

**1238
Detector
User Manual**



IET LABS, INC.
formerly manufacturer by
GenRad

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- R: 20 $\mu\Omega$ -1 T Ω
- C: <1 pF - 1 F
- L: 100 μ H-100 H

- Accuracy to 1 ppm
- Resolution to 0.1 ppm
- Voltage to 20 kV
- Power to over 1000 W
- Programmable IEEE-488 or BCD



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We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable IET specifications. If within one year after original shipment, it is found not to meet this standard, it will be repaired or, at the option of IET, replaced at no charge when returned to IET. Changes in this product not approved by IET or application of voltages or currents greater than those allowed by the specifications shall void this warranty. IET shall not be liable for any indirect, special, or consequential damages, even if notice has been given to the possibility of such damages.

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WARNING



OBSERVE ALL SAFETY RULES
WHEN WORKING WITH HIGH VOLTAGES OR LINE VOLTAGES.

**Dangerous voltages may be present inside this instrument. Do not open the case
Refer servicing to qualified personnel**

HIGH VOLTAGES MAY BE PRESENT AT THE TERMINALS OF THIS INSTRUMENT

WHENEVER HAZARDOUS VOLTAGES (> 45 V) ARE USED, TAKE ALL MEASURES TO
AVOID ACCIDENTAL CONTACT WITH ANY LIVE COMPONENTS.

USE MAXIMUM INSULATION AND MINIMIZE THE USE OF BARE
CONDUCTORS WHEN USING THIS INSTRUMENT.

Use extreme caution when working with bare conductors or bus bars.

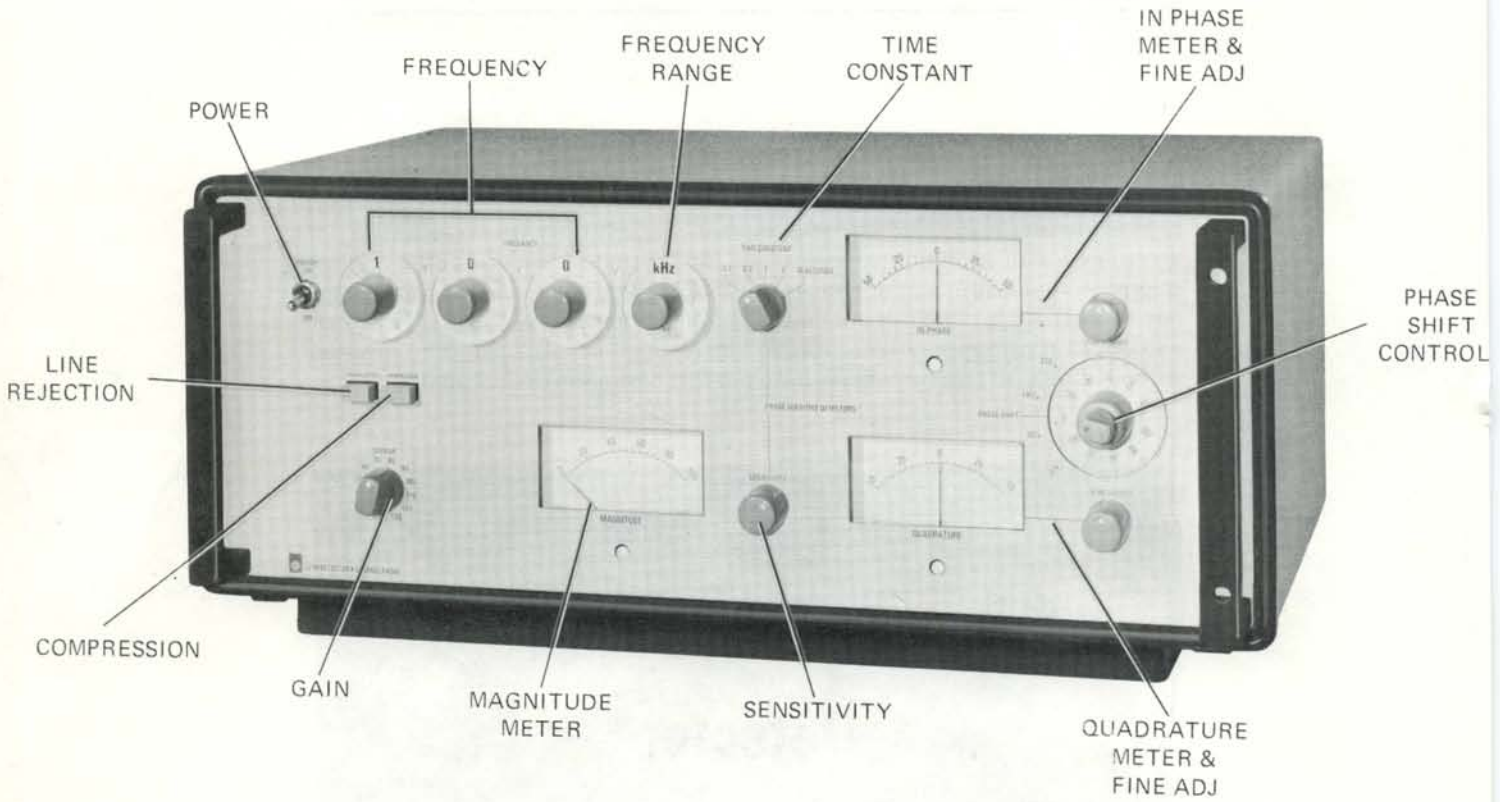
WHEN WORKING WITH HIGH VOLTAGES, POST WARNING SIGNS AND
KEEP UNREQUIRED PERSONNEL SAFELY AWAY.



CAUTION



DO NOT APPLY ANY VOLTAGES OR CURRENTS TO THE TERMINALS OF THIS
INSTRUMENT IN EXCESS OF THE MAXIMUM LIMITS INDICATED ON
THE FRONT PANEL OR THE OPERATING GUIDE LABEL.



Specifications

Frequency: 10 Hz to 100 kHz, flat or tuned. *Flat*, ± 5 dB from 10 Hz to 100 kHz. *Tuned*, controlled by 4 in-line readout dials with $\pm 5\%$ of reading accuracy, 2 to 4% bandwidth, and second harmonic ≥ 30 dB down from peak. *Line-rejection filter*, reduces line level by ≥ 40 dB while signal is down 6 to 10 dB at 10 Hz from line frequency; filter can be switched out.

Signal Input from bridge or other source: Applied to rear BNC connector. *Sensitivity*, also see curve; 100 nV rms typical for full-scale deflection at most frequencies, compression can be switched in to reduce full-scale sensitivity by 20 dB. *Impedance*, $1 \text{ G}\Omega // 20 \text{ pF}$. *Maximum input*, 200 V rms. *Voltage gain*, ≈ 105 dB in flat mode, ≈ 130 dB in tuned mode, controlled by 12-position switch. *Spot noise voltage* $< 30 \text{ nV} \times \sqrt{\text{bandwidth}_{\text{Hz}}}$ at 1 kHz with input impedance of $70 \text{ M}\Omega // 500 \text{ pF}$. *Monitored* by magnitude, in-phase, and quadrature meters; phase-sensitive detectors contain time-constant variable from 0.1 to 10 s in 5 steps.

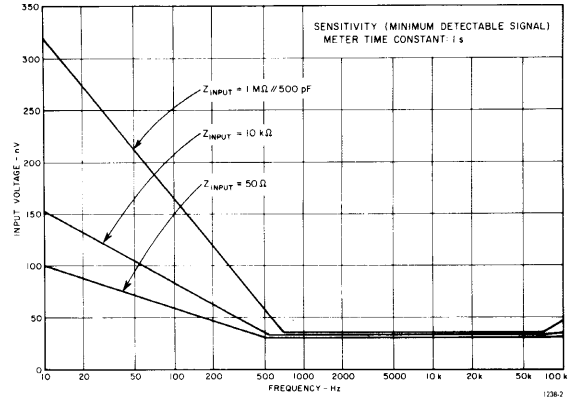
Reference Inputs from oscillator: Applied to rear BNC connectors. Two ≥ 1 -V rms reference signals required, with 90° phase difference between them. *Phase shifter* rotates both references continuously from 0 to 360° and two verniers rotate each reference individually $\approx 10^\circ$.

Outputs: *Main amplifier*, 4 V rms (approx 2.3 V for full scale on Magnitude meter) available at rear BNC connector. *Magnitude*, 6 V dc for full scale deflection; *phase detectors*, up to 1 V dc each for full scale deflection (depending on Sensitivity setting); available at rear 5-pin connector.

Required: Oscillator with 0 and 90° outputs; the 1316 Oscillator is recommended.

Power: 100 to 125 and 200 to 250 V, 50 to 60 Hz, 15 W.

Mechanical: Bench or rackmount. *Dimensions* (w \times h \times d): Bench, $19.75 \times 6.66 \times 12.93$ in. ($502 \times 169 \times 229$ mm); rack, $19 \times 5.22 \times 11.44$ in. ($483 \times 133 \times 291$ mm). *Weight:* Bench 25 lb (12 kg) net, 32 lb (15 kg) shipping; rack, 20 lb (10 kg) net, 27 lb (13 kg) shipping.



Catalog Number	Description
	1238 Detector
1238-9700	60-Hz Bench Model
1238-9701	60-Hz Rack Model
1238-9703	50-Hz Bench Model
1238-9704	50-Hz Rack Model

Also included in each 1621 Precision Capacitance Measurement System.

Condensed Operating Instructions

POWER.

a. Set the line-voltage switch (rear panel) to correspond with the available power (100-125 or 200-250 V).

b. If power-line frequency is 50 Hz, but the instrument was sold (or previously readjusted) for 60 Hz, *or the converse*, make the jumper change and readjustment described in para. 5.5.

UNTUNED MAGNITUDE DETECTOR.

a. Provide the signal to be detected via shielded cable to rear-panel BNC connector INPUT SIGNAL. Normal levels: $2 \mu\text{V}$ to 1 V; limit: 200 V rms max.

b. Set controls as follows:

FREQUENCY – any

FREQUENCY range – FLAT

TIME CONSTANT – 1 s

FINE ADJUST – midrange

PHASE SHIFT – 0°

SENSITIVITY – minimum (ccw)

GAIN – 20 dB (ccw)

COMPRESSION – push button out

LINE REJECTION – push button out

POWER – ON.

c. Turn the GAIN control for MAGNITUDE meter reading between 20 and 100 – relative voltage level (not volts). For comparisons requiring GAIN-control change, note: 2 steps are a factor of 10 (1 step, factor of 3.16).

d. Take the amplified signal from rear-panel BNC connector AMPLIFIER OUTPUT to a scope, recorder, or other instrument, if you wish to.

e. Set COMPRESSION push button in, if you want a quasi logarithmic function, making the 5-100 span of the meter response a factor of 100 in voltage (instead of 20).

f. Set LINE REJECTION push button in, if you want attenuation of the input-signal component at power-line frequency (by a factor of 100).

TUNED MAGNITUDE DETECTOR.

a. Set the controls as above, except:

FREQUENCY = frequency of desired signal

FREQUENCY range – decimal point and units.

b. Adjust source frequency or Detector FREQUENCY controls carefully for maximum response (best tuning).

c. Use the instrument as above, except that signal components and noise outside the 3% bandwidth are rejected. Tuned gain is 25 dB (factor of 18) greater than the FLAT gain. Normal input-signal levels: $1 \mu\text{V}$ to 400 mV.

DUAL-PHASE-SENSITIVE DETECTOR

a. Connect 2-phase reference signal from oscillator (GR 1316 recommended) to rear-panel BNC jacks REFERENCE INPUTS. Reference must be coherent with input signal; QUADRATURE leading, 90° ahead of IN PHASE.

b. Set the controls as above, except: *

- PHASE-SHIFT – set to make QUADRATURE meter zero and IN PHASE meter deflect to the right when input-signal phase is any initial angle \emptyset .
- FINE ADJ (QUADRATURE) – fine control of above.
- FINE ADJ (IN PHASE) – set to make INPHASE meter zero when input signal is $\emptyset \pm 90^\circ$. If 90° phase shift is not available, leave control at midrange.

c. Use instrument as above except IN PHASE and QUADRATURE meters now indicate relative voltages and senses of input-signal components at \emptyset and $\emptyset + 90^\circ$ respectively. Phase-sensitive detection provides very effective rejection of input-signal components not coherent with the reference.

d. Increase SENSITIVITY (cw) if necessary to measure small signals (approx 100 nV) even though MAGNITUDE meter deflection is very small. Range of this control: 16 dB (factor of 6).

e. Increase TIME CONSTANT if necessary to help in reducing noise (jumpy meters) with small input signals.

f. Avoid GAIN setting that makes MAGNITUDE meter deflect offscale, otherwise indications of IN PHASE and QUADRATURE meters may be invalid.

*The phase \emptyset of the initial signal should be significant in your test system. For example, in a capacitance bridge, obtain this signal by unbalancing the bridge with *only* C or G, *not* an arbitrary combination.

Introduction—Section 1

1.1 PURPOSE	1-1
1.2 DESCRIPTION	1-1
1.3 CONTROLS, INDICATORS, AND CONNECTORS	1-2
1.4 ACCESSORIES	1-2

1.1 PURPOSE.

The 1238 Detector is a sensitive, low-noise, analog instrument particularly suited for null detection in a highly precise bridge system such as the GR 1621. As you bring the bridge to balance, this detector continuously provides an indication of the remaining unbalance. You are also provided with the relative magnitudes and senses of its quadrature components. If, for example, the bridge measures C and G, separate zero-center phase-sensitive meters conveniently indicate the C and G components of unbalance. Also, these meters will resolve signals so small as to be "lost in the noise" of a magnitude-only detector.

To handle the great range of signal levels characteristic of bridges, this detector has manually selected gain, optional rejection of noise and harmonics by tuning, optional compression of the linear response characteristic, and a choice of 5 time constants for the phase-sensitive meters. Automatic protection circuitry saves the instrument from damage even if the input signal reaches 200 V while you have the gain set for 100 nV, full scale. The digital, in-line frequency controls match those of the companion 1316 Oscillator (used in the 1621 Precision Capacitance-Measurement System). Both instruments cover the frequen-

cy range of 10 Hz to 100 kHz with 3-digit resolution.

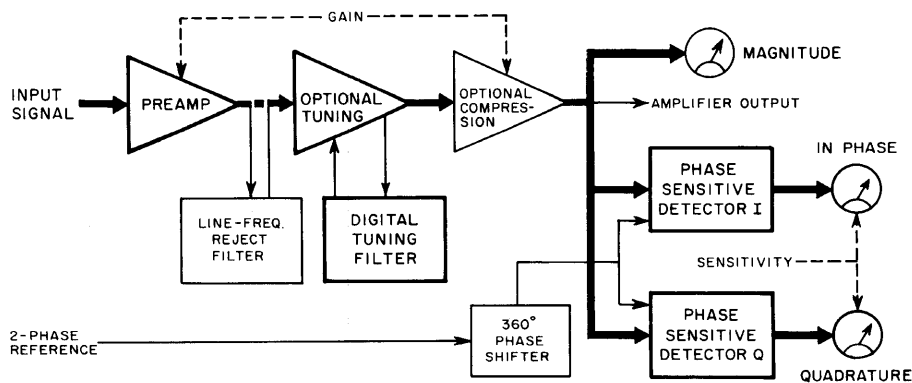
In addition to its prime purpose as a bridge detector, the 1238 is well suited as a low-noise amplifier with the very high input impedance of 1 GΩ in parallel with 20 pF. The filters may be switched out for a flat frequency characteristic. With the tuning filter in, the 1238 serves as an analyzer having about 3% bandwidth, better than 30 dB rejection of the 2nd harmonic, and a dynamic range (with the gain control) of at least 130 dB.

1.2 DESCRIPTION.

Figure 1-1.

The 1238 Detector is a high-gain, solid-state, tunable, metered amplifier with a pair of phase-sensitive detectors. They can be set to respond to any 2 quadrature (i.e., orthogonal) components of the input signal, if a pair of quadrature-related reference signals is provided, generally by the oscillator that drives the measurement system.

Figure 1-1 shows the 1238 circuitry by an elementary block diagram. The high-input-impedance preamplifier is well shielded and isolated; it has a separate power supply and all its control functions are handled by solid-state relays (insulated-gate field-effect transistors). Its first stage, a field-effect transistor, is diode protected against high-volt-



1238-3

Figure 1-1. Elementary block diagram.

age input signals. The digital tuning filter, 360° phase shifter, meters, and sensitivity control are components of the front-panel assembly. Each phase-sensitive detector is a separate plug-in board. Amplifier and power supply circuits are on the mother board, which is easily accessible from above and below for adjustment and servicing.

1.3 CONTROLS, INDICATORS, AND CONNECTORS.

Tables 1-1 and 1-2 list and describe the front and rear

panel controls, indicators, and connectors. Refer to the illustrations of Figures 1-2 and 1-3.

1.4 ACCESSORIES.

Table 1-3 lists the accessories supplied with the 1238 Detector. Table 1-4 lists connectors and patch cords suitable for connecting to the instrument and the recommended companion oscillator, which is shown in Figure 1-4.

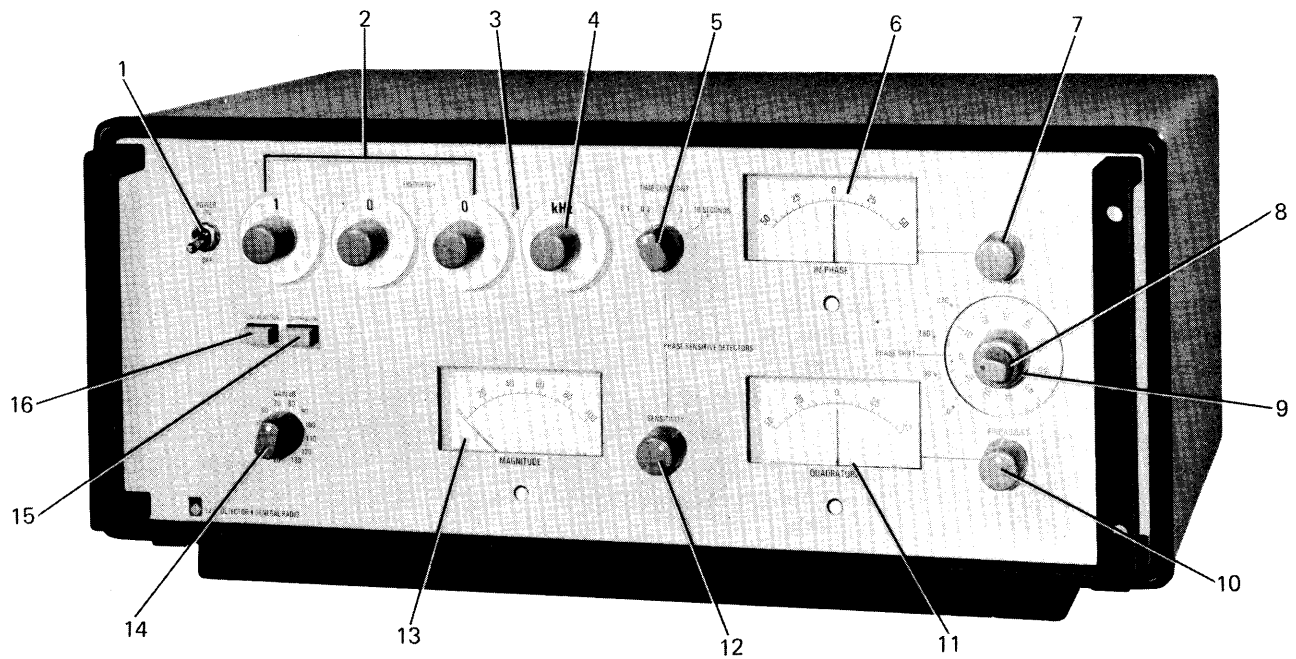


Figure 1-2. Front-panel controls and indicators.

Table 1-1

FRONT-PANEL CONTROLS AND INDICATORS

Fig. 1-2 Item	Name	Description	Function
1	POWER Switch	Toggle switch, up: ON; down: OFF.	Turns detector on and off.
2	FREQUENCY selector	Set of 3 rotary switches with decimal steps, 0 . . . 10.	Selects and indicates frequency to which detector is tuned (unless "FLAT"). With item 4, controls the digital tuning filter.
3	Decimal point	Set of 3 small, round, recessed lamps, one to the right of each digit in item 2.	Indicates proper location of decimal point in item-2 readout, as determined by item 4. Pilot-light indication: power is on.

Table 1-1 Cont.

FRONT-PANEL CONTROLS AND INDICATORS

Fig. 1-2
Item

Item	Name	Description	Function
4	Frequency range	Rotary switch with 5 positions: FLAT, Hz, Hz, kHz, kHz.	Selects flat amplifier characteristic or frequency range of tuned response. Indicates frequency units for item 2. Controls its decimal point, item 3.
5	TIME CONSTANT	Rotary switch with 5 positions: 0.1, 0.3, 1, 3, 10 SECONDS.	Controls the smoothing (integration) of detected signals and hence, effectively, the damping of items 6 and 11, but not 13.
6	IN-PHASE meter	Zero-center meter graduated 50-0-50; has mechanical zero-adjustment screw.	Indication of one component of input signal (such as C unbalance in 1621 system).
7	FINE ADJUST (IN-PHASE)	Stepless rotary pot.	Trims the phase of item-6 reference so the quadrature component is rejected.
8	PHASE SHIFT (smaller knob)	Rotary switch with 4 positions: 0°, 90°, 180°, 360°.	Selects phase shift of 2-phase reference in 90° steps, supplemented by items 7, 9, and 10.
9	PHASE SHIFT (larger knob)	Stepless rotary control, calibrated -50° to +50°.	Adjusts phase shift of 2-phase reference, over 100° centered on the indication of item 8. Set so items 6 and 11 respond to desired components of input signal.
10	FINE ADJUST (QUADRATURE)	Stepless rotary pot.	Trims the phase of item 11 reference so the in-phase component is rejected.
11	QUADRATURE meter	Zero-center meter graduated 50-0-50; has a mechanical zero-adjustment screw.	Indication of the input-signal component in quadrature with item 6 (Example: G unbalance in 1621 system).
12	SENSITIVITY control	Stepless rotary pot.	Fine control; used to keep IN-PHASE and QUADRATURE meters reading on scale (does not affect items 13 or 1R). Range 6:1.
13	MAGNITUDE meter	Meter, calibrated 0 to 100; has a mechanical zero-adjustment screw.	Indication of relative magnitude of input-signal (item 5R) components in pass band set by items 2, 16. Linearity depends on item 15.
14	GAIN, dB	Step attenuator, 12 positions: 20 . . . 130 dB.	Coarse gain control; used to keep MAGNITUDE meter reading on scale. (Turn cw if meter reads less than 30.)
15	COMPRESSION	Push-button switch (push to engage; push again to release).	Out: linear response, full gain. In: 20-dB-compressed response, 10 times-larger signal can be handled with MAGNITUDE meter on scale.
16	LINE REJECTION	Push-button switch (push to engage; push again to release).	Out: normal. In: 40 dB attenuation of line-frequency component of input signal. (Circuit can be adapted to either 50 or 60 Hz.)

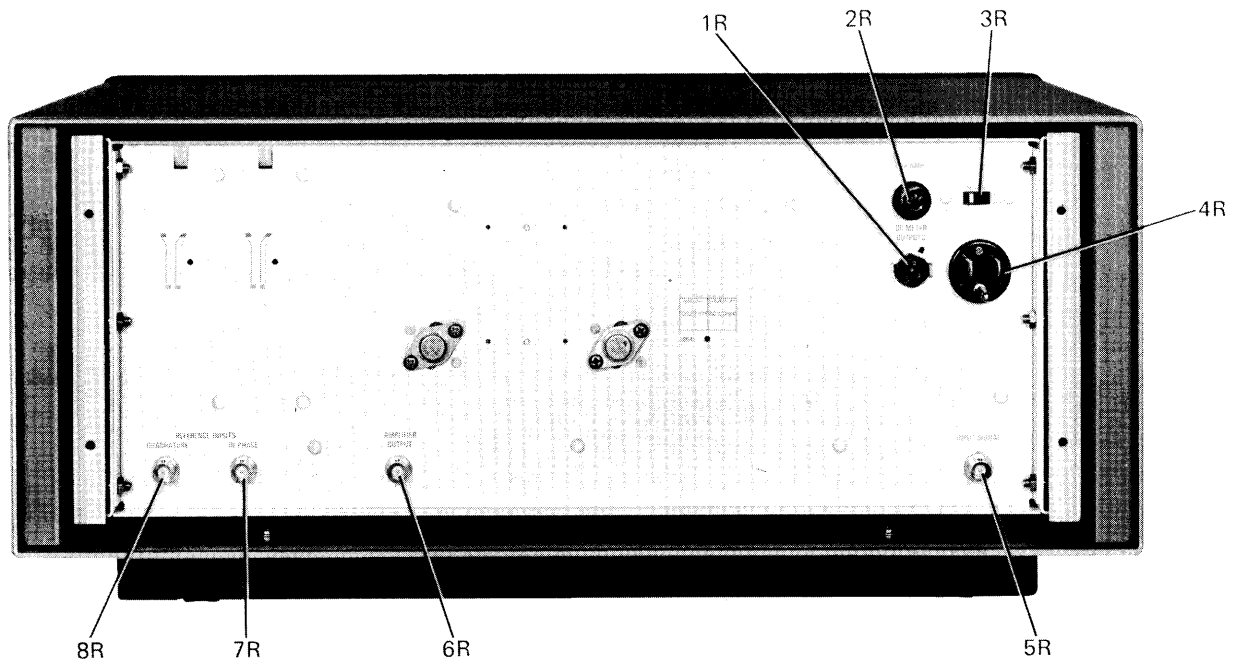


Figure 1-3. Rear-panel controls and connectors.

Table 1-2

REAR-PANEL CONTROLS AND CONNECTORS

Fig. 1-3 Item	Name	Description	Function
1R	DC METER OUTPUTS	5-pin socket (Figure 2-6).	Outputs for remote metering. Full-scale dc levels: MAGNITUDE, 6 V; IN-PHASE and QUADRATURE, 0.25-1.5 V, depending on item 12 (which does not affect ratio: dc out/signal in).
2R	1/2 AMP fuse	Fuse in extractor post holder	Protection against damage from short circuit
3R	Line-voltage switch	Slide switch (labeled 50-60 Hz) 2 positions: 100-125 V, 200-250 V.	Accommodates power supply to either range of line voltage.
4R	Power plug	3-pin power plug	Connection from power line and earth ground.
5R	INPUT SIGNAL	BNC Jack *	Main input. Impedance: 1 GΩ//20 pF for normal signal levels. Max level: 200 V rms.
6R	AMPLIFIER OUTPUT	BNC Jack *	Output for remote instrumentation. Level: 0-4 V rms (2.25 V at FS on item 13).
7R	IN-PHASE REFERENCE INPUT	BNC Jack *	One of two quadrature references required for phase-sensitive detection. See item 8R.
8R	QUADRATURE REFERENCE	BNC Jack *	The other — see item 7R. Required levels: 1 V rms min, each. Phase: Item 8R normally leads 7R by 90° ±5°.

*BNC jack accepts Amphenol "BNC" plug or military connector No. UG-88/U.

Table 1-3
ACCESSORIES SUPPLIED

Name	Description or Function	GR Part No.
Power cord	Stackable hammerhead dual connector (one end) and socket (other end) each molded integrally to plastic jacket of 3-wire AWG number 18 type SVT cable, rated at 7A, 230 V. The connectors, designed for 125-V operation, conform to the Standard for Grounding Type Attachment Plug Caps and Receptacles, ANSI C73.11-1963. Length: 7 ft.	(Type CAP-22) 4200-9622
Plug	For DC METER OUTPUTS socket; 5-pins; Amphenol No. 126-217.	4220-5401

Table 1-4
COMPANION OSCILLATOR, CONNECTORS AND PATCH CORDS

Name	Description or Function	GR Part No.
Oscillator	Stable, synchronizable, transformer-coupled, metered, sine-wave source. Frequency: 10 Hz to 100 kHz; Stability: 0.001% in 10 min; Calibration accuracy: $\pm 1\%$; Distortion: $< 0.2\%$; Power: 0-1.6 W (up to 5A or 125 V rms); Reference outputs — phase: 0° and 90° leading main output; level: 1.25 V rms; distortion: $< 0.4\%$; min load: 47 k Ω .	(Type 1316) 1316-9700 (Bench) 1316-9701 (Rack)
Patch Cords	Shielded cable with BNC plugs at each end; Length: 3 ft. (Type 776-C). Package of 10 Shielded cable with BNC plug and GR874 [®] connector at opposite ends; Length: 3 ft. Package of 10	0776-9712 (Type 776-B) 0776-9711
Adaptor	BNC plug to 874 connector (Fits BNC jack).	(Type 874-QBPA) 0874-9800

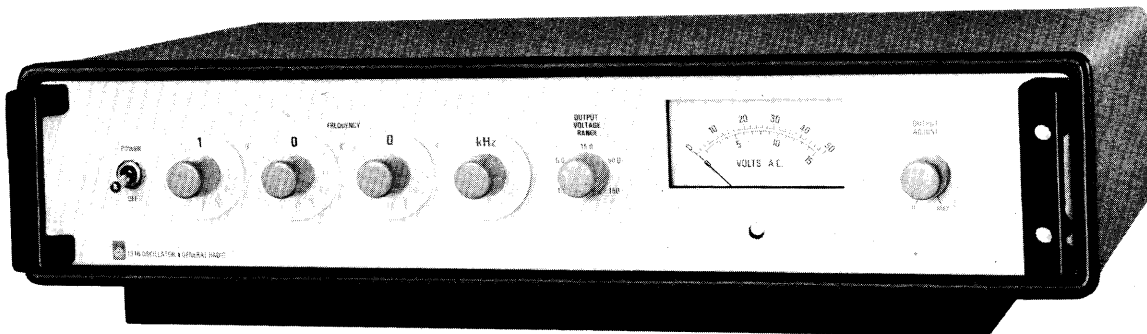


Figure 1-4. A recommended companion instrument, the 1316 Oscillator.

Installation – Section 2

2.1	GENERAL	2-1
2.2	DIMENSIONS	2-1
2.3	ENVIRONMENT	2-2
2.4	BENCH MODELS	2-2
2.5	RACK MODELS	2-2
2.6	POWER-LINE CONNECTION	2-4
2.7	LINE-VOLTAGE REGULATION	2-4
2.8	SYSTEM CONNECTIONS	2-4

2.1 GENERAL.

The 1238 Detector is available for either bench use or for installation in an EIA Standard RS-310 19-in. relay rack with universal hole spacing. Appropriate cabinet and hardware sets are available for conversion of a bench model for rack installation or vice versa.

Locate the instrument for convenience of operation and

in a suitable environment. The provisions for remote metering add flexibility to the arrangement of your measurement system.

2.2 DIMENSIONS.

The dimensions of bench and relay-rack models of the detector are given in Figures 2-1 and 2-2.

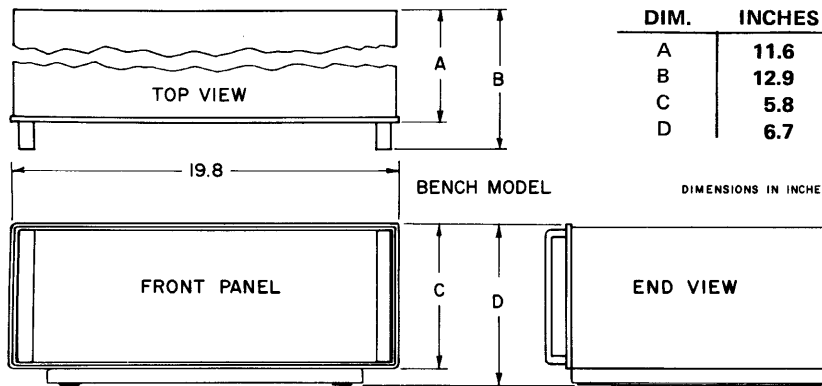


Figure 2-1. Dimensions of the bench-model instrument.

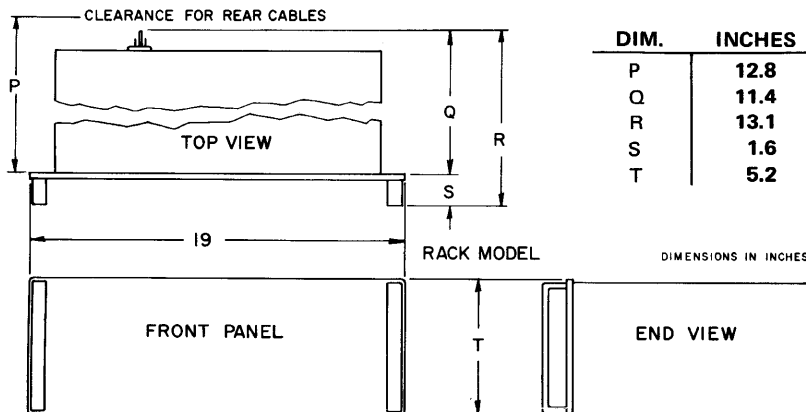


Figure 2-2. Dimensions of the rack-model instrument.

2.3 ENVIRONMENT.

The instrument is designed to operate in rooms where people work. Its specifications are valid over a temperature range of 0-55° C. Storage temperature range is -20 to +70° C.

It is important to keep vents unobstructed, for normal air convection. The environment of the instrument is directly affected by others nearby, particularly those below if they are hot.

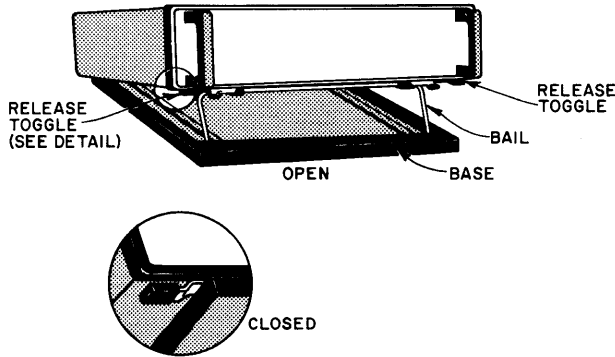


Figure 2-3. The instrument may be tilted for a higher viewpoint.

2.4 BENCH MODELS.

2.4.1 Position, Horizontal or Tilted.

Figure 2-3.

Each bench model comes completely assembled in a metal cabinet intended for use on a table or laboratory bench. If the user's viewpoint is much above bench level, he may prefer to tilt the instrument for a better view of front-panel legends and indicators. The base remains horizontal. Use the following procedure for tilting:

a. Reach under the cabinet, near the front, at each side of the pedestal base, and push each release toggle back. (It moves about 3/4 in.)

b. Lift the front of the instrument a few inches from its base, keeping each hand where a fingertip can touch the bail as it swings down.

c. Swing the bail forward while raising the instrument, then lowering it gently to rest on the bail. This is the tilted, or open position.

d. To reverse the procedure, first be sure the release toggles are pushed back.

e. Lift the cabinet slightly, as before; swing the bail back; then lower the cabinet fully.

f. Lock the cabinet and base together by sliding the release toggles forward. This is the horizontal, or closed position.

2.4.2 Cabinet Removal.

Figure 2-4.

To remove the bench-model cabinet, first stand the instrument in the normal position, free of all cables, and proceed as follows:

- a. Remove the 4 dress-panel screws (A) accessible through holes in the handles.
- b. Withdraw the instrument forward, out of the cabinet.

2.4.3 Conversion for Rack Mounting.

To convert a bench instrument for rack mounting, exchange the cabinet and install appropriate hardware, as follows:

a. Obtain the Rack-Mounting Cabinet described in Table 2-1 from General Radio Company.

b. Obtain, optionally, a Bracket Set (same table). Brackets are especially recommended for a heavy instrument, which needs support from the rear rail of the rack.

c. Remove the cabinet, as in para. 2.4.2.

d. Remove the rear cover from the bench cabinet with screws (B, Figure 2-5), for later installation on the rack cabinet.

e. Proceed with the rack installation: skip to para. 2.5.2, step b.

2.5 RACK MODELS.

2.5.1 General.

Each rack model comes completely assembled in a suitable metal cabinet, which is designed to stay semipermanently in a rack. The instrument can be drawn forward on extending tracks for access with support, or (with a lift) withdrawn completely. The cabinet and bracket set listed in Table 2-1 are included with a rack-model 1238 Detector. Table 2-2 lists the screw sizes for reference.

Description	Part No.
Cabinet with tracks; screws A, B,	4174-3624
Rear-support bracket set; screws C, E.	4174-2007

Ref Fig. 2-4 & 2-5	Description	No. — thds/in.	Length (inches)
A	Dress-panel screws with washers.	10-32	0.56
B	Thread-forming screws.	8-32	0.25
C	Thread-cutting screws.	10-32	0.50
E	Thread-forming screws.	8-32	0.19
F	Thread-cutting screws.	10-32	0.50

2-2 INSTALLATION

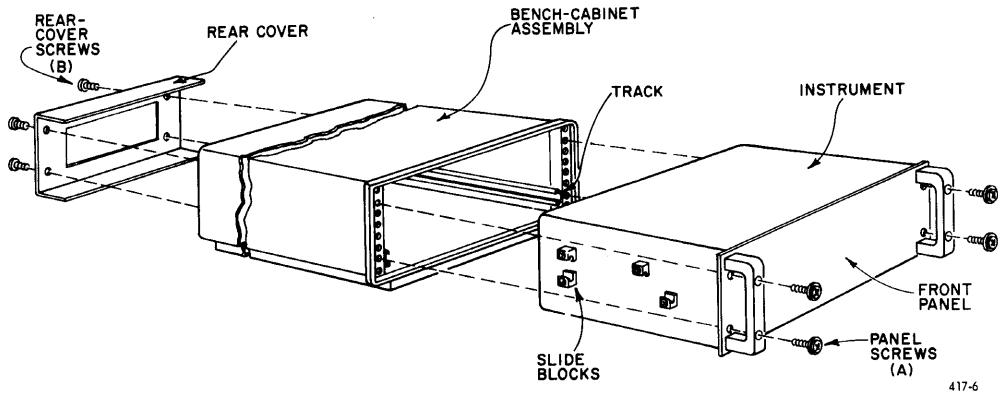


Figure 2-4. Bench-cabinet installation.

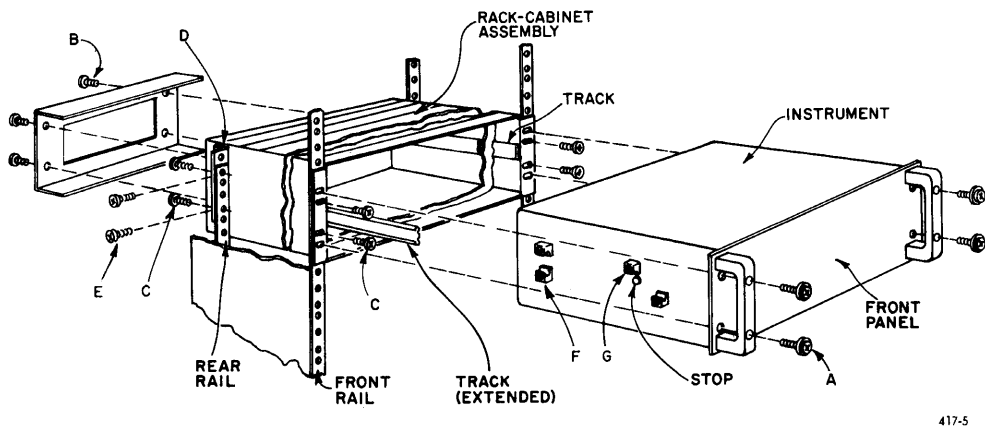


Figure 2-5. Rack-cabinet installation.

2.5.2 Installation.

Directions follow for mounting the cabinet in a rack and installing the instrument on its tracks:

a. Remove 4 dress-panel screws (A) and slide the instrument out of the cabinet. When free motion along the tracks is stopped, tilt the front of the instrument up slightly. Continue withdrawal, past the stops, pulling the instrument horizontally until it is free.

b. Insert the rack cabinet wherever desired in the rack — be sure it's level — and fasten it with 4 screws (C) to the front rails.

c. If the cabinet can be supported at the rear, remove the rear cover (screws B) for better access. Otherwise skip to step e.

d. Use brackets (D) to support the cabinet with the rear rails. Generously elongated screw holes allow positioning as desired. With screws (E) fasten brackets to cabinet. Pass screws (C) through brackets and screw them into the rear rail. (Details may be varied to suit particular situations.)

e. To install the instrument, first set its rear edge into the cabinet front opening. Slide the instrument back, making sure that the rear slide blocks and the upper front ones engage the tracks. (Stops prevent complete insertion.)

f. Slide the instrument forward *with* the tracks, keeping a hand on each side (fingers underneath). Slide the

Figure 2-5.

instrument *back* about 1/2 in. along both tracks, past the stops, by pressing down on the tracks (with thumbs) while tilting the front of the instrument up slightly.

g. Push the instrument back into the rack, checking for smooth operation of the tracks and slide blocks.

NOTE

The instrument is now readily accessible for behind-the-panel adjustments. It slides in and out freely on extending tracks. Obtain this advantage whenever desired by removing the panel screws (A).

h. Fasten the instrument in place using 4 dress-panel screws (A). (Pass your screwdriver through holes in the handles.)

i. Replace the rear cover, with its screws (B).

2.5.3 Conversion to Bench Use.

To convert a rack-mounting instrument for bench use, exchange the cabinet, as follows:

a. Obtain a Bench Cabinet, Part no. 4172-4017, from General Radio Company.

b. Remove the instrument from the rack cabinet, after removing the panel screws (A, Figure 2-5). (When free motion along the tracks is stopped, tilt the front of the instrument up slightly to clear the stops.)

c. Slide the instrument into the bench cabinet.

d. Fasten instrument to cabinet using dress-panel screws (A, figure 2-4).

e. Transfer the rear cover, with screws (B), from rack cabinet to bench cabinet.

2.6 POWER-LINE CONNECTION.

Power requirement for the 1238 Detector is 15 W at 100-to-125 or 200-to-250 V, 50-to-60 Hz. Make connection as follows:

a. Set the line-voltage switch on the rear panel (Figure 1-3) to correspond with the available power-line voltage. Use a small screwdriver to slide the switch.

b. Connect the external power line to the power plug using the power cord supplied or an equivalent 3-conductor cord (para. 1-4).

The fuse should have the current rating shown on the rear panel regardless of which line-voltage range is chosen in step a.

2.7 LINE-VOLTAGE REGULATION.

The accuracy of measurements accomplished with precision electronic test equipment operated from ac line sources can often be seriously degraded by fluctuations in primary input power. Line-voltage variations of $\pm 15\%$ are commonly encountered, even in laboratory environments. Although most modern electronic instruments incorporate some degree of regulation, possible power-source problems should be considered for every instrumentation setup. The use of line-voltage regulators between power lines and the test equipment is recommended as the only sure way to rule out the effects on measurement data of variations in line voltage.

The General Radio Type 1591 Variac® Automatic Voltage Regulator is a compact and inexpensive equipment capable of holding ac line voltage within 0.2% accuracy for input ranges of $\pm 13\%$. It will assure, for example, that an instrument rated for 100-125 (or 200-250) V can be operated reliably in spite of varying input voltages in the range 85-135 (or 170-270) V. The 1 kVA capacity of the 1591 will handle a rack full of solid-state instrumentation with no distortion of the input waveform. This rugged electromechanical regulator comes in bench or rack-mount versions, each with sockets for standard 2- or 3-wire instrument power cords.

Further details can be found in your GR catalog or in the *GR Experimenter* for October, 1967.

2.8 SYSTEM CONNECTIONS.

2.8.1 Inputs.

Connect the REFERENCE INPUTS jacks to the 2-phase reference ports of the oscillator supplying signal to the

bridge or measurement system. If that oscillator is the GR 1316, its corresponding jacks are labeled REFERENCE OUTPUTS. The normal relationship between the phases is QUADRATURE leading IN PHASE by 90° . (If you provide a lagging-quadrature reference pair, the calibrations of the PHASE SHIFT controls are reversed in sense, but their primary function is still valid.) Use BNC patch cords such as those listed in para. 1-4, adapted if necessary to your oscillator.

Connect the signal to be detected via the INPUT SIGNAL jack, making sure that the 200-V-rms limit is not exceeded. Use a BNC patch cord, as mentioned above.

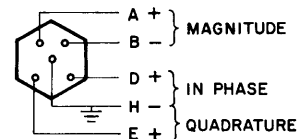
2.8.2 Outputs.

NOTE

The 1238 meters provide visual outputs; no output connections are necessary.

Connect the AMPLIFIER OUTPUT jack to a scope, a-c level recorder, or other instrument if you wish, using another BNC patch cord or adaptor. This signal is subject to the controls on the left half of the 1238 front panel only. The level is generally 0-4 V rms if the COMPRESSION button is "out"; however, 2.25 V corresponds to full scale on the MAGNITUDE meter. (In untuned, i.e. FLAT, operation, levels are limited to less than 4 V whenever GAIN is set to 20, 30, or 80 dB.) The available power is limited; keep the load impedance above 25 k Ω .

Connect remote indicators, such as voltmeters, if desired, via the DC METER OUTPUTS socket. Use a 5-pin plug, such as listed in para. 1-4, making connections as shown in Figure 2-6. The A-B circuit provides 0-6 V dc, corresponding to 0-100 on the MAGNITUDE meter. Do not ground that circuit. The D-H and E-H circuits provide 0-1 V dc corresponding to full scale deflection of the IN-PHASE and QUADRATURE meters respectively, when the SENSITIVITY control is set ccw. (That control affects only the 1238 phase-sensitive meters, not the remote circuit. Therefore, turning the knob cw causes full-scale deflection at lower DC METER OUTPUT voltages.) Pin H is grounded. Keep the load impedance in each of the 3 meter circuits above 25 k Ω .



1616-20

Figure 2-6. The DC METER OUTPUTS socket, exterior (rear) view.

2-4 INSTALLATION

Operation—Section 3

3.1 PRELIMINARY CHECKS AND SETUP	3-1
3.2 PHASE ADJUSTMENT	3-1
3.3 ROUTINE OPERATION	3-1

CAUTION

Do not connect a power cord until the line-voltage switch has been set properly.

3.1 PRELIMINARY CHECKS AND SETUP.

Refer to paragraph 1.3 for figures illustrating the controls, indicators, and connectors and for their functional descriptions. The recommended initial operating procedure follows:

a. Position the line-voltage switch on the rear panel according to the available power-line voltage (either 100-125 V or 200-250 V). To slide the switch, use the tip of a small screwdriver. Line frequency can be either 50 or 60 Hz for these preliminary and functional checks; a procedure will be described below for readjusting the line-frequency rejection filter (if necessary) to match your power source.

b. Check that the 3 meters read zero (2 of them at mid scale). If not, reset with the mechanical zero-adjustment screw just below each meter; use a small screwdriver.

c. Provide the 3 input signals, as described in para. 2.8 — a 2-phase reference and a coherent signal to be detected ($10\ \mu\text{V} - 100\ \text{mV}$).

d. Connect the power plug to a suitable power line, using the power cord supplied. Flip the POWER switch ON. Verify that a decimal point is illuminated in the FREQUENCY selector. In the FLAT position of the frequency range switch, the 1st decimal point serves only as a pilot light; in the other positions, the decimal points serve also as part of the FREQUENCY readout.

3.2 PHASE ADJUSTMENT.

Verify that the instrument is operational, as follows:

a. Set the front-panel controls as listed:

- POWER — ON
- FREQUENCY — FLAT
- TIME CONSTANT — 0.3 s
- PHASE SHIFT — 0°
- LINE REJECTION — push button out
- COMPRESSION — push button out
- GAIN — 20 dB

SENSITIVITY — ccw (minimum)

FINE ADJUST — midrange (both controls)

b. Turn the GAIN up (cw) until the MAGNITUDE meter reads 20-80.

c. Switch the FREQUENCY and frequency range controls to the input-signal frequency. The meter pointer will go off scale.

d. Turn the GAIN down (ccw) until the MAGNITUDE meter reads 20-80. If the source frequency is not calibrated within $\pm 5\%$, vary it and watch the meter for maximum response (correct tuning). Set to that frequency. Fine-tune either oscillator or detector for peak response. Reset the GAIN control as before.

e. Set the PHASE SHIFT controls so the IN PHASE meter indicates to the right (it may be off-scale) and the QUADRATURE meter reads zero. Use the lower FINE ADJUST control to refine that adjustment.

NOTE

The initial input signal has been used to establish which component of future input signals will be designated IN PHASE.

f. If the means are available to do so, shift the input signal exactly 90° and set the upper FINE ADJUST control for zero on the IN PHASE meter. Otherwise leave that control alone.

The 1238 Detector is now ready to use at the frequency of step d, above.

3.3 ROUTINE OPERATION.

3.3.1 Magnitude.

Observe or measure changes in magnitude of the input signal by watching the MAGNITUDE meter and turning the GAIN control. If the COMPRESSION push button is left "out," the meter responds linearly with voltage and the GAIN control varies 10 dB per step, 2 steps being a factor of 10 in voltage. The meter calibration is relative voltage; no units are specified.

If the frequency selector is set to FLAT, the magnitude you observe includes all components (10 Hz to 100 kHz). Otherwise, the components outside the 3% bandwidth of the tuning filter are excluded. This detector is primarily intended for single-frequency measurements, rejecting harmonics and noise. Gain is 25 dB (a factor of 18) higher when tuned than when FLAT. Refer also to para. 3.3.4.

3.3.2 Phase Sensitive Detection.

It is often convenient to have separate "phase sensitive" indications of 2 quadrature components of a single-frequency input signal. In fact if such a signal is vanishingly small, it may be necessary to employ phase-sensitive detection to obtain any reliable measure of the signal at all. The right-hand half of the 1238 Detector, panel is devoted to this function.

If the PHASE SHIFT has been set as described above, so long as the tuning remains unchanged, you can observe or measure (relatively) the input-signal components according to the following guidelines¹:

1. IN PHASE + ... like the initial signal
2. IN PHASE - ... 180° out of phase
3. QUADRATURE + ... 90° leading *
4. QUADRATURE - ... 90° lagging.*

The responses are normally linear, both meters being affected together by the GAIN, SENSITIVITY, and TIME CONSTANT controls. If the MAGNITUDE meter is reading on scale, the zero reading of either phase sensitive meter is valid even if the other is deflected off scale. Also, under that condition, the phase information indicated by the off-scale IN PHASE or QUADRATURE meter (or both) is correct.

3.3.3 Compression.

Figure 4-5.

Set the COMPRESSION push button *in*, if you want the quasi-logarithmic characteristic. With it, a 20-dB larger signal level is indicated by full scale on the MAGNITUDE meter, whereas there is a relatively minor change in gain at lower signal levels. In other words, compression is a voltage-dependent attenuation (or automatic gain control) which multiplies signal voltage by a smoothly varying factor that is 45% for small signals, reaches 35% for a signal that would normally be full scale on the MAGNITUDE meter, and is only 10% for one that would normally be a factor-of-10 overload. Figure 4-5. shows this relationship.

Use compression to save time and annoyance in situations with large variations of input-signal level and consequently the need to change the GAIN setting frequently. Also, use compression to avoid overloading the amplifier and MAGNITUDE meter when the input signal is approximately 1 V rms, the instrument is tuned, and the GAIN control is set as low as it will go.

*The opposite, i.e., 3 "lagging" and 4 "leading," is true if the QUADRATURE REFERENCE INPUT lags the IN PHASE. See para. 2.8.

¹+ means deflection to the right; -, to the left.

NOTE

COMPRESSION makes all meter responses and output signals quasi-logarithmic with respect to the input-signal level.

COMPRESSION introduces distortion, similar to limiting or clipping which can be seen in the AMPLIFIER OUTPUT waveform regardless of whether the instrument is tuned or FLAT. However, the tuning, if used, is just as effective in removing harmonics from the input signal (so they do not affect the indicators or the output signal) whether the COMPRESSION button is in or out.

COMPRESSION has a negligible effect on the phase of the signal being detected and therefore on the sense or null of the indication by IN PHASE or QUADRATURE meter.

3.3.4 Line-Frequency Rejection.

Set the LINE REJECTION push button *in* if you want the extra filtering thus provided.

NOTE

Leave this button *out* if the input-signal frequency is above 10 kHz.

The filter is fixed-tuned to either 50 or 60 Hz, and should preferably be set as you want it before you obtain the instrument. Directions for retuning are in para. 5.5.

One of the most common and pernicious kinds of noise or spurious components or "pickup" that can be superimposed on the desired input signal comes from the power lines. Of course, use care to avoid such noise: keep power currents from sharing ground circuits with the input signal, shield all low-signal-level components and interconnections; position sensitive equipment far away from electrical machinery; etc. But it often occurs that power-frequency noise is present despite all reasonable precautions, and that the desired signal has no important component at power-line frequency. Then it is expeditious to use a "notch" filter that will greatly attenuate any input-signal component at this frequency, but pass all other components unaltered.

Such a filter is built into the 1238 Detector for your convenience. To use it, simply set the LINE REJECTION button *in*. It provides you a 40-dB reduction in any line-frequency component that may be present, when the instrument is used FLAT; or it adds 40 dB to the substantial reduction provided by the digital tuning filter when that is set to a different frequency, such as 1 kHz.

There are 2 exceptions. Leave the LINE REJECTION button *out* if the input signal of interest is above 10 kHz because amplifier response up near 100 kHz will otherwise be attenuated. Leave the button out, also, if the signal of interest is within 10 Hz or so of line frequency.

Theory—Section 4

4.1 GENERAL	4-1
4.2 BLOCK-DIAGRAM DESCRIPTION	4-1
4.3 CIRCUIT DESCRIPTION	4-2

4.1 GENERAL.

Figure 1-1.

The 1238 Detector is a high-gain amplifier with a low-noise, high-impedance input stage, optional filtering, optional compression, and a pair of phase-sensitive detectors. Intended for use as an unbalance detector and indicator for precision bridges, it has calibration of frequency and gain. Although not intended as a voltmeter, its meters indicate the magnitudes of the amplifier output and each phase-detector output. The phase detectors are responsive to an orthogonal pair of components of the amplified signal. Any desired pair can be chosen by manipulation of a phase shifter acting in the 2-phase reference-signal channel.

The circuitry includes field-effect and bipolar transistors, and linear integrated-circuits, as amplifiers and buffers. Insulated-gate-field-effect transistors are used as solid-state relays to supplement mechanical switches in some of the control functions.

4.2 BLOCK-DIAGRAM DESCRIPTION.

Figure 4-1.

Main Signal Channel. The input signal is routed directly into the preamplifier, which contains an amplitude limiter that safeguards the circuit from damage by input signals up to 200 V. Three attenuators in the preamplifier are set electrically by the GAIN control, via the family of control signals CA, CB, CC.

The LINE REJECTION push button determines (via the pair of control signals CX) whether the line-frequency rejection filter is included in the signal channel. This is a narrow-band-stop filter.

Farther along the main amplifier chain, the frequency range switch determines which group of digitally-selected elements is used in the tuned-filter stage, or, if you select FLAT, connects an untuned network. That switch, together with the 3 digital FREQUENCY switches, tune the instrument to a selected frequency. In order to reject unwanted-frequency components without introducing difficulty in keeping source and detector in tune, the tuned filter has a bandwidth of about 3%.

The fourth attenuator is also set electrically by the GAIN control, via the pair of control signals CD. Similarly, the quasi-logarithmic circuitry is connected or disconnected by the COMPRESSION push button via control signal CZ.

The main signal being processed is designated SIG1 at the INPUT SIGNAL jack, SIG1A, SIG2, SIG3, and SIG3A at intermediate stages most of which are in the diagram, Figure 4-1, and SIG4 at the AMPLIFIER OUTPUT jack. SIG4 drives the MAGNITUDE meter (via the meter rectifier circuit) and both phase detectors.

Phase-Detector Circuitry. The REFERENCE INPUTS, internally designated REFI and REFQ, are each split into a pair of signals. NORTH is a replica of REFI, SOUTH is 180° out of phase. Similarly, EAST is like REFQ, WEST, 180° away.

The PHASE SHIFT switch and continuous control rotate the phase of the quadrature pair PHASI/PHASQ within

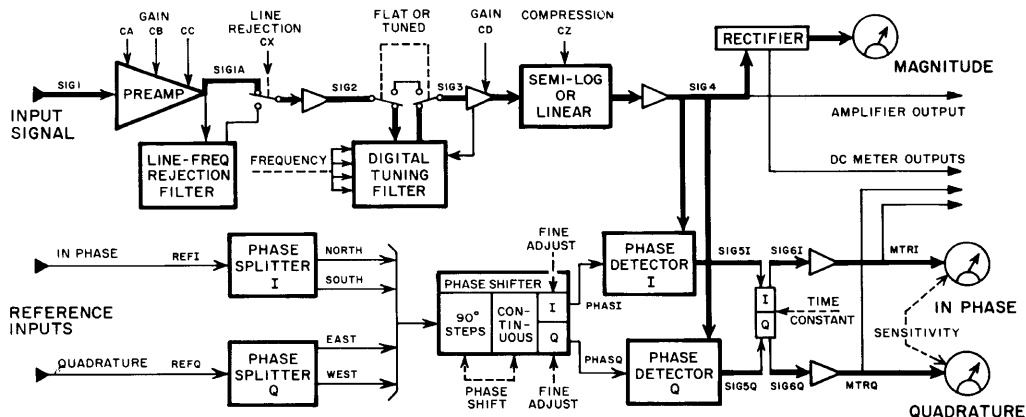


Figure 4-1. Overall block diagram.

the framework set up by NORTH, EAST, SOUTH, and WEST (which, as the nomenclature implies, is a full circle). The FINE ADJUST controls trim the phases of PHASI and PHASQ separately as may be required to make them exactly orthogonal.

Thus, the PHASE SHIFT controls determine what quadrature pair of components of SIG4 will be resolved by the phase sensitive detectors. For example, if PHASE SHIFT is set to ϕ° , the IN PHASE meter responds to the component ϕ° leading the IN PHASE REFERENCE INPUT and the QUADRATURE meter responds to the component $\phi + 90^\circ$ leading. (However, that sense obtains only if the QUADRATURE REFERENCE INPUT leads the IN PHASE by 90° . If it lags, replace "leading" by "lagging" in the statement above.)

In each phase detector, PHASI (or PHASQ) drives a synchronous switch which detects the appropriate component of SIG4. The resulting dc signal is amplified by circuits with an adjustable time constant, for smoothing, to drive the IN PHASE (or QUADRATURE) meter. The SENSITIVITY control affects these meters simultaneously, with a range of 6:1 but does not affect the meter-drive signals MTRI and MTRQ.

Outputs. The AMPLIFIER OUTPUT is the ac signal SIG4. The 3 DC METER OUTPUTS consist of MTRI, MTRQ, and a rectified voltage proportional to the MAGNITUDE-meter current.

4.3 CIRCUIT DESCRIPTION.

4.3.1 Preamplicifier (B Board).

Figure 6-5.

Although its etched circuit is part of the B board, the preamplifier is well isolated, decoupled, and shielded from the higher-level circuitry. A separate power supply, also on the B board, serves the preamplifier. A separate ground GS1 is tied through $10\ \Omega$ to chassis ground at AT1. GS1 is also the electrical midpoint between the power-supply terminals BP1 (+15 V) and BN1 (-15 V).

SIG1 from the INPUT SIGNAL jack drives the high-impedance field-effect transistor Q1 through a safety network. The midpoint between C1 and C2 is limited to instantaneous levels between $\pm 2\ \text{V}$ (clipping starts at $\pm 1.2\ \text{V}$).

As shown in Figure 4-2, the voltage of the desired signal E_s appears across the preamplifier input as SIG1, except for a negligible drop in the leads R_i and R_o and in source resistance R_s , if that is reasonably small. E_n represents an unwanted signal or noise source, which might send large currents through the ground loop R_o and R_g if R_1 were not present. (Though there are several physical causes for E_n , its frequency is usually that of the signal E_s .) Because of the resistance values, most of E_n appears across R_1 , and a negligible fraction across R_o . Therefore, the noise is largely eliminated from the preamplifier input.

Typically, the preamplifier output signal SIG1AA (60 dB above the SIG1 level) is so much larger than E_n that the

voltage across R_1 can be neglected in determining SIG1AB. That is, SIG1AA = SIG1AB, and we simply designate the preamplifier output as SIG1A, without specifying which ground is the reference.

The input-stage field-effect transistor Q1 is biased for best low-noise performance. Its gate is set at $-150\ \text{mV}$ with respect to its source by the use of R_9 and Q_4 to set the dc voltage at Q_3 emitter. The feedback loop through Q_3 , Q_5 , and Q_1 , by acting to hold Q_3 base slightly below that dc level, maintains the desired bias on Q_1 .

Gain through Q_1 and Q_3 depends on the feedback from Q_5 emitter to TP1. When CA is zero, Q_2 is a high impedance and that gain is unity. When CA is +15 V, Q_2 effectively grounds C3 and the gain is 20 dB. CA, like CB-, CC-, and CD-series signals is controlled by the GAIN switch, A-S8. Refer to Table 4-1, 1st 2 rows.

Between Q_5 and Q_8 , the signal goes either directly or through a voltage divider. If CB1 is $-15\ \text{V}$ and CB2 zero, the path is directly through Q_6 . If CB1 is zero and CB2 is $-15\ \text{V}$, the path is through Q_7 and a .01 divider, for 40 dB of attenuation. The gain through Q_8 , Q_9 , Q_{10} together is 100, or 40 dB. Refer to Table 4-1, next 3 rows.

Between Q_{10} and Q_{14} the signal goes through the 3rd part of the attenuator circuitry. When CC1 is $-15\ \text{V}$, the path is direct. When CC2 is $-15\ \text{V}$, attenuation is 20 dB, and similarly CC3 switches in 40 dB of attenuation. At any one time, one of the CC-series signals is $-15\ \text{V}$; the other two are 0 V. Q_{14} contributes no gain.

In summary, the preamplifier gain, from SIG1 to SIG1A is -40 , -20 , 0, 20, 40, or 60 dB depending on the GAIN control setting.

4.3.2 Line Rejection Filter (B board).

Figure 6-5.

The LINE REJECTION push button determines whether the signal passes through this filter or not. It does when the push button is in, making CX2 negative 15 V, CX1 zero and Q_{16} conducts. The straight-through connection is made when the push button is out. CX1 is negative 15 V; CX2, zero; and Q_{15} conducts. U_1 contributes only unity gain except for signal components at frequencies in the rejection "notch".

The active-filter network, Figure 4-3, has 3 equal capacitors, making $\beta = 1$ in the expression for an ideal single-frequency rejection filter:

$$R_{34} = \frac{(1 + \beta)(1 + 2\beta)}{\beta} R_1,$$

which has a transmission null at the frequency:^{1, 2}

$$f_0 = \frac{1}{2\pi RC\sqrt{3\alpha(1-\alpha)}}.$$

1. Hall, H. P., "RC Networks with Single-Component Frequency Control", IRE Transactions - Circuit Theory, Vol CT-2, No. 3, September 1955.

2. Hall, H. P., "Single-Component-Controlled RC Null Circuits", GR Experimenter, July 1961.

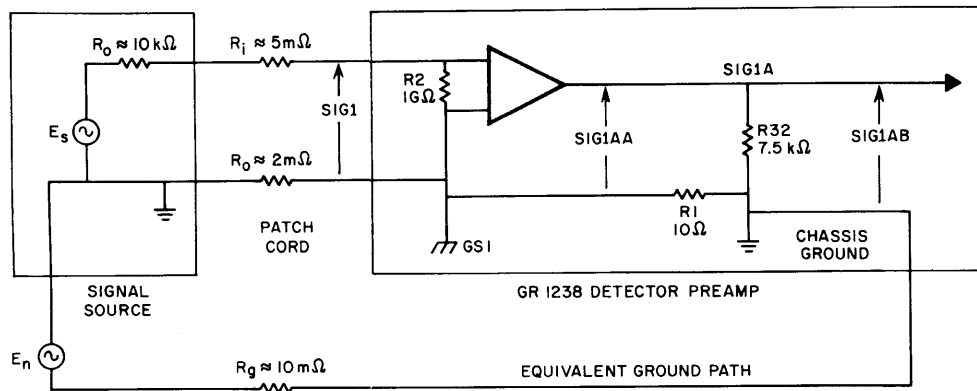


Figure 4-2. Preamplifier circuitry simplified to show the separation of ground GS1 from chassis ground, for the rejection of noise that may be present in a ground loop.

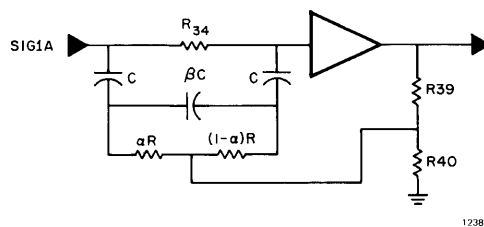


Figure 4-3. The filter used for LINE REJECTION – simplified diagram.

Table 4-1

GAIN-CONTROL LOGIC AND GAIN BY STAGES

Active components in the stage	GAIN control signal	Control-signal states* and dB gain per stage ^Δ											
		0	0	0	+	+	+	+	+	+	+	+	+
(SIG1) Q1, 2, 3, 5 (Q5E)	CA	0	0	0	+	+	+	+	+	+	+	+	+
	CB2	0	0	0	20	20	20	20	20	20	20	20	20
	CB1	-	-	-	-	-	-	0	0	0	0	0	0
Q6, 7, 8, 9, 10 (Q10C)	CC3	0	0	0	0	0	0	-	-	-	-	-	-
	CC2	0	0	0	0	0	0	40	40	40	40	40	40
	CC1	0	0	0	0	0	0	0	0	0	0	0	0
Q11, 12, 13, 14 (SIG1A) Q34, U4 [†] (SIG3A)	CD1	-40	-40	-20	-40	-20	-20	-40	-40	-20	-20	0	0
	CD2	30	30	30	30	30	30	30	30	30	30	30	30
		-	0	-	0	-	0	-	0	-	0	-	0
Q17 ... Q25 (SIG4)		0	-	0	-	0	-	0	-	0	-	0	-
		30	40	30	40	30	40	30	40	30	40	30	40
GAIN-control setting		20	30	40	50	60	70	80	90	100	110	120	130

*States are designated +, -, 0 for +15 V, -15 V, or zero, respectively

^ΔU1 and U5 are each unity-gain stages.

[†]Tuned gain 30 dB; FLAT gain about 5 dB.

There are 2 adjustments (Figure 5-2). R89 trims the effective value of R34. R139 and an associated jumper determine α , keeping R constant at 8.41 k Ω . For an ideal notch, then, R₃₄ should be 50.5 k Ω . It is set slightly higher, however, to widen the notch (at the price of imperfect rejection at its center). That choice reduces the notch center frequency very slightly (less than 1%) below f_o in the formula above. The effective notch center frequency is set as desired with R139, which can change α by about $\pm 10\%$.

The buffer stage, Q34 has unity gain. Its output is designated SIG2.

4.3.3 Digital Tuning Filter (Panel; B board). Figure 4-4.

An RC active filter* amplifies the component of SIG2 to which the filter is tuned. The resonant frequency is the reciprocal of $2\pi RC$. The response characteristic (gain and effective Q) is maintained by keeping the two R's equal, the two $\frac{1}{2} C$'s and the C in proportion to each other, and the effective gain of the amplifier constant. However, the R/C ratio is not critical, as their product is varied in such a way as to select frequency in digital steps to 3 significant figures.

Therefore, the 3 capacitances are tracked together. C changes as you turn the frequency-range switch, from 1.050 down to .001050 μF in 4 decade steps. Similarly, the 2 resistances are tracked together. R changes by parallel combinations (additive conductance) as you turn the 3 FREQUENCY controls, from 0.667 to above 667 $\mu \Omega$ in digital steps of 0.667 $\mu \Omega$.

The effective gain of the amplifier is stabilized at a value close to 6 by the inner feedback loop around U4, incorporating the voltage divider R54, R55, and R56. The nominal tuned gain between SIG2 and FDBK is 40 dB; between there and SIG3A, -10 dB; overall, 30 dB.

However, if you set the frequency selector to FLAT, the entire digital tuning network is removed, the outer feed-

back loop is opened, and 470- Ω resistor is inserted between the signal path at SIG3 and ground. The overall gain between SIG2 and SIG3A is about 5 dB (almost negligible) and untuned.

The following relationships are readily derived from the schematic diagram. They are useful to show how critical are the amplifier gain and the matching of resistor or capacitor sets in determining the gain and bandwidth of the active filter. The filter gain is G; at resonance, it is G_o ; $2\pi f_o = \omega_o$; and Q is the ratio of resonant frequency to bandwidth.

$$G = \frac{\text{"FDBK"}}{\text{"SIG2"}} = \frac{K}{A + j\omega B + D/j\omega}$$

$$G_o = K/A, \quad \omega_o = \sqrt{D/B}, \quad \text{and } Q = \sqrt{BD/A},$$

where A, B, and D depend on component values, but A also on K; and where K is the amplifier gain (with the inner feedback loop closed).

$$A = 1 + \frac{C_3}{C_1} + \frac{C_2}{C_1} \left(1 + \frac{R_1}{R_2} - K\right) + \frac{R_1}{R_2},$$

$$B = R_1 \frac{C_3}{C_1} (C_1 + C_2), \quad \text{and } D = \frac{1}{R_2 C_1},$$

where the subscripts are assigned left-to-right in Figure 4-4; the nominal values are so related that: $C_1 = C_2 = \frac{1}{2} C_3$ and $R_1 = R_2$. Ideally, to make $G_o = 100$, $K = 5.94$; and to make the bandwidth 3%, $Q = 33$.

The digital tuning network is mounted on its front-panel switch assembly and shown schematically in Figure 6-4. However, a set of 4 trimmer capacitors is located with U4 on the B board:

C26, between FDBK and TRIM1, trims the upper $\frac{1}{2} C$;
 C25, between TRIM2 and TRIM1, does the same on range 3;
 C27, between SIG3 and ground, trims C;
 C20, between TRIM3 and ground, trims C on range 3;
 where range 3 spans 1.0 to 10 kHz.

*Sallen and Key, "A Practical Method of Designing RC Active Filters," *IRE Transactions - Circuit Theory*, Vol. CT-2, No. 1, March 1955.

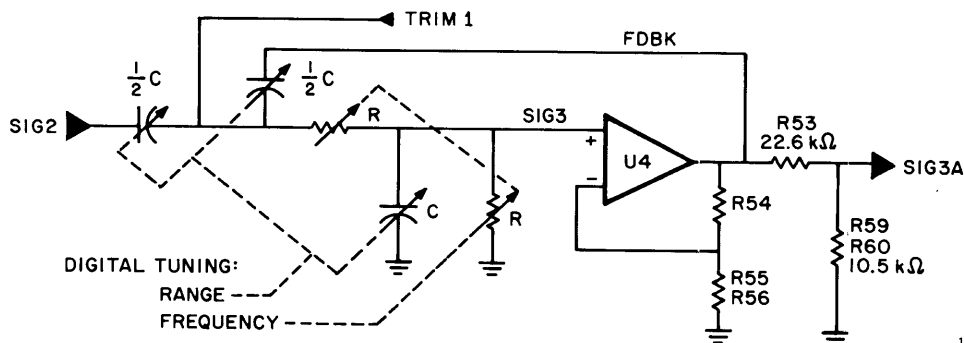


Figure 4-4. The filter used for tuning FREQUENCY - simplified diagram.

1238-6

4.3.4 Compressed/Linear Amplifier (B board). Figure 6-7.

The signal SIG3 next passes through an attenuator, 0 or 10-dB loss, and 2 amplifiers that buffer the compression network and contribute 40 dB of gain. The attenuator is switched by the GAIN control, which acts by making the CD2 level -15 V to enable direct conduction through Q17 or the CD1 level -15 V to select the lossy path through Q18. CD1 is zero when CD2 is -15 V and vice versa.

Q19, Q20, and Q21 together contribute a gain of 6 (15.5 dB). Q23, Q24, and Q25 together have a gain of 17 (24.5 dB).

The COMPRESSION push button makes CZ negative 15 V (zero), for the in (out) position, closing (opening) the circuit through Q22 and the pair of diodes CR5/CR6.

Since full scale on the MAGNITUDE meter corresponds to 2.25 V rms (3.18 V pk) at WT57 and the same at the output of Q25, a gain of 17 means the corresponding level at Q23 base is 187 mV pk. That level is characteristic whether you select compression or not. However, without compression there is no attenuation between Q21 and Q23; with compression this attenuation is a factor of 10. R71 is adjusted for that purpose.

The factor-of-10 compression can be expressed by means of an auxiliary scale on the MAGNITUDE meter, with 1000 at the top instead of 100. Such a scale, drawn straight, is provided in Figure 4-5

4.3.5 Output Amplifier/Meter Rectifier (B board).

The output amplifier U5 has unity voltage gain. It drives the phase detectors, the AMPLIFIER OUTPUT circuit, and the MAGNITUDE meter rectifier with SIG4, isolating Q25 from these loads. VR21 and VR22 limit the voltage level ahead of U5 to 6.1 V pk, for protection of the circuits that follow. Therefore, SIG4 can be 0-4 V rms without clipping.

The full-wave rectifier CR7/CR8 is followed by large capacitors, in a voltage-doubler circuit which make the MAGNITUDE-meter peak-responsive. R85 and R86 limit its current to the full-scale value (200 μ A) at full AMPLIFIER OUTPUT voltage of 2.25 V rms. Pins A and B of the DC METER OUTPUTS jack connect the rectifier to your optional, remote, ungrounded magnitude meter, which

should have current-limiting resistance similar to that of R85/R86, or to a dc recorder with impedance of 25 k Ω or more.

4.3.6 Phase Splitter (C board).

Figure 6-10.

There are 2 identical C boards, distinguished by the letters I (in phase) and Q (quadrature) in this discussion.

NOTE

C-board signals named in the following few paragraphs are in the "I" category except for names in parenthesis, which are the "Q" equivalents.

The phase splitter circuit Q201/Q202/Q203 passes the REFERENCE INPUT signal REF1 (or REFQ) with negligible gain or phase shift, the corresponding output being NORTH (or EAST). This circuit also generates the inverse signal SOUTH (or WEST) so that the pair of outputs are 180° apart in phase.

Therefore, the outputs NORTH, EAST, SOUTH, and WEST are 90° apart as their names imply, with the sense of the sequence determined by the externally supplied signals. Normally, the QUADRATURE REFERENCE INPUT leads the IN PHASE; then EAST leads NORTH, but the converse is possible.

4.3.7 Phase Shifter (panel, D board).

Figure 6-12.

The PHASE SHIFT switch A-S1 and continuous control A-R3/A-R4 enable you to rotate the phase-detector reference pair PHASI/PHASQ to any desired phase positions in the entire 360° circle of possibilities.

The PHASE SHIFT switch works as follows, if the continuous control is set at 0°: for switch positions 0°, 90°, 180° 270°, PHASI becomes NORTH, EAST, SOUTH, WEST, respectively; and PHASQ is always 90° ahead, i.e., EAST, SOUTH, WEST, NORTH, respectively. The PHASE SHIFT continuous control shifts both PHASI and PHASQ through an angle of $\pm 50^\circ$ about the positions just described, but keeps them always essentially 90° apart. The two FINE ADJUST controls are uncalibrated (in contrast with the PHASE SHIFT switch and continuous control); one shifts the phase of PHASI, the other of PHASQ, over $\pm 10^\circ$ ranges.

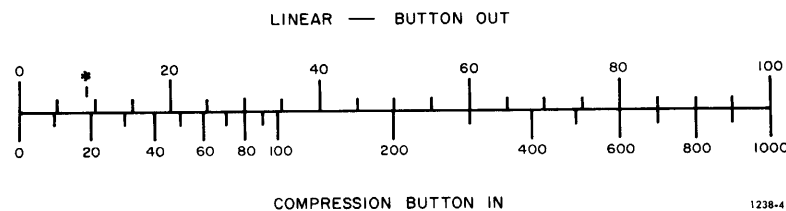


Figure 4-5. MAGNITUDE meter responses. Upper scale: linear with voltage, as marked on meter. Lower scale: compressed, units being percentage of full-scale linear response. Compressed scale is not on the meter. Asterisk (*) marks ideal (noise-free) level of full-scale IN PHASE meter response.

They have adequate range to enable you to set PHASI and PHASQ exactly 90° apart, for any combination of control settings, with REFQ as much as 5° away from its nominal quadrature phase relation to REF1.

If REFQ leads REF1 by 90° , as is recommended in the 1621-system instructions, EAST leads NORTH, PHASQ leads PHASI, the PHASE SHIFT calibrations are degrees that PHASI leads REF1, upscale on the QUADRATURE meter indicates a component leading the upscale-IN-PHASE-meter component by 90° , and that component, in turn, leads the IN PHASE REFERENCE INPUT signal by the PHASE SHIFT angle. However, if REFQ lags REF1, replace "lead" with "lag" in the preceding statement.

The D board is mounted to the rear of the PHASE SHIFT switch A-S1 and serves as terminal board as well as mount for fixed resistors associated with the potentiometers mentioned above.

4.3.8 Squaring Amplifier and Synchronous Switch (C board).

The sinusoidal phase reference PHASI (or PHASQ) passes through buffer Q204 to the inverting (–) input of comparator U201 which is used as a zero-crossing detector. The moment PHASI goes "+", the output of U201 jumps to -0.5 V; when it goes "–", to $+3.2$ V. A small amount of hysteresis is provided by the feedback through R218 and C207 so that the comparator will make only one transition at every substantial zero-crossing of PHASI, and not respond to possible low-level noise. (U201 has a response time less than $0.1 \mu\text{s}$.)

Q205 current is turned on and off "hard" for equal time intervals. The output of Q206 is a symmetrical square wave of nearly the full ± 15 V amplitude permitted by the power

supplies. Feedback through R224 improves the symmetry of the above-mentioned hysteresis and enhances the overall stability.

The heart of the phase-sensitive detector is the synchronous switch, Q207 driving Q208, both field-effect transistors.

The square wave from Q206 serves to open and close the synchronous switch, driving d-c buffer amplifier U202 with that "slice" of SIG4 which coincides with the "+" half of the square wave. During that half cycle, diodes CR204 and CR205 are nonconducting; Q208 is "on" because Q207 is "on"; but the latter blocks even leakage or the transient current through the capacitance of CR204 from reaching Q208 or the signal path to U202. During the "–" half cycle, both diodes conduct, both Q207/Q208 gates are biased strongly negative, and R230 pulls the signal at U202 down to zero.

4.3.9 Time-Constant Circuit and Meter Driver.

The unity-gain buffer U202 provides a low-impedance source for the time-constant circuit (C216 in series with A-R10 . . . A-R19). TIME CONSTANT switch A-S2 selects the resistors in pairs, so that the I and Q phase detectors always have the same time constant. It is simply the product of the values of the selected resistor and C216.

Meter driver U203 has a gain of 3, between its input SIG6 and its output MTRI (or MTRQ). For minimum SENSITIVITY, full scale on the IN PHASE meter (for example) corresponds to MTRI = 1.5 V; for maximum SENSITIVITY, 245 mV. The latter corresponds to SIG6 = 82 mV, SIG4 = 280 mV pk = 200 mV rms, and a MAGNITUDE meter reading of 9 or 10 (about -20 dB referred to full scale), assuming the signal is in phase.

Service and Maintenance—Section 5

5.1 GR FIELD SERVICE	5-1
5.2 MINIMUM PERFORMANCE STANDARDS	5-1
5.3 DISASSEMBLY	5-5
5.4 OUTLINE OF ADJUSTMENTS	5-6
5.5 ADJUSTMENT PROCEDURES	5-8
5.6 TROUBLE ANALYSIS	5-9

5.1 GR FIELD SERVICE.

The two-year warranty attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone the nearest GR service facility (see back page), giving full information of the trouble and of steps taken to remedy it. Describe the instrument by type number (front panel), serial, and ID numbers (rear panel).

Instrument Return. Before returning an instrument to General Radio for service, please ask our nearest office for a "Returned Material" number. Use of this number in correspondence and on a tag tied to the instrument will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

For return shipment, please use packaging that is adequate to protect the instrument from damage, i.e., equivalent to the original packaging. Advice may be obtained from any GR office.

5.2 MINIMUM PERFORMANCE STANDARDS.

5.2.1 General.

Figure 5-1.

The equipment, methods, and criteria for verifying the specified performance of the 1238 Detector are given below. Pertinent adjustments are described in para. 5.4 and 5.5. If performance is grossly inadequate, erratic, or cannot be corrected by the adjustments, refer to trouble analysis, para. 5.6.

Equipment needed for the measurements and procedures of this section is listed in Table 5-1. Set the front-panel controls to the standard positions of Table 5-2, except as specified otherwise, in all the procedures of Section 5.

CAUTION

Keep the oscillator level below 10 V to safeguard the attenuator.

5.2.2 Gain and Tuning.

Use the following procedure to check the gain and tuning, first with an indicated FREQUENCY of 515 Hz.

a. Make the test setup shown in Figure 5-1. Supply the attenuator with an external, series, high-impedance load in an 874-X Insertion Unit, through which the signal goes to the 1238 Detector INPUT SIGNAL jack (connection Y). The alternative connection, to measure the voltage at the attenuator output (connection X) is to be made by rearranging cables; switches are not recommended. Make initial settings as listed in Tables 5-2 and 5-3, except tune the 1238 Detector to an indicated FREQUENCY of 515 Hz.

NOTE

The high series impedance simulates the internal impedance of the 1616 Precision Capacitance Bridge.

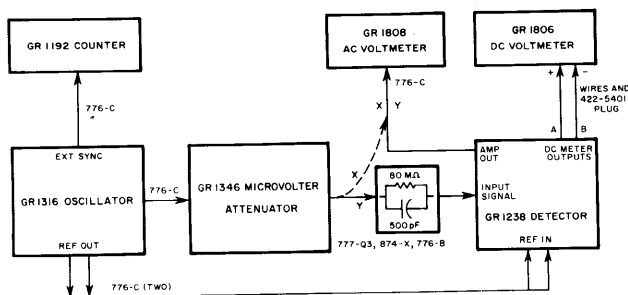


Figure 5-1. Test setup for performance evaluation. X-X and Y-Y represent alternative cable arrangements; do not use switches.

Table 5-1

TEST EQUIPMENT

Item	Requirements	Recommended Type*
Oscillator	Frequency: 10 Hz – 100 kHz Voltage: 0-4 V rms into 600 Ω Distortion: <0.2% (100 Hz-10 kHz) Output impedance: < 5 Ω Reference outputs: 2-phase, phase separation: 90 \pm 10 $^\circ$, voltage: 1.25 \pm 0.25 V rms into 50 k Ω .	1316
Electronic Voltmeter	Voltage range: 1.5 – 150 V F.S. Ac accuracy: \pm 1% of reading \pm 0.1% of FS, (up to 3 times worse below 40 Hz). Frequency range: 10 Hz to 200 kHz Scales: Volts rms and dBm (ref 1 mW into 600 Ω).	1808
Electronic Voltmeter	Voltage range: 1.5 – 150 V F.S. Dc accuracy: \pm 2% of reading Input impedance: 10 M Ω .	1806
Attenuator (metered)	Audio-frequency "microvolter". Attenuation: 0-120 dB in 20-dB steps; Accuracy: \pm .04 dB/step \pm 154 dB below input level. Frequencies: 10 Hz – 100 kHz Accuracy of meter: \pm 4%.	1346
Counter	General-purpose	1192
Scope	General-purpose, with plug-in differential amplifier, time base, and probe.	Tektronix 5103N/D10, 5A20N, 5B10N and P6060.
Adaptors	Connectors: shielded banana, 874. Component mount with GR874 connectors.	777-Q3 874-X
Patch cords (cables)	With connectors: BNC, BNC; length: 36" (5 required) With connectors: BNC, GR874; length: 36".	776-C 776-B
Resistors	Type: composition Power: 1/8 W Values: 18 M Ω \pm 10% (2); 22 M Ω \pm 10% (2) (or any other combination to make 80 M Ω).	Ohmite "Little Devil"
Capacitors	Type: mica Value: 510 pF \pm 10%	Cornell-Dubilier CD19 . . .
Metered adjustable autotransformer	Output line voltage 0-117% of input line (nominal 120 V). Meters: 0-150 V, 0-1 and 0-5A, 0-150 and 0-750 W.	W5MT3AW

*Equivalent may be substituted.

5-2 SERVICE

Table 5-2

STANDARD SETTINGS FOR 1238 EVALUATION

Control	Setting
POWER	ON
FREQUENCY	FLAT
TIME CONSTANT	0.3 s
FINE ADJUST	Midrange (both controls)
PHASE SHIFT	180° (large dial at 0°)
SENSITIVITY	Minimum (ccw)
GAIN	40 dB
COMPRESSION	Disabled (button out)
LINE REJECTION	Disabled (button out)

Table 5-3

PRELIMINARY SETTINGS IN TEST SETUP

Instrument	Control	Setting
1316 Oscillator	FREQUENCY	500 Hz
	OUTPUT V RANGE	1.5 V
	OUTPUT ADJUST	MAX (cw)
1346 Microvolter	METER F S	ATTEN ONLY
	F S OUTPUT V	40 dB
	OUTPUT	ON
1192 Counter	GATE TIME	1 s
	FREQUENCY	button in
	All other buttons	out
	AC/DC	AC
	TRIGGER LEVEL	midrange
1806 Voltmeter	DISPLAY	1 s
	MEASUREMENT	DC+
	DC INPUT R	100 M
	DC ZERO	See 1806 manual
	Terminal configuration	Ungrounded
1808 Voltmeter	VOLTS F S	15
	Range	1.5 V (0 dBm)

Table 5-4

GAIN CHECKOUT

Attenuator dB	INPUT dBm [†]	INPUT rms	GAIN dB	OUTPUT* dBm [†]	OUTPUT V
0	- 15	138 mV	20	5	1.38
20	- 35	13.8 mV	30	-5	0.44
			40	5	1.38
40	- 55	1.38 mV	50	-5	0.44
			60	5	1.38
60	- 75	138 μV	70	-5	0.44
			80	5	1.38
80	- 95	13.8 μV	90	-5	0.44
			100	5	1.38
100	-115	1.38 μV	110	-5	0.44
			120	5	1.38
120	-117 ^Δ	1.09 ^Δ μV	120	3	1.09
			130	13	3.46

[†] Level in dB referred to zero at 774.6 mV (1 mW in 600 Ω).

*Nominal level.

^ΔNominal; set as required to obtain 3 dBm when GAIN = 120.

b. Verify that the 1238 digital tuning filter is peaked within ±5% of the FREQUENCY setting, as follows. Tune the oscillator to a peak response on the ac voltmeter. The 3rd FREQUENCY dial of the oscillator has a continuous adjustment range slightly in excess of a decade, to facilitate such tuning. Reduce the oscillator level (OUTPUT ADJUST) if necessary to keep the voltmeter reading on scale. Read the frequency on the counter; for a nominal 515 Hz, the acceptable range is 489-541 Hz.

c. Verify that the tuned gain is 40 ± 3 dB for the GAIN setting of 40 dB, as follows. Use the ac voltmeter to measure the level at the attenuator (connection X in Figure 5-1). Drop the attenuator setting to 20 dB and set the oscillator output so that measurement is -35 dBm (13.8 mV). The oscillator level will be about 138 mV.

Now rearrange the cables so the ac voltmeter measures the AMPLIFIER OUTPUT of the 1238 Detector (connection Y); the voltmeter should read 5 dBm (acceptable: 2-8 dBm or 0.975-1.943 V rms). Record the measurement, preferably in dBm, for later reference.

d. Verify that the FLAT gain is below the tuned gain by no more than 31 dB (25 is nominal) as follows. Reset the oscillator level for a voltmeter reading of 5 dBm. Switch the 1238 frequency range to FLAT and the 1346 attenuator to 0 dB. The voltmeter should read -6 dBm or higher. Return the attenuator to 20 dB.

e. Verify that the 2nd-harmonic rejection is at least 30 dB, as follows. Tune the oscillator to double the frequency of step b (as indicated accurately by the counter). Reset the voltage at the attenuator output (connection X) to -35

dBm. Return the 1238 frequency-range switch to the proper test-frequency setting of step c, and the voltmeter to connection Y. The voltmeter should read less than -25 dBm, if we assume a nominal reading of 5 dBm in step c.

f. Verify that the GAIN steps are 10.0 ± 1.1 dB each, and that the cumulative error never exceeds 5.5 dB, as follows. Retune oscillator and detector to approximately 515 Hz as in step b. Set the oscillator level as before, so the output from the attenuator at 0 dB is -15 dBm (connection X). Set the 1238 GAIN to 20 dB and reconnect the voltmeter to read OUTPUT (connection Y). Record the output level, preferably in dBm.

Refer to Table 5-4; you have set up the first row (step c was the 3rd row). Similarly, check each of the GAIN settings from 20 to 120 dB and record the measured output. The easiest way to handle the results is to add 10 dB to every other measurement (nominal value -5 dBm) so that all results are nominally 5 dBm. Any two adjacent measurements may differ by as much as 1.1 dB. The largest and smallest may differ by as much as 5.5 dB.

NOTE

At small input signal levels, take an average reading on the voltmeter. To be sure the OUTPUT voltage measures signal, not noise, observe whether the indication drops by 20 dB for a 20-dB increase of attenuation.

If, for example, with GAIN = 100 dB, when you switch the attenuator from 80 to 100 dB, the OUTPUT measurement drops from 3.2 dBm (the nominal is 5 dBm) to -16.5 dBm, the noise accounts for about 0.3 dB. If it is necessary to obtain maximum accuracy, because you are in doubt about the instrument meeting the specifications, then, use a higher signal level. But never go high enough to make the OUTPUT 14.3 dBm (4 V rms). In this example, go back to the 80-dB setting and raise the oscillator level 10 dB (to a reading of 13.2 dBm). Then correct subsequent output measurements, by subtracting 10 dB, to complete your set of data.

When the attenuator reads 120 dB, increase the oscillator level as required to get a signal clearly above noise (3 dBm average OUTPUT reading is recommended) before switching to a GAIN of 130 dB. Verify that the OUTPUT increases by $10 \text{ dB} \pm 1.1 \text{ dB}$ between the GAIN settings of 120 and 130 dB. Finally, verify that the signal you have is coming through the attenuator (not a stray path) by switching the microvolter OUTPUT control OFF and ON. The OFF indication should be less, by at least 6 dB.

This completes the 515-Hz checkout. Now make a similar checkout, except for the GAIN control steps, at 4 other frequencies, as follows.

g. Retune the 1238 Detector to 49.9 Hz. Repeat steps b, c, d, e. Repeat also for 1238 Detector FREQUENCY

settings of 6.51 kHz, 33.3 kHz, and 97.7 kHz, except step e for the highest frequency.

5.2.3 Line Rejection.

The following procedure is to check the line-frequency rejection filter. Use the test setup as before, but set the 1238 frequency range to FLAT, the 1234 attenuator at 20 dB, the 1238 GAIN at 40 dB.

a. Tune the oscillator to 40 Hz and set its OUTPUT ADJUST for an attenuated voltage (connection X) of -9 dBm. Retune to 50, 60, and 70 Hz, watching the voltage. If it stays within ± 0.1 dB ($\pm 1\%$ in voltage), the variation can be neglected; otherwise the level should be reset for each new frequency in steps b, c, below.

b. Determine the central frequency to which the filter is adjusted and verify the 40-dB rejection as follows. Depress LINE REJECTION. Measure the AMPLIFIER OUTPUT level (connection Y) for oscillator frequencies of 50 and 60 Hz. The lower reading is central. Check that it is at least 40 dB (2 steps of the voltmeter range switch) below the level measured with the LINE REJECTION button "out."

c. Verify that skirt rejection is within specifications, as follows. Tune the oscillator 10 Hz above the central frequency. Check that the difference between LINE REJECTION "in" and "out" is at least 6 dB but no more than 10 dB. Retune to a frequency 10 Hz below the central frequency and repeat this check. Finally, leave the push button "out."

5.2.4 Magnitude Calibrations.

This procedure verifies that the MAGNITUDE meter is calibrated properly with respect to the output level both without and with compression.

a. Set the oscillator OUTPUT VOLTAGE RANGE to 1.5, the 1346 attenuator to 40 dB, the 1238 GAIN to 50 dB, FREQUENCY to 515 Hz, and tune the oscillator for peak output, as before. The dc meter should already be connected, ungrounded, between pins A and B of DC METER OUTPUTS.

b. Adjust the oscillator level so the 1238 MAGNITUDE meter is deflected precisely to full scale. Check that the dc voltmeter reads $6.0 \text{ V} \pm 10\%$ (5.4 – 6.6 V). (Normally, the corresponding ac voltmeter reading is about 2.3 V.)

c. Depress the COMPRESSION pushbutton and switch the attenuator to 20 dB. The dc voltmeter should read the same as in step b, within $\pm 5\%$.

d. Release the pushbutton. Reset the attenuator to 40 dB.

5.2.5 Phase-Sensitive Circuitry.

Check as follows that the PHASE SHIFT controls are functional and that the phase-sensitive meters respond with

the required sensitivity. The test frequency should be 515 Hz and the MAGNITUDE meter should already be reading at full scale. Reconnect the dc meter to pins D and H (ground) of DC METER OUTPUTS.

a. Reduce the signal level 20 dB by switching the attenuator to 60 dB. Set SENSITIVITY to maximum (cw). Set the PHASE SHIFT dial for maximum deflection (+ or -) of the IN PHASE meter. Concurrently, set the oscillator OUTPUT ADJUST to make that deflection exactly full scale. Check the zero condition by switching the attenuator to 120 dB for a moment; the IN PHASE meter should then read $0 \pm 1/2$ division.

b. Check that the dc voltmeter reads 243 mV $\pm 20\%$ at full scale on the IN PHASE meter, + if this meter reads +, and conversely. (The limits are 190-295 mV.)

c. Check that the 2 phase-sensitive channels have similar gain, as follows. Switch the PHASE SHIFT 90° and peak the QUADRATURE meter using the PHASE SHIFT dial. The reading should be full scale, within ± 1 division. Check the zero as in step a.

d. Check that the 2 phase-sensitive channels can be made orthogonal and that the FINE ADJUST control is functional as follows. While the QUADRATURE meter reads FULL SCALE, set the IN PHASE meter to zero, using the PHASE SHIFT dial. Verify that this zero occurs at different settings on that dial, depending on the IN PHASE FINE ADJUST knob. These settings should cover a range of at least 10° (nominal 20°) on the PHASE SHIFT dial. Leave the FINE ADJUST knob at midrange and the IN PHASE meter reading zero. Notice the PHASE SHIFT reading for a reference.

e. Check the continuity of the IN-PHASE-channel phase shift as follows. Rotate the PHASE SHIFT dial approximately 45° each side of that reference. The meter deflection should vary smoothly with this rotation, reaching about ± 35 on the meter scale. Find another reference phase where this meter reads zero (approximately 180° from the first one) and repeat. Near one zero, the meter deflects in the same direction as you rotate the dial, near the other, in the opposite direction.

f. Similarly, check the QUADRATURE-channel phase shift. This meter should read zero about 90° from the phase reference found in step d. Deflection should be in both senses, as before.

g. Check the zero adjustment of the phase-sensitive meters, when the time constant is large, as follows. Set TIME CONSTANT to 10 s, GAIN to 20 dB, and the Microvolter OUTPUT OFF. Wait at least 2 minutes. Verify that these meters read 0 ± 1 division. Return TIME CONSTANT to 0.3 s.

h. Check the noise level with the setup adapted for sensitivity measurement as follows. Set PHASE SHIFT for peak response on the IN PHASE meter. Reduce the oscillator level to 0.5 V or less. Then set the 1346 Microvolter thus:

METER FULL SCALE – 1 V, ac
FULL SCALE OUTPUT VOLTAGE – $1 \mu\text{V}$
OUTPUT – ON
LEVEL – maximum (cw)

Disconnect the counter and both voltmeters from the test setup. Set the 1238 TIME CONSTANT to 10 s. Set the oscillator level for 1/10 full scale on the Microvolter meter; then turn the Microvolter OUTPUT OFF. Set the 1238 GAIN to 130 dB.

The noise level may be rather large on the MAGNITUDE meter (such as 35) but the average reading of the IN PHASE meter should be 0 ± 15 (0 ± 3 divisions). If not, check that the oscillator and detector are securely fastened in their cabinets, cables are reliably shielded, and the front-panel output terminals of the attenuator are also shielded.

i. Verify that the low-frequency sensitivity is 100 nV or better for full-scale deflection, as follows. Switch the 1346 Microvolter OUTPUT ON. The IN PHASE meter should deflect to 50 or offscale. Allow at least 30 s for the circuit to stabilize.

j. Check that the sensitivity at 100 kHz is better than 100 nV for 2/3-scale deflection, as follows. Set oscillator and detector FREQUENCY to 100.0 kHz; tune for a maximum MAGNITUDE response (with a larger signal as in step b). Set PHASE SHIFT with large attenuation and GAIN (both 120 dB) so that the QUADRATURE meter reads 0 ± 3 divisions while the IN PHASE meter reads approximately full scale. (The oscillator level should be about 0.2 V; TIME CONSTANT = 1 s.)

Check the noise level as in step h. The noise level on the MAGNITUDE meter will be larger than before (such as 90) but the average reading on the IN PHASE meter should be 0 ± 20 (0 ± 4 divisions).

Switch the Microvolter OUTPUT ON. Within 30 s, the IN PHASE meter should deflect at least 35 (possibly 50 or off scale). Readjust the PHASE SHIFT if necessary to bring the QUADRATURE reading to an average of 0 ± 25 and switch the PHASE 2 steps (180°). The IN PHASE meter should slowly reverse polarity. This completes the performance checkout.

5.3 DISASSEMBLY.

Figure 2-4.

5.3.1 Cabinet Removal.

Remove the 4 front-panel screws (A) accessible through holes in the handles. Disconnect all cables and the power cord at the rear. Slide the instrument forward out of the cabinet. For more detail, refer to Section 2.

5.3.2 Lamp Removal.

For replacement of a burned-out lamp, use the following guidelines:

a. With the cables disconnected, slide the instrument forward, out of its cabinet a few inches, as described above. The lamp holders will be apparent, one directly behind each

decimal point in the FREQUENCY readout. The uppermost terminal of each (wired together and to ground) is part of the retaining clip.

b. Slip the clip off by lifting this terminal up and back; then unhook the lower part of the clip.

c. Pull the lamp out toward the rear, using a bit of adhesive tape, or tip the instrument so the lamp falls out.

d. To replace the retaining clip behind a new lamp, engage the lower part first. Then lift the upper part up and forward, snapping it into position.

5.3.3 Knobs and Dials – Removal.

CAUTION

Do not pull on the dial to remove a dial/knob assembly. Always remove the knob first. Do not use a screwdriver or other instrument to pry off the knob if it is tight, since this may damage the dial. Do not lose the spring clip in the knob when it is removed.

To remove the knob and dial (if any) from a front-panel control, either to replace one that has been damaged or to replace the associated control, proceed as follows:

a. Grasp the knob firmly with dry fingers close to the panel and pull the knob straight away from the panel.

b. Observe the position of the setscrew in the bushing when the control is fully ccw.

c. Release the setscrew with an Allen wrench; pull the bushing off the shaft. The dial will come off with the bushing.

NOTE

To separate the bushing from the knob, if for any reason they should be combined off the shaft, drive a machine tap a turn or two into the bushing to provide sufficient grip for easy separation. If the retention spring in the knob falls out, reinstall it in the interior notch with the small slit in the inner diameter of the wall.

5.3.4 Knobs and Dials – Replacement.

To replace a knob (with or without a dial):

a. Slip the bushing on the shaft and rotate the former to the correct position as observed in disassembly.

b. Hold the bushing in position so it, or the attached dial, is spaced away from the panel by at least the thickness of a filing card. Hold the bushing even farther forward, if necessary, to prevent the shaft tip from protruding. However, hold the PHASE SHIFT dial back, so its front surface is flush with the panel.

c. Tighten the setscrew in the bushing.

d. Place knob on bushing with retention spring opposite the setscrew.

e. Push knob on until it bottoms and pull it lightly, to check that the retention spring is seated in groove in bushing.

5.3.5 – Shield Covers.

The bottom cover, extending under two thirds of the instrument, can be removed for access to the mother-board circuitry. Remove 6 screws along the front and rear edges of the cover, *not* the other 4 screws (which hold transverse shields). The cover is off in Figure 5-3.

Lift out the preamplifier shield (in the left rear corner, Figure 5-2), if necessary, after removing 5 screws. One screw shows clearly in the figure, 2 others are at the rear, and 2 at the side of the instrument.

For access to the rectifier circuitry atop the power transformer (A-T1), remove the 2 screws and cover. (Only the screw holes show in the figure; the cover is off.)

5.4 OUTLINE OF ADJUSTMENTS. Figures 5-2, 5-3.

This paragraph lists adjustments in alphanumeric order, giving their purposes. Instructions for setting most of these are given in para. 5-5. You can locate all adjustments but one, by reference to Figure 5-2; B-R108 is in Figure 5-3.

B-C20. Trims resonant frequency of digitally tuned active filter, on lower "kHz" range only (Set after C27.)

B-C25. Trims resonant gain of same filter (SIG3A/SIG2) on lower "kHz" range only. (Set after C26.)

B-C26. Trims resonant gain of that filter on upper "kHz" range (minor effect on lower ranges). Interacts noticeably with C27 (both affect gain, but in the opposite sense).

B-C27. Trims resonant frequency of that filter on upper "kHz" range (minor effect on lower ranges). Interacts noticeably with C26 (both affect frequency in the same sense).

B-R9. Sets bias level of preamp input stage (for minimum noise level).

B-R55. Sets low-frequency-resonant (and FLAT) gain of digitally tuned active filter (SIG3A/SIG2).

B-R71. Sets the COMPRESSION level.

B-R86. Sets the MAGNITUDE meter response with respect to the AMPLIFIER OUTPUT level (SIG4).

B-R89. Trims the shape of the LINE REJECTION notch, i.e., the effective Q of the filter. Also affects the resonant frequency, secondarily.

B-R108. Main power-supply regulator adjustment.

C-C214. Trims square-wave drive for synchronous switch, at high freq, for 0 phase-detector offset.

C-R231. Trims dc level of SIG5 for zero offset of phase detector (low frequency and small TIME CONSTANT). Interacts with R234.

C-R234. Trims level of current injected at SIG6 for zero offset of phase detector (low frequency and large TIME CONSTANT).

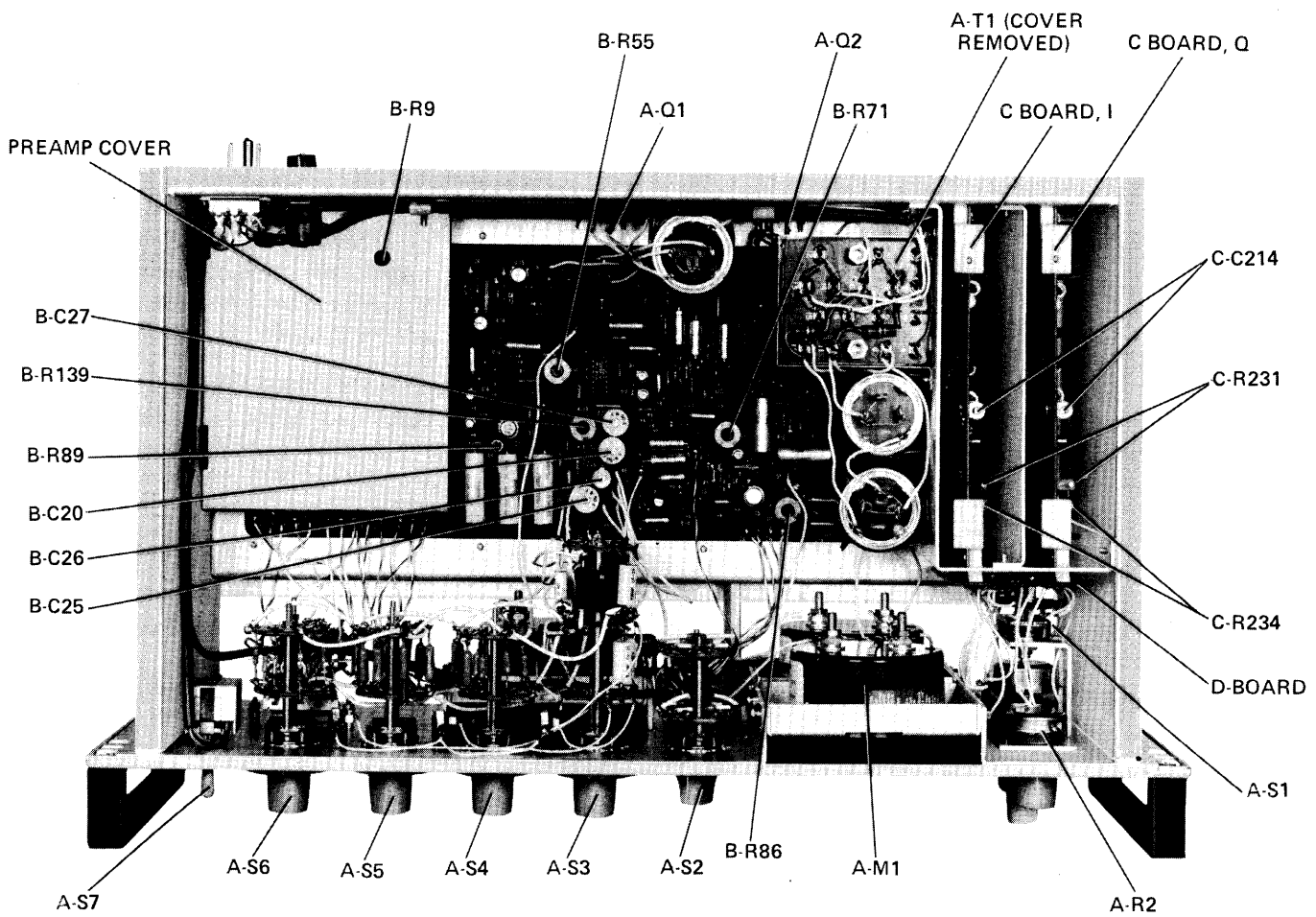


Figure 5-2. Interior, top view.

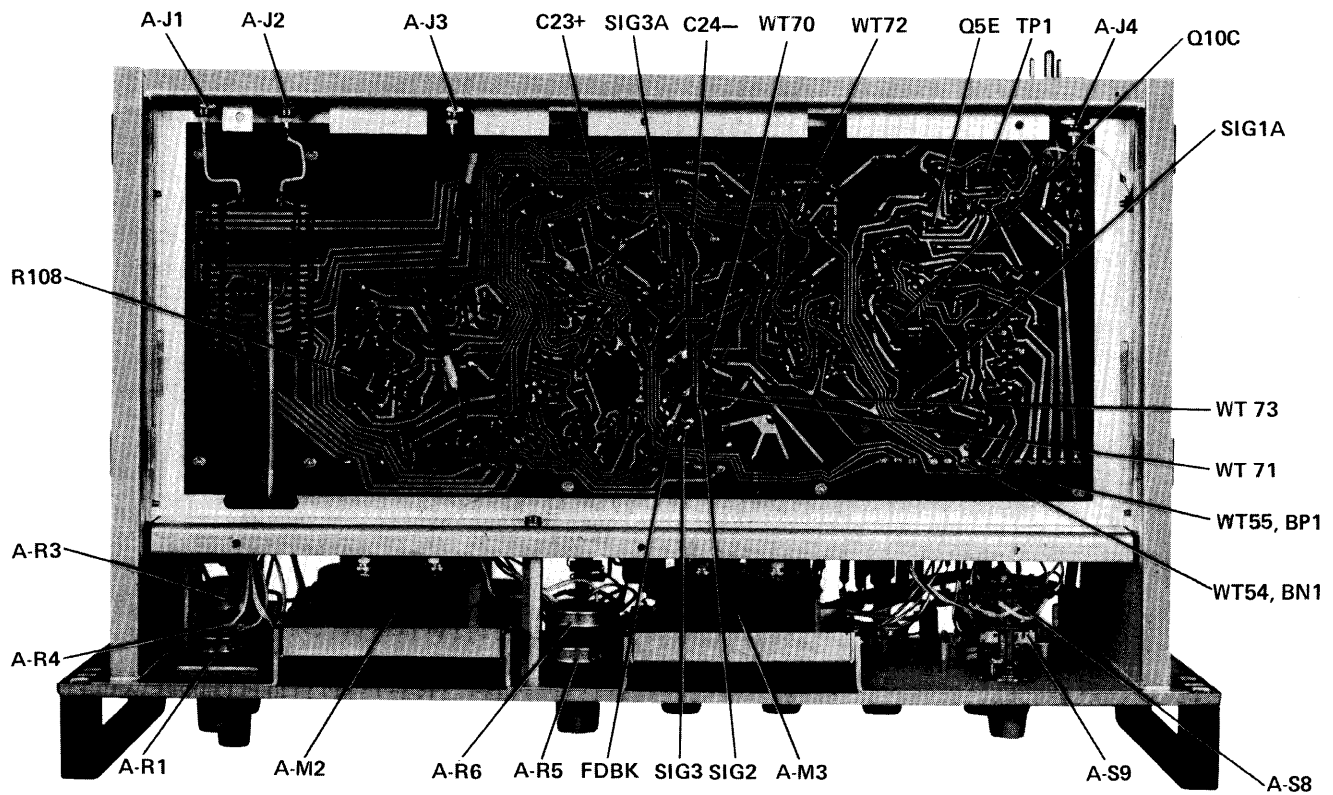


Figure 5-3. Interior, bottom view, shield cover removed. Designators not starting with A- have a B-prefix assumed.

5.5 ADJUSTMENT PROCEDURES.

The following discussion explains the purpose and conditions for each adjustment, without any detail about setup. The sequence is logical for a complete readjustment of the instrument, but nearly any one adjustment can be implemented separately. Refer to para. 5.2 for details of instrumentation and measurement.

NOTE

After making each adjustment (except in para. 5.5.1 and 5.5.2) lay a sheet of aluminum across the top of the instrument to simulate the cabinet and notice whether the parameter you have set is affected. If it is, readjust to obtain the desired results with the sheet in place.

5.5.1 Power Supply.

Set the main negative supply voltage to -15.0 V dc with B-R108. Do so with a voltmeter connected from chassis ground (GS3) to the case of A-Q2 (WT35) on the rear panel. A-Q2 is farther from the fuse than A-Q1 (Figure 5-2).

5.5.2 Preamplifier Input-Stage Bias.

Set the voltage at TP1 to 150 mV with B-R9. Use an ungrounded voltmeter connected from the shell of A-J4 (WT2) to TP1 (Figure 5-3).

5.5.3 Low-Frequency Gain.

Set the tuned gain (SIG4/SIG1) to 20 dB with B-R55. Be sure to tune the oscillator for maximum output with the detector FREQUENCY set to 500 Hz; the COMPRESSION button must be "out" and GAIN at 20 dB. Measure INPUT SIGNAL (SIG1) and AMPLIFIER OUTPUT (SIG4) as in para. 5.2.

5.5.4 Magnitude Meter Calibration.

Set the MAGNITUDE meter to full scale when the corresponding DC METER OUTPUT is 6.0 V dc, using B-R86. The points to monitor are pins A and B (+ and -, respectively); see Figure 2-6. The signal level should be large enough to calibrate with a GAIN setting of 100 dB or less, thus assuring a noise-free output.

5.5.5 COMPRESSION Adjustment.

Set the compression to 20 dB with B-R71, as follows. First establish the INPUT SIGNAL level required for full scale on the MAGNITUDE meter, as in the preceding paragraph, with the pushbuttons "out." Then, depress COMPRESSION, increase the INPUT SIGNAL level exactly 20 dB, and adjust for the same MAGNITUDE reading.

5.5.6 High-Frequency Tuning and Gain.

If the low-frequency gain is correct, trim the digitally tuned active filter as follows. Set FREQUENCY to 100.0 kHz and GAIN to 20 dB, and measure resonant frequency

and gain as in para. 5.2. There is strong interaction between the adjustments, particularly in regard to gain. Set B-C27 to bring the resonant frequency to 100.0 kHz; set B-C26 to bring the corresponding gain to 20 dB; repeat as necessary. Finally, correct the gain and verify that the resonant frequency is well within $\pm 4\%$. Both gain and resonant frequency must be determined at the oscillator frequency that produces a peak output from the detector. (Do not tune with the detector FREQUENCY controls.)

5.5.7 Medium-Frequency Tuning and Gain.

If the low- and high-frequency gain and tuning adjustments are correct, trim the filter as in para. 5.5.6, except as follows: set FREQUENCY to 5.00 kHz, use B-C20 for tuning, and use B-C25 for gain adjustment.

5.5.8 Line Rejection.

The following procedure is to set the line-frequency rejection filter to either 50 (or 60) Hz, whichever is correct for your electric power.

a. Cut the unwanted wire jumper and put another one in, as follows: 50 Hz, connect WT72 to WT73 (60 Hz, connect WT70 to WT71). See Figure 5-3. Heat the joints moderately, when soldering, to avoid damaging the etched-board foil.

b. Establish a reference level as in para. 5.2.3, with the frequency range set to FLAT, GAIN at 40 dB, and push buttons "out." Set the oscillator to exactly 50.0 (or 60.0) Hz and its level so the AMPLIFIER OUTPUT is 0 dBm.

c. Press LINE REJECTION "in" and adjust B-R139 for a minimum AMPLIFIER OUTPUT. If this minimum is larger than -40 dBm, the filter must be given a higher effective "Q". Do this by turning B-R89 cw. Readjust B-R139 for a new minimum.

d. Check the skirt rejection at frequencies of 40 and 60 (or 50 and 70) Hz. If the AMPLIFIER OUTPUT level at either skirt is less than -10 dBm, the "Q" must be raised further, as described above. If the level at either skirt is greater than -6 dBm, the "Q" is too high; turn B-R89 ccw; repeat steps c and d, if necessary, for the best combination of adjustments.

e. Attach a label on the rear panel, near the power plug, announcing that the filter is set for 50 (or 60) Hz.

5.5.9 Phase-Sensitive Detector Zeros.

There are 3 d-c offset adjustments to be set for zero when the signal level is zero. The REFERENCE INPUTS, however, must be normal. Proceed in the following sequence:

a. Set the GAIN to 20 dB, INPUT SIGNAL level to zero, and SENSITIVITY to maximum (cw). Tune the oscillator to 500 Hz.

b. With the TIME CONSTANT set to 0.3 s, adjust C-R231 on each C board for zero on the corresponding meter (the IN PHASE meter for C-board, I; the QUADRATURE meter for C board, Q).

5-8 SERVICE

c. With a TIME CONSTANT of 10 s, set each of the C-R234 adjustments similarly. The long time constant might cause this procedure to be rather tedious unless you use the following technique: let the circuit stabilize for 30 s; observe the reading "X"; reset C-R234, cw if "X" is negative; wait 7 s; realizing that the meter has moved just half-way to its final position, estimate a final reading "Y"; reset C-R234 again, on the basis of the "experience" just gained, unless, of course, "Y" is zero; after another 7 s, the meter points about halfway between "Y" and a final position "Z"; again reset C-R234 unless "Z" is zero; etc.

d. Because of interaction between these adjustments, repeat steps b and c as often as is necessary to be assured of a zero reading for either time constant.

e. Tune the oscillator to 100 kHz and set the TIME CONSTANT to 0.3 s. Adjust C-C214 on each C board for zero on the corresponding meter. If the range of C-C214 is inadequate for this purpose, it may be necessary to change the value of C-R230. Decrease this resistance if the meter points left (negative), and vice versa.

5.6 TROUBLE ANALYSIS.

The analysis of trouble is usually straightforward because there is essentially only one channel of amplification and the 2 detectors are identical. The phase shifters are readily monitored with a scope. If the trouble appears to be related to circuitry on one of the C boards (phase splitter, phase detector, or meter driver circuits) it may be helpful to interchange the 2 boards, observing the resultant effect on performance.

5.6.1 Power Supply.

The following normal values and tolerances are useful references for troubleshooting.

Total Power. 15 W nominal, 16 W max, from 115 (or 230 V) power line.

Main DC-. At case of A-Q2 (Figure 6-2), reference: chassis; -15 ± 0.1 V, settable.

Main DC+. At case of A-Q1, (Figure 6-2), reference: chassis; $+15 \pm 0.4$ V.

Preamp DC- (BN1). At WT54 (Figure 5-3), reference: GS1 (shell of INPUT SIGNAL jack A-J4); -15 ± 0.8 V.

Preamp DC+ (BP1). At WT55 (Figure 5-3), reference: GS1; $+15 \pm 0.8$ V.

Negative 12. At B-C24 negative (Figure 5-3), reference: chassis; -12 ± 0.6 V.

Positive 12. At B-C23 positive (Figure 5-3) reference: chassis; $+12 \pm 0.6$ V.

NOTE

The preceding 6 voltages should be within the given tolerances for line voltage in the range 112 ± 13 V rms (or 225 ± 25 V, depending on position of line-voltage switch, rear panel). Use the recommended variable autotransformer.

5.6.2 Operating Levels and Gains.

One of the first determinations in analysis of trouble is that the malfunction is within the normal operating range of the instrument. For example, inability to provide an undistorted output signal at high level (full scale on the MAGNITUDE meter) is a malfunction at most GAIN settings, but is perfectly normal at a setting of 20, 30, or 80 dB. A handy collection of such data is given in Table 5-5 as a supplement to the Specifications.

Table 5-5

CHARACTERISTIC GAINS & OPERATING LEVELS								
Control Settings			Amplifier (SIG1 to SIG4)				Full-scale Input	
COMPRES- SION	FRE- QUENCY	GAIN dB	dB	Gain	Max undistorted Input	Max undistorted Output	MAG meter*	IN PHASE meter**
				V Ratio				
Linear	Tuned	130	130	3.2×10^6	$1.3 \mu\text{V}$	4 V	700 nV*	65 nV
		20	20	10	400 mV	4 V	220 mV	20 mV
Linear	FLAT	130	105	1.8×10^5	$22 \mu\text{V}$	4 V	13 μV	1.1 μV
		80	55	560	1.4 mV	0.8 V^\dagger	(4 mV)	360 μV
		30	5	1.8	400 mV	0.7 V^\dagger	(1.3 V)	110 mV
		20	-5	0.56	400 mV	0.2 V^\dagger	(4 V)	360 mV
Compressed	Tuned	130	110^Δ	$3 \times 10^5 \Delta$	—	—	7 μV	140 nV
		20	0^Δ	1^Δ	—	—	(2.2 V)	45 mV
Compressed	FLAT	130	85^Δ	$1.8 \times 10^4 \Delta$	—	—	1.3 μV	2.5 μV
		20	-25^Δ	$.056^\Delta$	—	—	(40 V)	800 mV

* Includes hypothetical data: starred = hidden by noise; parenthesis = overload.

** Assuming SENSITIVITY control cw and frequency low or medium. For minimum SENS, multiply by 6.3; for 100 kHz, by roughly 2.

† Table includes all control settings that allow distortion not due to COMPRESSION to occur below F.S. on MAG meter, i.e., below 2.25 V output.

Δ Assuming signal level is F.S. on MAG meter. Gain is greater at lower levels.

5.6.3 Gain by Stages.

Analysis of trouble in the main amplifier channel is usually facilitated by comparing the overall tuned gain (SIG4/SIG1) with the GAIN setting, at each of the 12 settings. Refer to Table 4-1. There, the channel is broken into 5 sections, only 1 of which is unchanged by GAIN changes. Each of the other 4 is switched in a unique way.

For further analysis, check signal levels and waveforms at intermediate points corresponding to the junctions of the 5 sections. These points are identified in Figure 5-3 as follows: Q5E, Q10C, SIG1A, and SIG3A.

NOTE

There is a jumper wire, carrying SIG1A between Q14 and R34, which can be cut (inside of preamp cover) if necessary for isolation of circuitry.

5.6.4 Digitally Tuned Active Filter.

If the section containing integrated circuit B-U4 is faulty, check whether gain is normal as follows: SIG2 to SIG3A, 30 dB (tuned); SIG2 to FDBK, 40 dB (tuned). Measurement points are shown in Figure 5-3. If necessary disconnect the wire carrying SIG3 to B-WT16 from the frequency range switch A-S3. Then the gain (K) from SIG3 to FDBK should be 15.5 dB.

If the abnormality appears only at certain settings of the FREQUENCY controls, investigate the associated switches and the parts mounted on them. Both the gain and effective "Q" of the active filter depend critically on the ratios of C and R switched in at any one time. (So it is that some parts, such as capacitors B-C5A, B-C5B, B-C5C, B-C5D, are matched sets, and must be replaced only as sets.)

In the theory para. 4.3 are equations for the digital tuning filter. Using them, one can find the significance of small inaccuracies in filter parameters. For example, an error of 0.1% in any single R or C value has the consequences tabulated in Table 5-6. (In Figure 4-4 the capacitors C₁ and C₂ are each labeled "1/2 C": SIG2 goes to C₁, FDBK to C₂. C₃ and R₂ are the grounded components.) Notice that C₁, C₂, and C₃ are associated with the frequency-range switch; R₁ and R₂ with the 3 decade FREQUENCY switches.

The importance of keeping the gain K stable is brought out by noticing that a 0.1% decrease in K reduces the gain through the tuned, active filter by 10% (nearly 1 dB).

The filter parameters, in the left column of Table 5-6, have 4000 different sets of normal values. However, to make a systematic check of the filter performance only 34 settings are required. Use the setup and procedure of para. 5.2 to measure resonant frequency and gain (and, if you wish, bandwidth) at the following settings of FREQUENCY:

1. 50.0 Hz, 5.00 kHz, 50.0 kHz, 500. Hz.
2. 501, 502, 509, 50X Hz.
3. 510, 520, 590, 5X0 Hz.
4. 100, 200, 900, 1000 Hz.

You have thereby checked every set of components and every switch contact used in this filter.

Table 5-6

If this is 0.1% below nominal	There will be this change in performance		
	ω_0	Q or G ₀	G ₀
C ₁	+ .025%	+ 3.3%	+ .28 dB
C ₂	+ .025	- 6.6	- .56
C ₃	+ .050	+ 3.3	+ .28
R ₁	+ .050	+ 1.7	+ .15
R ₂	+ .050	- 1.7	- .15

5.6.5 Phase Shifters.

To analyze the performance of the PHASE SHIFT and FINE ADJUST controls, use a scope to monitor PHASQ and PHASI. Refer to the Signal Index in Section 6. They should be 90° apart and fairly constant in amplitude (within a 2:1 range, max to min) for all settings of these controls. PHASI should be related to the IN-PHASE REFERENCE INPUT (REFI) through the angle indicated by the PHASE SHIFT controls. Analyze first at a frequency of 500 Hz, then at other frequencies if necessary.

If normal phase relationships are not found, check that the REFERENCE INPUTS are being supplied, as specified. Then check for the phase-splitting function, i.e., that the 4 signals NORTH, EAST, SOUTH, and WEST make a full set, 90° apart. Reference to the schematic diagrams and a trial interchange of the two C boards will help you decide whether to replace a C board or repair the circuit on the switch and its associated D board.

Refer to Figure 6-6 for points below the C board, Q, where you can measure PHASQ, WEST, and EAST. The corresponding points at the C board, I, location are PHASI, SOUTH, and NORTH.

5.6.6 Phase-Sensitive Detectors.

Analyze by swapping C boards. Because there is no gain through U202, SIG5 should be a d-c signal equal to the average of a half cycle of SIG4. Of course, the dc signal will be +, -, or even zero, depending on the phase relationship between PHASI (or PHASQ) and SIG4.

There should be no d-c gain between SIG5 and SIG6, but the gain between SIG6 and MTRI (or MTRQ) is normally 3. A typical value of MTRI is 240 mV for 9 (just under 2 divisions) on the MAGNITUDE meter, if you set an optimum PHASE SHIFT. This level also corresponds to full scale on the IN PHASE meter.



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