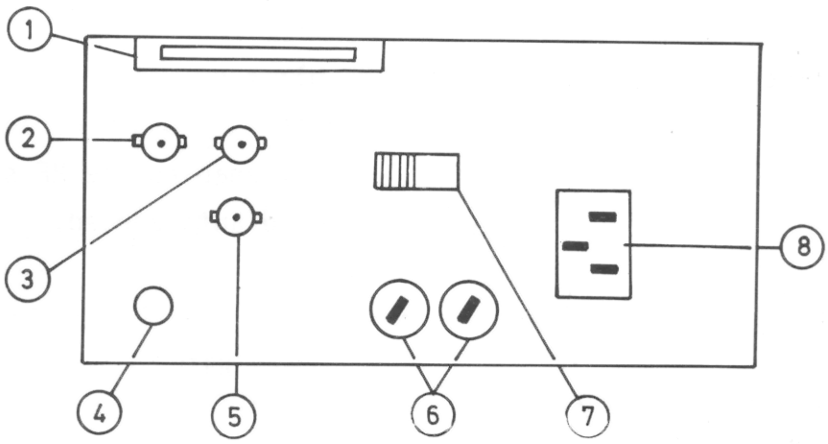


Fig.2 Rear Panel Controls

(2) LEVELLING OUTPUT

When this socket is connected to the levelling input of a sweep generator it is possible to level the RF output of the sweep generator. This output can respond at fast rates of change and sweep speed but correction information e.g. Cal Factor is not included.

(3) RECORDER OUTPUT

When this socket is connected to an X-Y recorder a plot can be made over the full dynamic range of 50dB in either the dBm or Watt mode. Full correction information e.g. Cal Factor and linearity Factor is included.

(4) REAR SENSOR INPUT

For ease of use in rack mounted automatic test systems this optional accessory P/No.6960-060 enables the RF sensor to be connected to the rear of the instrument. When fitted, this option disables the front panel sensor input and a blanking plug is provided for the input connector.

(5) BLANKING OUTPUT

By connecting this output to the RF blanking input of a sweep generator it is possible to turn off the RF output during the 6960 Autozero function. This facility enables the RF sensor to remain connected to a test system and auto-zeroed.

(6) AC SUPPLY FUSES

Supply input fuses are rated at 250mA-T for 210-250V operation or 500mA-T for 105-120V operation.

Note: The instrument employs double fusing, and should the fuse in the neutral line rupture, certain areas in the instrument may remain at mains potential.

(7) AC SUPPLY LOCKING PLATE

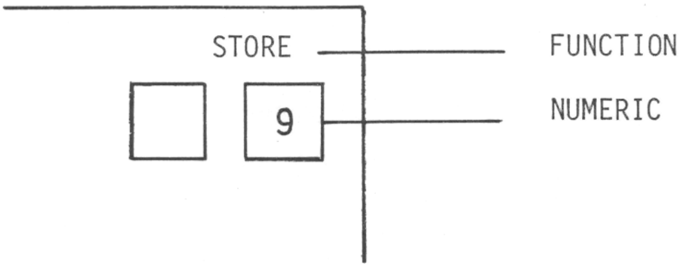
The instrument is normally despatched with the plate locking the supply selector switch to the 210-250V position. To change to 105-120V operation, remove the locking plate, adjust the switch, reverse the locking plate and refit.

(8) AC SUPPLY INPUT

Accepts a.c. supply input of 45-440Hz; the earth pin is internally connected to chassis.

Introduction

10. All operations are carried out via the front panel key switches,(or via the GPIB = 6960-001 version or optional accessory P/No.3964-600) which are used to enter commands and numerical values. Most keys have two functions, the prime function being indicated on the front panel above each key,



Most functions called up have to be followed by a numeric entry terminated by the ENTER key.

11. Any function command recalls to the display the last numerical value assigned to that function. This can be retained merely by using the ENTER key or new values entered, terminated by the ENTER key:- e.g. to set a LINEARITY FACTOR of 7.5.

Function Selection	Display Reads
LINEARITY FACTOR	8
7	7
.	.
5	5
ENT	New Power Reading

In the above example if 8 was the figure recalled and should be retained, only the ENTER key need be pressed to achieve this.

12. When the instrument is first switched on numerical values from non-volatile memory are assigned to the following functions:-

CAL FACTOR	100%
DUTY CYCLE	100%
LINEARITY FACTOR	8
AVERAGE	1

In addition the AUTORANGING mode is set and UNITS display mode is in dBm.

13. (1) If a mistake is made on entry and realised - clear that entry by terminating with the ENTER key and re-selecting the function.

(2) If an error message is displayed e.g. 05 (Manual entry error) initiated by entering a Cal Factor of 500, this will be seen for only a short period, the instrument defaulting to the last valid numerical entry for that function.

(3) To totally clear all values entered in the instrument, RESET can be activated and all values will be recalled as in para 12 above.

(4) A table of Error codes is shown in table 1(near para 3).

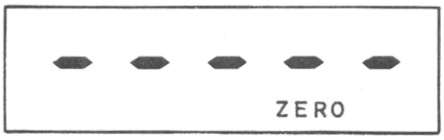
KEYSWITCH FUNCTIONS

14. (1) Calibration is carried out by connecting the RF power sensor and sensor cable to the internal power reference.

(2) AUTOZERO function is carried out by the following procedure:-

<u>Function Selection</u>   <u>Display Reads</u>

AUTO
ZERO



Once complete the Auto-zero routine is turned off. The display "hunts" between the zero display and a low level power reading in dBm.

(3) AUTOCAL function is carried out by the following procedure:-

Function Selection	Display Reads
AUTO CAL	

The internal power reference is turned on, illuminating the LED diode on the front panel. Once calibration is complete the power reference is turned off and the LED is extinguished.

(4) POWER REFERENCE/UNITS. It is possible to verify the autocal by pressing the POWER REF key. This turns on the power reference continuously. The display will show OdBm or alternatively using the UNITS key show the power reference as lmW:- e.g.

Function Selection	Display Reads
POWER REF	
UNITS	

The UNITS key has a toggle action - further depressing returns the display to dBm.

(5) Each RF Sensor is uniquely calibrated for power voltage linearity correction. This is known as LINEARITY FACTOR. On switch-on a numerical value of 8 is assigned but for enhancement of power accuracy the individual RF power sensor value shown on each sensor, can be entered. See example in para 11.

This procedure can be followed prior to AUTOCAL and after AUTOZERO to minimise the number of operations.

(6) CAL FACTOR. Each RF power sensor is measured and provided with a calibration curve of Calibration Factor. This correction figure takes into account how much RF to d.c.conversion takes place, including the full effect of the VSWR of the power sensor. The accuracy is enhanced because the CAL FACTOR can be entered to 0.01% resolution avoiding the errors of scale interpolations or switched steps.

The RF sensor can now be disconnected from the power reference and connected to the source to be measured.

15. AVERAGE. This key function provides a weighted response that automatically gives optimum resolution for the fastest response time on any particular range. See table 2 below.

TABLE 2 RESOLUTION

AVG.FACTOR	RANGE	POWER LEVEL dBm *	RESOLUTION dB *	TIME
1	5	+10 to +20	0.01	250ms
1	4	+0 to +10	0.01	250ms
1	3	-10 to +0	0.01	250ms
1	2	-20 to -10	0.1	250ms
1	1	-30 to -20	1.0	1s

* using 6910 Power Sensor

Table 2 shows that the AVERAGE FACTOR of 1 gives 1dB resolution on range 1. In order to increase the resolution a number between 1 and 254 can be entered giving a corresponding increase in response time. See table 3 below.

TABLE 3 AVERAGE FACTOR

AVG.FACTOR	RANGE	POWER LEVEL dBm*	RESOLUTION dB*	TIME
1	1	-30	1	250ms
4	1	-30	0.1	1s
19	1	-30	0.01	5s
49	1	-30	0.001	12s

The times shown in table 3 are based on each display update taking 250ms. Operation on the GPIB, however, can be 10 times faster at 25ms for a single reading.

16. DUTY CYCLE - Given a duty cycle figure the 6960 can then compute the peak pulse power from the average reading. Selecting the DUTY CYCLE key will show the current duty cycle %. If just switched on this will be preset to 100% for CW measurements. Any value of duty cycle between 0.001% to 100% may be entered. Very low repetition waveforms may be measured for peak power by selecting an appropriate averaging factor.

17.(1) RANGE. Normally the 6960 is in autoranging mode and the range at which a measurement is being taken can be seen or changed using the RANGE key. A typical application would be to hold a range, so that the peaking meter on the front panel can be used for final RF adjustments, so avoiding any range changes due to autoranging.

(2) To hold a range - press RANGE key - display reads current range - select same range or different - display indicates range hold.

Function Selection	Display Reads
RANGE	4AU
3	3hd

(3) To return to autoranging mode - press RANGE key - display reads current hold range - select - (minus) key - display indicates auto range selected.

Function Selection	Display Reads
RANGE	3hd
-	AU

18. UNITS key. This is a toggle action keyswitch changing the units of measurement from dBm to mW, and/or back to dBm or mW. The conversion from linear Watts to dBm is performed by a numerical logarithmic algorithm, to eliminate temperature drift effects due to ambient temperature rises, in analog conversion circuitry.

19. (1) dB REL facility. This allows an offset to be made both in the Watts and dBm mode. The offset can be the gain in dB's or attenuation in dB's of the component connected in front of the RF Power sensor. This most useful feature allows direct reading on the display of the incident power.

(2) To make a comparative measurement e.g. between two RF levels at different frequencies or a drift measurement over a period of time, any power level may be referenced to 0dB by the following method.

Display Reads	Function Selection	Display Reads
-21.3 dBm	dB REL	- - - - dBm
	ENT	0000 dBrel

Instead of a separate numerical entry, ENTER also references to 0dB.

(3) To make an offset measurement using an attenuator enter the attenuator value plus the minus sign (-). The minus sign may be entered before or after the numerical entry.

Display Reads	Function Selector	Display Reads
-21.3 dBm	dB REL	- - - - dBm
	- 6 ENT	-15.3 dB rel

(4) To make a gain measurement offset by dB gain figure, the procedure is exactly the same as para 3 but the minus key is not used.

If the gain was 10dB in the above example the display would read:-

(5) Both gain and loss offset figures in dB can also be entered in the Watts mode. In this instance if power was being measured via a directional coupler the main line power could be established from the coupling value, e.g.:-

RF Power	Coupling Factor	Display Reads	Offset	Display Reads
1W	30dB		-30dB	

(6) dB REL in the watts mode may also be used to monitor linearly changes from a unity figure where 1 = 100%. Therefore a power change by one half = 0.5 = 50% = 3dB.

20 (1) STORE. The 6960 contains a non-volatile memory backed up by a battery supply with a 10 year life. The instrument contains 9 stores, locations 1-9 where all the front panel instrument settings can be stored and recalled.

Operation is made by pressing the STORE Key and one of the relevant numeric locations 1-9.

(2) On power down, all previously stored information is retained in non-volatile memory. The current instrument front panel settings are stored and located in Store 0. On power-up the 6960 automatically recalls from memory and implements correction factors of 100% for CAL FACTOR and Duty Cycle, a Linearity Factor of 8, the last AUTOCAL and AUTOZERO. Full information on the last measurement including Autozero and Autocal remains in Store 0 until recalled.

21. (1) RECALL Recall of any one of ten stores, location 0 - 9, can be made, containing in Store 0 all the last current instrument settings including Autozero, Autocal information, in Stores 1-9 recalling instrument settings from non-volatile memory.

(2) When the instrument leaves the factory the standard power down default and power up recall conditions are as para.20(2).

(3) In applications where remote unattended power monitoring takes place, a mains break, power failure or power down would mean that on mains supply being restored the 6960 would not recall the previous last current settings. It is possible to reset the 6960 power up condition, defaulting to the last current settings e.g. Enter the measurements conditions in the normal way.

Function Selection	Operation
AUTOZERO	As para 14 (2)
AUTOCAL	" " 14 (3)
LINEARITY FACTOR	" " 14 (5)
CAL FACTOR	" " 14 (6)
DUTY CYCLE	" " 16
AVERAGE	" " 15
UNITS	" " 18

To transfer this information to the power-up memory, use the following key operations.

STORE [.]   N.B. [ENT] is not used

(4) To restore power up memory as para 20(2) Set up the standard conditions as:-

Function Selection	Numeric Value
LINEARITY FACTOR	8
CAL FACTOR	100
DUTY CYCLE	100
AVERAGE	1
UNITS	dBm

To transfer this information to the power-up memory,use the following key operations.

STORE [—]

22. LOCAL For GPIB operation a remote command disables all front panel key operations except LOCAL. When LOCAL is used manual operation is restored to the front panel. The liquid crystal display indicates "remote" when a GPIB operation has changed the instrument settings.

23. RESET This key starts the microprocessor routines as if the instrument was just switched on. Using RESET pre-allocated numeric values of Cal Factor, Duty Cycle, Linearity Factor etc. are imposed, where the power up mode has been changed as in para 21(3).

24. SELF TEST

Holding the RESET key and one other at the same time this initiates the self test routine. Both keys are held until the tESt display is shown. Pressing the – key initiates the keyboard test. Depressing each key in turn will then display its face significance e.g. ENTER = E If the 0 key is depressed when tESt is displayed then the liquid crystal display and annunciators are flashed to denote correct operation.

For full details on setting up the 6960 using the SELF TEST facility refer to 6960 Servicing Information Chapter 5.

GENERAL PURPOSE INTERFACE BUS (GPIB) FUNCTIONS

25. The GPIB interface, either factory fitted or, offered as an optional accessory allows the instrument to be coupled to a controller.

The essential purpose of the GPIB functions and mnemonics are described below. Further information on the general features and applications of the GPIB system can be obtained from the separate GPIB manual offered as an optional accessory.

26. <u>SH1: Source handshake</u> (complete capability)

The source handshake sequences the transmission of each data byte from the instrument over the bus data lines. The sequence is initiated when the function becomes active, and the purpose of the function is to synchronize the rate at which bytes become available to the rate at which accepting devices on the bus can receive the data.

27. <u>AH1: Acceptor handshake</u> (complete capability)

The acceptor handshake sequences the reading of the data byte from the bus data lines.

28. T5: Talker function (talk only function)

The talker function provides the 6960 with the ability to send device dependent messages over the bus to other devices. The ability of any device to talk exists only when it has been addressed as a talker.

29. L4: Listener function (no listen only function)

The listener functionprovides a device with the ability to receive device dependent messages over the bus. The capability exists only when the device is addressed to listen via the bus by the controller.

30. SR1: Service request function (complete capability)

The service request function gives the 6960 the capability to inform the controller when it requires attention.

31. RL1: Remote/local function (complete capability)

The remote/local function allows the 6960 to be controlled either by the local front panel keys or by device dependent messages over the bus.

32. DC1: Device clear function (complete capability)

Device clear is a general reset and may be given to all devices in the system (DCL) or only to addressed devices (SDC). On receipt of DCL or SDC the 6960 performs a software reset, returning the instrument to its power-on state, as 'RE' reset command.

Note: A self test failure may cause a GPIB interface error condition or suspend GPIB activity. The 6960 must be switched off to clear this condition.

33. El: Open collector drives

The GPIB drivers fitted to the 6960 have open-collector, rather than tristate, outputs.

GPIB OPERATION

Setting the GPIB address

34. The instrument's talk/listen address is selected by the address switch as shown in Fig.3. The address switch is positioned on the GPIB interface unit alongside the GPIB connector on the rear panel. The instrument's internal address register will be updated by reading the setting of the address switch. This operation is performed at power-on and on receipt of a device clear message. The current GPIB address is shown on the display on switch on when the interface is correctly installed.

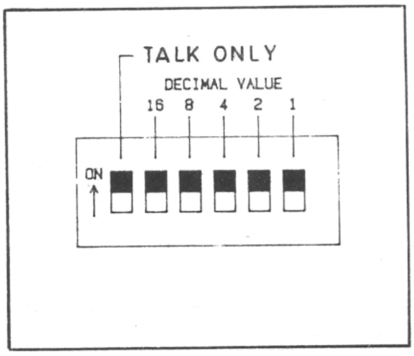


Fig.3 GPIB Address Switch

Note: The valid GPIB address range is 0-31. The 6960 address is preset to 9 at the factory. Before changing this check controller manuals for reserved addresses.

35. Remote operation

On receipt of an instrument command from the GPIB the 6960 switches to remote operation, indicated by the "remote" annunciator being displayed. No instrument settings are changed but all front panel keys except LOCAL are disabled and their functions come under GPIB control.

36. Unless inhibited by the Local Lockout (LLO) message the instrument can be returned to local control by pressing the LOCAL key or sending a Go to Local (GTL), Interface Clear (IFC) or Not Remote Enable (REN) GPIB message.

GPIB Program Codes

37. All valid GPIB program codes are listed in Table 4. These include equivalents for all front panel keys (except LOCAL) with additional codes for special functions.

38. Program codes may be combined in a string without individual terminators, although spaces or commas may be included to improve clarity. These will be ignored by the instrument.

Data Entry and Terminators

39. It is possible to send a whole string of commands to the 6960. When doing so it is not necessary to seperate each command, but comma's, semi-colons or spaces may be entered to improve the legibility of your program. The maximum length of any string is 78 characters.

There are two forms in which data may be sent to the 6960. One in which only single numbers are sent and another which accepts data in floating point format, Floating point numbers should be in the form of sign of negative, up to 4 digits plus a decimal point in any position followed by the numeric entry terminator 'E', e.g. '89 SE'. The type of numeric entry is defined by the particular command being sent.

40. GPIB Error Codes

All invalid GPIB operations are flagged via SRQ's. By serial polling an error code number can be read from the message string These codes are listed in table 5.

Table 4

GPIB Program Codes

UNn	............Set displayed units.
DRm	............Enter dB offset.
STn	............Store current settings.
RLn	............Recall stored settings.
SRn	............Set range.
AVm	............Set average number.
LFm	............Enter linearity factor.
DCm	............Enter duty cycle.
CFm	............Enter sensor calibration factor.
PRn	............Power reference on/off.
AC	............Auto calibration.
AZ	............Auto zero.
RE	............Reset
TRnn	...........Trigger mode.
RS	...........Read settings.
RC	...........Read calibration data
SQn	...........Set SRQ mask.
E	...........Numeric entry terminator

n .....Single byte number entry, requires no terminator.

m .....Floating point numeric entry, requires 'E' terminator.

GPIB Error Codes

Table 5

06	Entry greater than 9999
07	GPIB syntax error
08	GPIB input buffer overflow (greater than 80 characters)
09	Talk only error
10	Under range
11	Over range

41. GPIB Program Code Detail

42. 'UN' Set units. 'n' should be 0 or 1. 0 sets units to dBm, 1 to watts. A typical command would be 'UN1'.

43. 'DR' Enter dB offset. When units are set to dBm entering this command will allow dB relative measurements to be made either to the entered value or to the current reading. If the units are Watts, the entered value will act as an offset. This allows you to correct for an attenuator in front of the sensor.
A typical command would be 'DR-10E'. Sets dB's relative to -10dBm or puts an offset of -10dB into a reading in Watts i.e. a 10dB attenuator.
The range allowed is -100 to +100dB.

44. 'ST' Store current settings. Allows the current instrument settings to be stored to non-volatile memory for future use, Stores 1 to 9 are allowed. The command format is 'ST5'. Stores current settings in store 5. 'ST-' or 'ST·' may be sent to change the power up condition. 'ST-' will ensure that the power up condition will be the same as before the supply was removed. 'ST·' defaults the power up condition so that Cal Factor, Duty Cycle are 100%, Linearity Factor 8 and Average Factor 1.

45. 'RL' Recall stored settings. Recalls settings stored using the 'ST' command. In addition 'RL0' may be used to restore the instrument settings before the last power down or reset.
The command format is 'RL7', Recalls store 7.

46. 'SR' Set range. Sets the amplifier range. If a number is entered, that range will be held. If a minus sign is entered, the amplifiers will change range automatically. The ranges are numbered 1 to 5 with range 5 being the least sensitive.
The command format is 'SR-'. Sets auto-range.

47. 'AV' Set average number. Enters average number in the range 1 to 254. As the average number is increased the averaging increases and the displayed resolution increases. The default value is 1. A typical command would be 'AV50E', which sets the average number to 50 and allows maximum resolution after 50 display updates.

48. 'LF' Enter linearity factor. Enters RF power sensor linearity factor in the range 5 to 14.99.

A typical command would be 'LF8·5E'. Sets linearity factor to 8.5.

49. 'DC' Enter duty cycle. Enters duty cycle of a pulse rf source, allowing display of peak power. The allowable range is 0.001% to 100%. A typical command would be 'DC0.15E'. Enters duty cycle of 0.15%.

50. 'CF' Enter sensor calibration factor. Enters sensor cal.factor in the range 70% to 100% for the frequency in use.
A typical command would be 'CF93.5E'. Sets cal.factor to 93.5%.

51. 'PR' Power reference on/off. Send 'PR0' to turn the power reference off or 'PR1' to turn it on.

52. 'AC' Auto calibration. Performs instrument/sensor auto calibration. The Seebeck sensor linearity factor or diode sensor cal.factor should have been entered and an auto zero performed before performing auto calibration.
The command syntax is 'AC'.

53. 'AZ' Auto zero. Performs instrument/sensor auto zero.
The command syntax is 'AZ'.

54. 'RE' Reset. Resets instrument to power up state. The current settings are stored in store 0. (depending on power up mode). The command syntax is 'RE'. This should be the only command sent.

55. 'TR' Trigger mode. Sets the trigger mode or starts a measurement after a hold condition. The modes are as follows:-

TR00	Normal operation. (As in local)
TR1n	Free run fast.
TR20	Trigger immediate then hold.
TR3n	Trigger immediate fast then hold.
TR40	Free run with settling time.
TR60	Trigger immediate with settling time then hold

Trigger modes 1 and 3 require a second number, which is an averaging number in the range 0 to 6. Zero will be no averaging at all and 6 is equivalent to a normal reading with the average set to 1. The normal average does not affect readings taken in the fast mode. These two modes allow faster readings to be taken but increases the inaccuracies of the measurement.

Note: TR50 is not used.

When settling time is enabled the GPIB output buffer is not loaded with new data till the settling time is reached. The settling time is calculated as number of display updates required = 5 times the entered average number for TR00 and TR40. For Trigger Mode TR20 and TR60 settling time = Average Number. A measurement can be started from the hold condition by either sending a new trigger mode command or by sending Group Executive Trigger. The trigger mode returns to normal when the instrument is sent to local.

56. 'RS' Read settings. Loads the GPIB output buffer with the complete Instrument settings. The next read via the GPIB will be this data in a field up to 90 characters long. Each section of data contains a 2 digit prefix followed by the data and a comma as terminator. The prefixes are the same as the GPIB command except for 'RFn' and 'HFn' which stand for relative flag and range hold flag. 'RF1' indicates instrument is in dB relative or Watts with offset mode. 'RF0' indicates units are dBm or Watts.

'HF1' indicates that the present range is held and 'HF0' that auto range is enabled.

A typical read setting result would be:-

'UN0,DR-1000E-02,SR3,AV+2000E-02, LF+9100E-03,DC+1000E-01,
CF+9580E-02,PR1,TR60,SQ1,RF0,HF0,PU1'

This would mean that the instrument settings are:-

Units set to dBm.
Last dB relative entry -10dB.
Range 3.
Average set to 20.
Linearity factor set to 9.1.
Duty cycle set to 100%.
Sensor cal.factor set to 95.8%
Power reference is on.
Trigger mode is trigger immediate with settling time then hold.
SRQ mask is set for SRQ on end of measurement.
Not in dB relative or Watts with offset modes.
Not in range hold.

N.B. No normal data may be output until the whole of the string has been read.

57. 'RC' Read calibration data. This command is the same as read settings except the data from the auto-zero and auto-cal is output. The prefixes used are as follows:-

AZ	Auto zero point
AC	Auto calibration point
OA	Range 1 offset
OB	Range 2 offset
OC	Range 3 offset
OD	Range 4 offset
OE	Range 5 offset

58. 'SQ' Set SRQ mask. Sets when SRQ's will be raised. The options are on end of measurement, on error or on end of GPIB operation. To cancel all SRQ's (default on power up) send 'SRQ'. Each SRQ option has a binary weighted value, which are:-

1. On end of measurement.
2. On error.
4. On end of GPIB operation.

To send the correct mask, add up the binary values of the options required and send 'SQ' followed by the result e.g. 'SQ3', which allows SRQ's to be sent on end of measurement and on error. The on end of GPIB operation SRQ is useful to indicate the end of an instruction which takes a long time to execute, e.g. Auto zero.

59. Reading data

When the measurement data is read from the 6960, various status data is also sent. A typical output string would be 'VDW+3020E-3'. The meanings of status part of the output string are as follows:-

1st Character. V = valid data.
S = waiting for settling time
U = under range
D = over range
K = waiting for valid reading after GPIB or keyboard operation.

2nd Character.	A =	instrument on range 1.
	B =	" " " 2.
	C =	" " " 3.
	D =	" " " 4.
	E =	" " " 5.
3rd Character.	D =	units are dBm.
	R =	" " dB relative.
	W =	" " Watts.
	O =	" " Watts with offset.

The rest of the string is the data in exponential format. Therefore our example of 'VDW+3020E-3' indicates we have a valid measurement of 3.02 milli-Watts on range 4.

Note : The 6960 power meter must be sent to REMOTE or receive GROUP EXECUTE TRIGGER (GET) before any data is output. After receipt of data, send to REMOTE or GET again to receive more data.

Typical String

VDW+3020E-3 crlf (EOI)

EOI is sent with line-feed (lf).

60. <u>Serial Poll</u>

In response to a Service Request (SRQ) the controller should send each instrument capable of generating that SRQ, a serial poll. A single byte of data is returned from each instrument which indicates if it generated the SRQ and if so why. In the case of the 6960 the binary data would be as follows:-

Bit 7. Always zero.

Bit 6. 1 indicates SRQ active.

Bit 5. 1 indicates error caused SRQ, 0 for normal operation.

Bit 4. Always zero.

Bits 0-3. Error number if SRQ due to error, 0 if end of measurement or 1 for end of GPIB instruction.

61. Talk only

In the talk only mode, data is output in the normal format but only at the end of a settling time. The trigger mode is set to Free run with settling time (see 'TR40' GPIB command).

EOI is not sent in this mode (this only applies to issue 3 software and above, which is effective from serial no. 220).

62. Cautionary Note

When sending commands to the 6960, the programmer should ensure that no spaces are sent in the middle of commands. This can occur on some controllers when sending numeric variables over the GPIB.

Chapter 3-2

APPLICATIONS

CONTENTS

APPLICATIONS OF 6960

Introduction

1. The techniques for RF power measurement are now well defined and must involve the sensing element responding directly or linearly to the amount of RF power applied to the sensing element i.e. the heating effect. Once RF conversion to dc takes place, further amplification and signal processing can be made to establish the exact power applied to the sensor. In previous generations of power meters the signal processing has always been analogue, but now the 6960 brings to RF power measurement microprocessor enhancement of the signal processing circuitry. Not only is the display digital but information entered into the 6960 is in numeric form to high resolution.

   Measurements that can be made with the 6960 fall into 4 main categories:-

   Absolute power
   Peak pulse power
   Transmission Loss/Gain
   Comparison or ratio measurements

   Other applications of 6960 include:-

   Fast levelling of sweep generators.
   Large dynamic range recording with correction factors included.
   RF Blanking of sweep generators.

2. Preparation for use

   Before making a measurement the RF sensor must be connected to the power meter by an RF power sensor cable. In order to calibrate the instrument and sensor as a system, the sensor must be connected to the Power Reference output.

   Autozero and Autocal are then performed at 50MHz giving 0dBm (1mW) displayed with a traceable uncertainty of $\pm$0.7%

3. Absolute Power Measurements

The 6960 may now be coupled to an RF Source whose output is to be measured. At this point correction factors may be entered into 6960 to give the best enhancement of accuracy possible.

From the RF power sensor obtain the Linearity Factor and the Cal Factor at the frequency of operation and measurement. Enter these numerically via the keypad to 0.01 resolution.

The measurement has now taken into account power voltage linearity, RF to dc conversion losses, frequency response (sensitivity) and VSWR effects.

4. Peak Pulse Power Measurements

An RF power meter when measuring directly pulse power will only display the average power based on the duty cycle. In the past it has been necessary to calculate the peak pulse power from the average power, by using formulae.

The 6960 can now compute the peak pulse power from the average power by a numerical entry of the duty cycle, from 0.001 to 100%. For low rate p.r.f.'s a steadier display may be obtained by setting a higher average factor number.

5. Transmission Loss/Gain

Any component having either attenuation or gain characteristics can be measured at a simple frequency or swept over a suitable frequency band. In the latter application the full response of the device under test can then be plotted from the analog recorder output. By using the other analog output from the 6960 the swept frequency source can also be levelled to give an effective normalised recording.

See Fig. 1

6 Comparison or ratio measurements

In order to observe or plot changes relative between one power level and another, the 6960 make the measurement in two forms:-

(a) Referenced to 0dB

(b) Referenced to an offset value, +dB or -dB

(a) Referenced to 0dB. In a typical application of amplifier bandwidth the maximum power is found and referenced to 0dB using the 6960. The frequency may then be altered in plus and minus direction until the 3dB points are reached. The exact frequency at which this occurs can be read from the source or via a frequency counter.

(b) Referenced to an offset value. In order to measure higher power than the sensor can safely handle, either an attenuator pad or coupler may be added ahead of the sensor. By entering the value of attenuation or coupling as -dB's as a numerical offset into 6960, the full RF power may be measured.

To measure the input power to a system with only the output being available and the gain known, by entering this value as dB's the 6960 will display directly the input power to the system.

7. Other applications

Sweeper Levelling - Use the LEVELLING OUTPUT for fast levelling of voltage tunable oscillators or sweep generators.

Recording - Use the RECORDING OUTPUT to obtain the full 50dB dynamic range of the power sensor, including all correction factors.

RF Blanking - Use this BLANKING OUTPUT to turn off the source RF while an AUTOZERO is performed. This enables the RF Sensor to remain connected in the system.

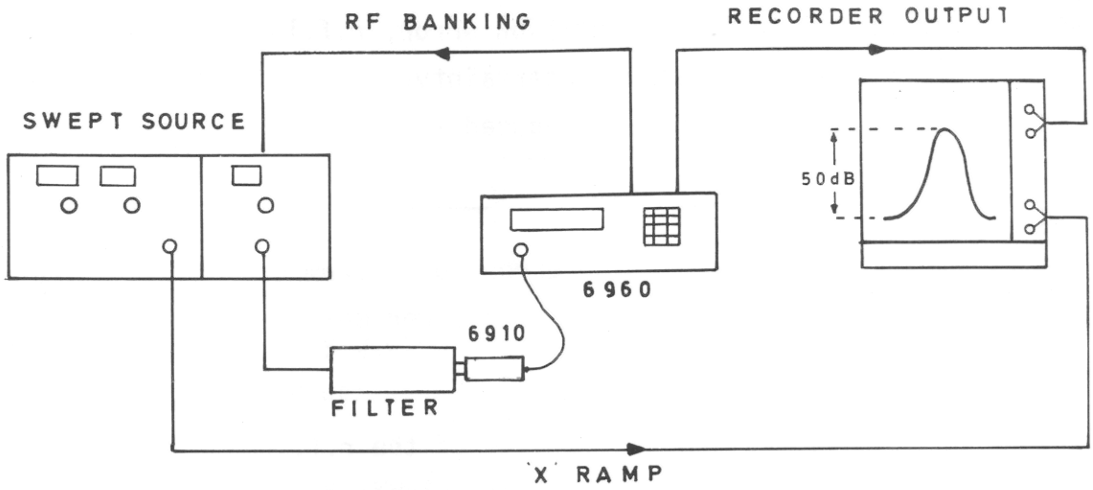


Fig.1 A typical measurement set up using recording and RF blanking facilities of 6960.

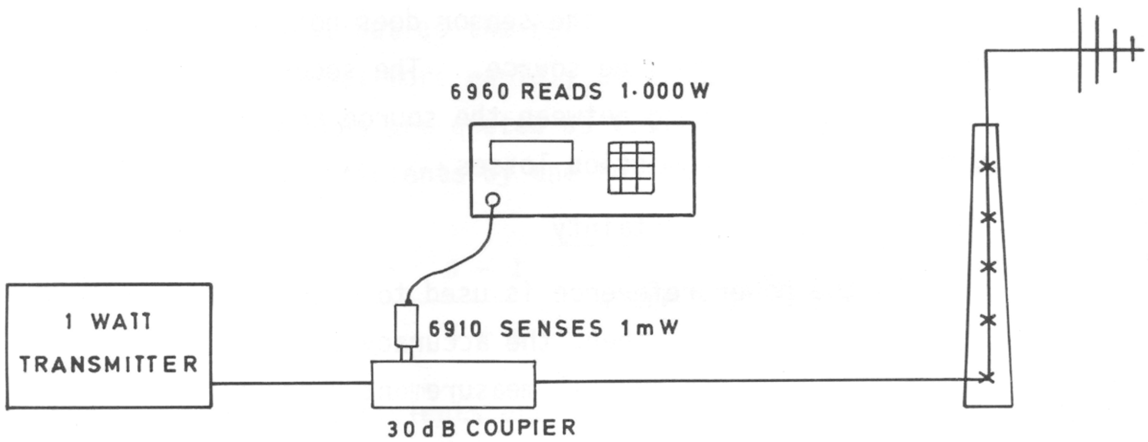


Fig.2 A typical offset measurement being used for direct high power reading.

8. POWER MEASUREMENT UNCERTAINTIES

1. RF power measurements are never free from uncertainties. These can be due to instrumentation error, r.f.losses, mismatch uncertainty and sensor calibration uncertainty. High errors are possible unless these uncertainties are reduced to a minimum.

<u>Error sources - Instrumentation error</u>

2. The instrumentation error comes from component tolerances and calibration uncertainty of the power meter.

<u>RF losses</u>

3. RF losses are due to some of the r.f. power applied to the sensor being dissipated in various components of the sensor together with radiation losses.

<u>Mismatches</u>

4. Large uncertainties can arise from either sensor or source mismatches. The first effect of these mismatches is to cause a transmission loss, i.e. the sensor does not receive the maximum available power from the source. The second effect is multiple reflections occurring between the source and the sensor causing unpredictable transmission losses.

<u>Power reference uncertainty</u>

5. As the power reference is used to calibrate the power meter and the power sensor together, the accuracy of the reference oscillator becomes part of the overall measurement uncertainty.

<u>Calculating measurement uncertainty</u>

6. For a source and load having complex reflection coefficients of $_S$ and $_L$ respectively, the ratio of transmitted power to maximum available power is as follows:-

$$\frac{P_L}{P_O} = \frac{(1-|\Gamma_S|^2)(1-|\Gamma_L|^2)}{|1-\Gamma_S\Gamma_L|^2}$$

This has a maximum of:-

$$\frac{(1-|\Gamma_S|^2)(1-|\Gamma_L|^2)}{(1-|\Gamma_S||\Gamma_L|)^2}$$

And a minimum of:-

$$\frac{(1-|\Gamma_S|^2)(1-|\Gamma_L|^2)}{(1+|\Gamma_S||\Gamma_L|)^2}$$

Uncertainty is usually quoted as a percentage uncertainty. From the previous formulae:-

Positive uncertainty = $100 * ((1+|\Gamma_S||\Gamma_L|)^2 - 1)$

Negative uncertainty = $100 * ((1-|\Gamma_S||\Gamma_L|)^2 - 1)$

The positive and negative uncertainties are essentially the same for low reflection coefficients, but as the reflection coefficients increase the positive uncertainty increases more rapidly than the negative uncertainty. If the source and load matches are quoted as V.S.W.R.'s then they may be converted to reflection coefficients by the following simple formula:-

$$|\Gamma| = \frac{S - 1}{S + 1}$$ where S is the V.S.W.R.

If the reflection coefficients are small, typically less than 0.15, the positive and negative uncertainties can be taken to be equal and the uncertainty can be approximated by:-

Percentage uncertainty = $200 * |\Gamma_S| |\Gamma_L|$

7. Typical uncertainty calculations

(1) Calculate the mismatch uncertainty for a source reflection coefficient of 0.33 and a sensor reflection coefficient of 0.05.

$$\begin{aligned}\text{Positive uncertainty} &= 100 * ((1+0.33*0.05)^2-1)\\ &= 100 * ((1+0.0165)^2-1)\\ &= 100 + (1.0333-1)\\ &= 3.33\%\end{aligned}$$

$$\begin{aligned}\text{Negative uncertainty} &= 100 * ((1-0.33*0.05)^2-1)\\ &= 100 * ((1-0.0165)^2-1)\\ &= 100 * (0.967272-1)\\ &= -3.273\%\end{aligned}$$

(2) Calculate the uncertainties for a source V.S.W.R. of 1.3:1 and a sensor V.S.W.R. of 1.05:1.

The V.S.W.R.'s must first be turned into reflection coefficients.

$$|\Gamma_S| = \frac{1.3-1}{1.3+1} = \frac{0.3}{2.3} = 0.130$$

$$|\Gamma_L| = \frac{1.05-1}{1.05+1} = \frac{0.05}{2.05} = 0.024$$

As both the source and sensor mismatches are low we can use the approximation formula.

$$\begin{aligned}\text{Percentage uncertainty} &= 200 * 0.13*0.024\\ &= 0.624\%\end{aligned}$$

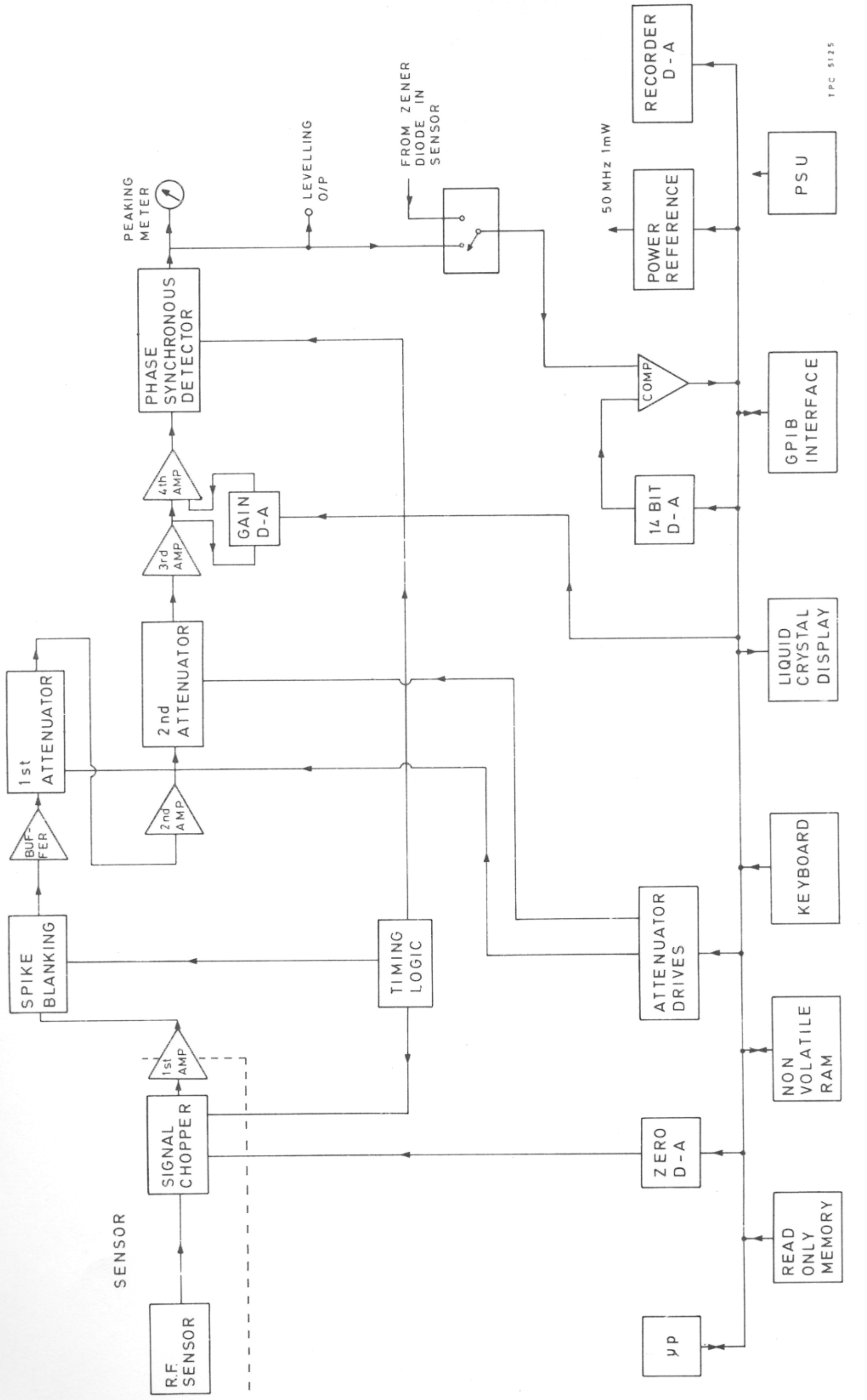


Fig. 3 Block diagram of 6960

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