OPERATING AND SERVICE INSTRUCTIONS

WITH PARTS LIST S-1688

PHASE ANGLE VOLTMETER

MODELS 212 A, B, & C S-

Patents are pending for a number of circuits used in this instrument

NORTH ATLANTIC INDUSTRIES, INC.
Plainview New York

CODE IDENTIFICATION 07342

#4

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

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ERRATA SHEET

REPLACEMENT PARTS LIST

The following parts have been added to those instruments containing internal/external reference selection.

Reference Designation	Description	NAI Part No.	Total Qty.
R69	Resistor 100K, 1/4W	801986	1
R70	Resistor, 2.7K, 1/4W	802191	1
C35	Capacitor, 8-50uf	803540	1
C36, C37	Capacitor, Select at Test		2
S5	Switch, Slide	804751	1

3/5/69

SECTION I

1.1 INTRODUCTION AND DESCRIPTION

The Model 212 Phase Angle Voltmeter is a completely transistorized modularized instrument which combines the ability to measure both phase angle and magnitude of complex AC signals and vector compoents with respect to a reference voltage. Designed to operate phase sensitively within a frequency range of 60Hz to 10KHz, it utilizes passive phase shifter circuits to assure long term stability and high accuracy over the spectrum. Front panel controls permit instantaneous selection of range and function.

As a TOTAL voltmeter, the Model 212 is capable of measuring signals within a frequency range of 1OHz to 100KHz. The Model 212C has its frequency response limited to that of the signal isolation transformer.

As a phase-sensitive null meter, the Model 212's 2uv nulling sensitivity permits high resolution ratiometric measurements. This allows measurements of low-level voltages of the reference frequency in the presence of noise, hum, and other spurious signals. As a phase meter, angles are read on a parallax-free scale calibrated in 1° increments.

The Model 212 is available in three basic configurations:

1.2 MODEL 212A - No Signal or Reference Isolation

The Model 212A will perfrom all the basic functions for which the instrument has been designed, except that it does not contain any means for isolating the reference or signal inputs.

1.3 MODEL 212B - Reference Isolation Only

The Model 212B is identical to the Model 212A with the exception of the added reference isolation transformer.

1.4 MODEL 212C - Both Reference and Signal Isolation

The Model 212C differs from the Model 212B not only by the addition of signal isolation, but it also includes a front panel switch for switching the transformer in or out of the signal input circuit.

1.5 APPLICATIONS

A. Phase Sensitive Null Indicator

B. Measures separately the in-phase and quadrature components of an AC signal.

C. Measures phase shift in any AC system.

D. Sensitive AC electronic voltmeter.

E. Testing of servos, computers, synchros, resolvers, inductosyn.

F. Precise AC ratiometry

G. Phasing of servo motors, chopper amplifiers, magnetic ampifiers.

H. Measuring both torque and non-torque producing signals in servo amplifiers.

I. Align carrier amplifier and notch networks

J. Impedance meter

K. Power factor meter

L. Measuring response of vibrational system.

Detailed descriptions of these applications are shown in the Application Notes appended hereto.

1.6 GENERAL SPECIFICATIONS

The following specifications applies to all North Atlantic Models 212A, 212B, 212C Phase Angle Voltmeters. Where a special modification or variation is involved, the governing specification will either be a separate specification control document, the buyer's purchase order, or a supplement contained in this manual. Specifications for special instruments are identified by the specification "S" number appearing on the instrument nameplate - e.g. 212A-S1234.

Voltage Range (Full Scale Output):	300 uv to 300V in 13 ranges
Frequency Range:	Total Voltage - 10Hz to 100KHz (Direct) Phase Sensitive - Single Frequency between 60 Hz and 10 KHz
Accuracy:	Voltage: Total ±2% of full scale 20Hz to 50KHz (Direct) ±5% of full scale 10Hz to 100KHz Fund ±2% at frequency of operation Phase ±1° as read on the Phase Dial or when using E cos θ characteristic, ±3% of full scale angle.
Calibration:	Voltage: Zero center, low stiction meter calibrated 3-0-3 and 10-0-10 scales

	Phase Dial - Continuously calibrated in 1° increment from -6° to $+96^{\circ}$ over four quadrants 0°, 90°, 180°, 270°.
	Resolution - 0.2°.
Signal Input Impedance:	Model A - 10 megohms, shunted by 60uuf nominal.
	Model B - 10 megohms, shunted by 60uuf nominal.
	Model C - Direct Mode: 10 megohms shunted by 75uuf nominal. Transformer Mode: 300K Nom at 400Hz.
Reference Input Impedance:	100K min.
Reference Input Voltage:	Model 212A - 750mv to 150V max.
	Models 212B, 212C - 1.5V to 150V max.
Input DC Voltage Level:	Models 212A, 212B - 400V Max.
	Model 212C - 0V Transformer Mode (with no external blocking capacitor). 400V Direct Mode
Overload:	10 x overload capability. Overload light will ignite at approximately 11 x full scale setting.
Noise:	Less than 15uv, Total and Fund Modes.
Nulling Sensitivity:	Less than 2uv, Phase Sensitive Modes.

Harmonic Rejection:	<u>Fundamental</u> 400Hz operation: 2nd Harmonic 30DB Min. 3rd Harmonic and up 45DB Min. All other frequencies of operation (see diagram fig. 4.4) <u>Phase Sensitive</u> 400Hz operation: 2nd & 3rd Harmonic - 55DB all others greater than 55DB <u>All Other Frequencies of Operation</u>: 2nd Harmonic - 55DB 3rd Harmonic - 40DB to 70DB depending on frequency of operation (see diagram fig. 4.4) all others - 60DB.
Non-Coherent Signal Rejection:	For frequencies removed from signal frequency by approximately 5Hz or more (effective pass band of meter movement) response is essentially nil for levels up to 10 X the value of the full scale in use. Appropriate filters can increase the allowable level of the non-coherent signal to 300 times the value of the full scale in use on the most sensitive modes.
Power:	115V/125V or 230V/250V ±10% - 50-440Hz - 40W
Fuse:	For 115/125V Power: .5A, type 3AG

Revised 3/13/69

	For 230/250V Power: .25A, type 3AG

1.7 MECHANICAL SPECIFICATIONS

Size:	Panel is 5-1/4" x 19" W
	Depth behind panel is 12".
Weight:	Approximately 15 lbs.
Mounting:	Rack or bench mounted.
Front Panel Paint:	Gray #26440 per Fed. Std. 595
Line Cord:	6' long, std.
Front Panel Input:	Inputs are standard, 5-way binding posts, spaced on 3/4" centers. Ground terminals are colored black and marked ground.

Specifications subject to change without notice.

Revised,
3/13/69

SECTION II

PREPARATION FOR USE

2.1 REMOVAL FROM PACKAGE

This instrument has been thoroughly tested, inspected, and evaluated at the factory prior to shipment. Particular care has been taken in the design of the special wrapping and packaging material used in the container to ensure that no damage result from the typical handling encountered during shipment. However, upon removal from package, the instrument should be externally inspected for any obvious damage. Should such be observed, refer to the Warranty Policy previously presented. The instrument may now be mounted (either rack or bench) and checked per Performance Evaluation Procedure (Section V).

INPUT CONVERSION
FOR
POWER TRANSFORMER
202819

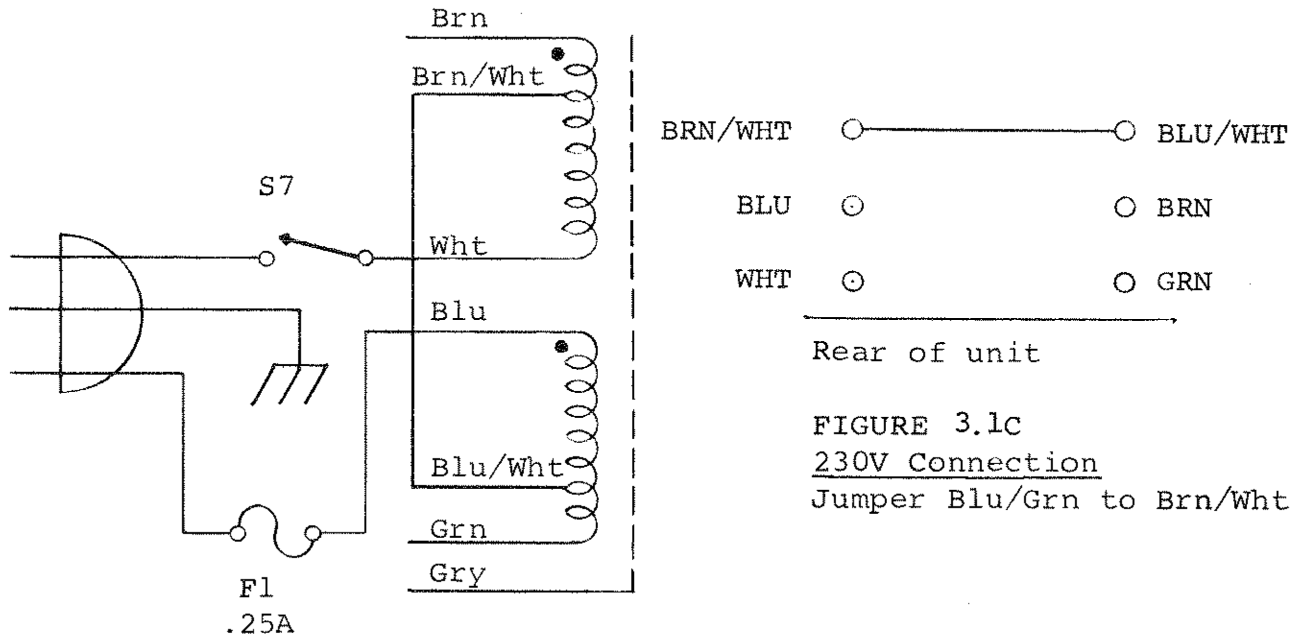

FIGURE 3.1C
230V Connection
Jumper Blu/Grn to Brn/Wht

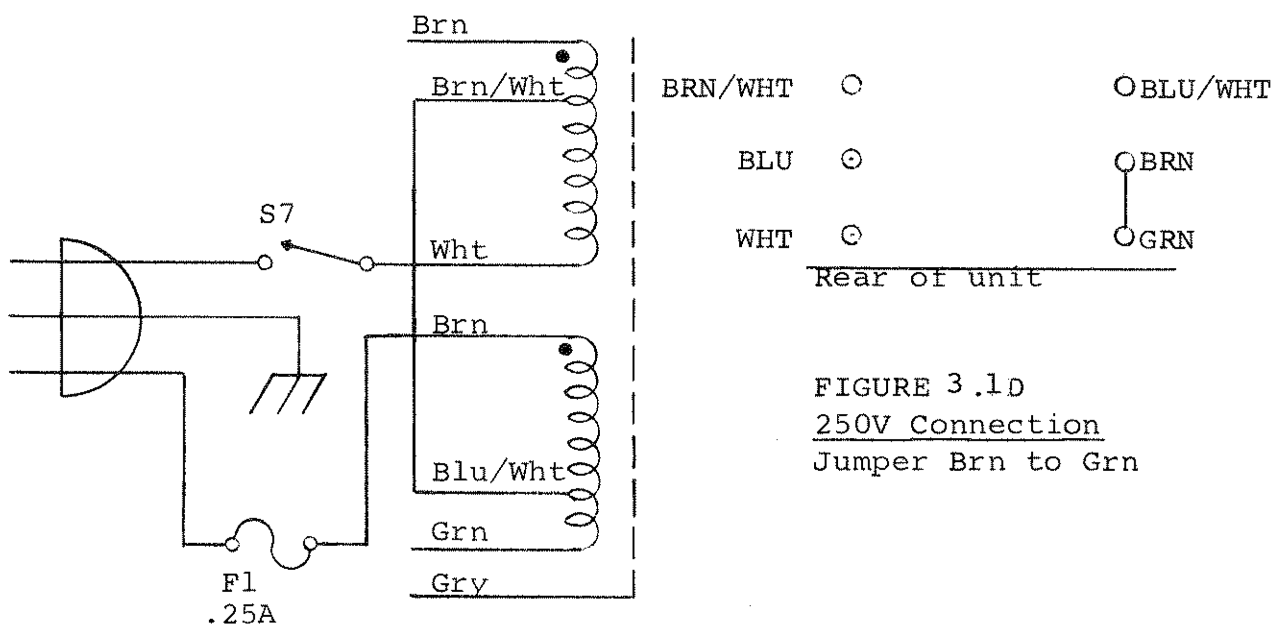

FIGURE 3.1D
250V Connection
Jumper Brn to Grn

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3.3 CONTROLS, DISPLAYS, INPUTS

Prior to attempting to operate this instrument, it is advisable that the user familiarize himself with every control, display, and input connection as described below.

3.3.1 Reference Adjust

The REFERENCE ADJUST Control is used for adjusting the reference level to read half scale (red line) on the meter. This control is used when the FUNCTION switch is in the REF ADJ position.

3.3.2 Function Selector

The FUNCTION Selector selects the desired mode of operation for the instrument. In the four Phase Angle Voltmeter positions, the instrument is connected so that it may read a voltage E cos θ where θ is the angle by which the signal vector leads the reference vector. Any of the four quadrants may be selected over which the calibrated phase shifter will operate. Thus, the total angle by which the reference vector is shifted in degrees will be either 0°, 90°, 180°, or 270° plus the reading of the Phase Dial.

In the TOTAL position, the instrument functions as a standard voltmeter and will read all voltages over a frequency range of 10Hz to 100KHz. In the Fundamental position, the instrument will read the total vector of the fundamental component of the input signal. (See Figure 4.4 for filter characteristics).

The FUNCTION Selector must be positioned in the REF ADJ position in order to make the proper reference adjustment.

3.3.3 Range Selector

The Range Selector is a rotary switch which selects the proper attenuators for the desired full scale voltage as marked on the front panel.

3.3.4 Phase Dial

The Phase Dial is calibrated to read the degrees of phase shift introduced by the calibrated phase shifter networks within the particular quadrant selected by the Function Selector. The Phase Dial is calibrated from -6° to $+96^{\circ}$ in 1° graduations. Mechanical positioning of the Dial on its shaft is critical and for this reason, should it be necessary to repair or replace, the procedure under Phase Dial Alignment should be followed. (Page 5.22)

3.3.5 Frequency/Phase Trim (R 43 - Located on the rear panel)

R43 is a screw driver adjust control used to align the signal and reference channels. Its function is to trim the instrument for minor differences in the frequencies of measured signals.

3.3.6 Overload Indicator

The lamp marked Overload is turned on whenever a prescribed signal level is exceeded. This indication warns of impending amplifier overload and the attendant inaccuracies which will occur when larger saturating signals are present. The Overload Indicator is factory set to turn on at 11 x full scale. (The instrument will function within its specified accuracy up to and including a 10 x overload.)

3.3.7 Meter

The Meter is a zero center low stiction microammeter calibrated to read the RMS value of a sinewave. For all voltmeter readings, the pointer deflects to the right. For phase-sensitive measurements, the meter deflection may be to the left or right. It has a calibrated zero center 3-0-3 and 10-0-10 with mirror backing for more precise readability.

CAUTION: By its nature, the instrument is required to handle inputs considerably in excess of its full scale reading. Although a high overload capability has been designed in, discretion should be used to avoid application of signals in a manner which will drive the needle hard against the stops. Therefore, always approach a measurement from the least sensitive position and return to this position before making circuit adjustments. This approach will avoid any damage which may occur to the meter.

3.3.8 Input Terminals

In the Model 212A, five terminals are provided at the front panel for connection to external test circuits. Terminals for both the signal and reference inputs are colored black for circuit ground and colored red for high side of the input.

In the Model 212B, the REF input terminals are colored red and black which indicates polarity with respect to the SIG terminals (i.e. red is in-phase with red, and black is in-phase with black). These posts are on standard 3/4" spacing and will accommodate banana plugs, wire, or alligator clips.

CAUTION: Maximum signal input must not exceed 300V RMS and maximum reference input must not exceed 200V. Higher voltages will break down the input capacitors in the instrument. (See Specifications, Section I).

A third, all metallic, chassis ground termination is provided at the SIG input for connecting the circuit ground (the Black plastic one) to chassis ground. A link is provided between these terminals to allow maximum flexibility of connections. The link is provided to permit grounding at the input terminals or to a remote point in measuring setup. Great care should be given to grounding methods used to avoid ground loops and stray fields. The instrument will not read properly if the input is not grounded.

The following applies to Model 212C Instruments Only

The Model 212C instruments are characterized by the inclusion of a Signal Isolation Transformer with facility for switching the transformer in or out of the circuit. The items listed here exist on the Model 212C front panel only.

Input Selector Switch - The Input Selector Switch is a slide switch which removes the input transformer from the input circuit in the DIR position allowing for single ended direct coupled inputs. In the TRANS position, floated inputs or differential inputs, as well as single ended isolated inputs, may be fed into the Signal Channel.

NOTE: In the event that signals containing DC are to be injected in the Transformer Mode, a large blocking capacitor should be used externally.

Sig Input Terminals - Four SIG Input Terminals are provided on the front panel of the Model 212C which allow flexibility for Direct and Transformer inputs. It should be noted that the center terminal is common to both Direct and Transformer inputs and is high for Direct inputs and low for Transformer inputs.

The metal binding posts as on the Model 212A and 212B instruments are chassis ground.

3.4 OPERATION

Plug the instrument into the proper power source. Turn the Power Switch on and allow the instrument to warm up for a short period (3 to 5 minutes) for stable operation.

CAUTION: Before making phase or voltage measurements, review the section on grounding techniques in the application notes appended hereto.

3.4.1 To Measure Voltage

Set the Range Selector to the appropriate scale and the Function Selector to the appropriate position. Connect the voltage to be measured to the Signal input terminals and read the voltage from either the 0-10 or 0-3 volts scales using the proper scale factor as determined by the Range Selector position.

With the Function Selector in the Total Position, the voltmeter operates as a standard AC Voltmeter. This reads the total vector voltage at any frequency (within specifications) including all harmonic effects. With the Function Selector in the Fund position, the Model 212 will read only the fundamental voltage within the range of the filter.

Notice that with no input to the instrument (terminals not shorted), the meter deflects on the low ranges. This condition is and represents a true measurement of stray fields capacitively coupled to the input. Shielding the input will reduce this deflection to a minimum level. Measurements made on high impedance circuits require that a special attention be paid to capacitive as well as inductive pickup.

Twisted and/or shielded cable will reduce the effect though the cable capacity could serve to load the source. Care must be taken where possible to insure that ground loops do not exist by virtue of the signal and reference grounds being connected. These loops can result in erroneous readings.
(Refer to the Application Notes appended hereto).

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3.4.2 To Measure Phase Angle

3.4.2.1 Reference Adjustment

A. Switch the Function Selector to the REF ADJ position.

B. Inject the reference signal into the REF terminals and adjust the Reference Level Control to cause the meter to read a value as indicated by the red mark on the meter scale.

3.4.2.2 Phase Shifter Adjustment

A. This adjustment is factory set and should seldom need to be touched except following servicing and/or component replacement. Using a signal source, equal to full scale on any range greater than 1.0 volts, connect the signal to both inputs and adjust the reference level in accordance with the preceding.

B. Place Function Selector in 0° position and the Phase Dial at 90°. Place Function Selector in 90° position and the Phase Dial at 0°.

If the meter does not read zero for both these tests, use the back panel screw driver adjustment, R43, to provide a zero which is the best compromise for both cases. This control adjusts the phase shifter between the signal and reference channels. In general, once this setting is made there is little reason to re-adjust the control.

The rezeroing of the R43 Frequency/Phase Trim will in no way affect the accuracy of the phase bridge adjustments.

3.4.2.3 Phase Angle Measurements - With Calibrated Phase Shifter

A. Switch the Range Selector to a suitable position and inject the signal to be measured into the proper terminal.

B. Set the Phase Dial to 0^{O}.

C. Switch the Function Selector to a PAV position (phase sensitive) which will cause the meter to read to the right.

D. Turn the Phase Dial to cause the meter to read near maximum. This step is to provide a coarse deflection of the phase angle.

E. Switch the Function Selector 90^{O}.

F. Turn the Phase Dial until the meter reads 0.

G. Switch the Range Switch to two ranges more sensitive (e.g. if Step 9 is performed on the 100mv Range, then this should be done on the 10 mv Range position).

H. Adjust the Phase Dial more precisely for a null on the meter.

I. Switch the Function Selector to a position (0^{O}, 90^{O}, 180^{O}, 270^{O}) which gives a meter deflection to the right.

J. The phase angle is then the sum of the Function Selector angle plus the Phase Dial angle. This rule eliminates the possibility of ambiguity. In the event the user makes a measurement with a deflection to the left in Step I, add or subtract 180^{O} from the sum of the quadrant and Phase Angle Dial.

3.4.2.4 Measurements of In-Phase (0^{O}) and Quadrature (90^{O}) Components

A. With reference level properly set, place Function Selector in the 0 position. Set the Phase Dial to 0^{O}.

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B. The meter now reads the in-phase component of a signal. This is also E cos θ where θ is the angle between the reference and signal.

C. Switch the Function Selector to 90°. The meter now reads the quadrature component or E sin θ.

In general, one of these components is usually much smaller than the other and for greater accuracy, it is convenient to change the range of the instrument. This can be done until the Overload Lamp lights thereby warning of an impending overload condition. This light indicates that total signal exceeds eleven (11) times the full scale value. Measurements can be made for overloads up to 10 times full scale. Measurements under all these conditions will be most accurate if the zeroing process described in the Application Notes is followed.

3.4.2.5 Measurements Under Overloaded Conditions

Measurements under overloaded conditions can be made where it is desired to increase the null capability or to make the small quadrature signal level measurements. As stated previously, the signal levels in the Signal Channel may be 10 x the full scale reading as indicated by the range switch setting. Under some special conditions, these signals may exceed this 10 x specification by small amounts without overloading the amplifiers in the signal circuits. These signals, however, should never be increased beyond the level which will cause the overload indicator to light.

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Accuracy measurement of phase angles can be made using the E cos θ or E sin θ characteristic. Voltage measurements are made from the in-phase (0°) or quadrature (90°) component of the fundamental signal (Fund Position). The quotient will then be the cosine, or sine, or tangent of the unknown phase angle. Trigonometric tables, slide rule, or graphs included in the appended Application Notes are suitable for converting to degrees. The accuracy achievable using this technique depends upon the procedure, and for that reason, it is suggested the Application Notes be reviewed before using this method.

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3.4.3 DIFFERENTIAL MEASUREMENTS

In making differential measurements using a transformer, there are two sources of error. One is due to capacity from either side of the primary to the high side of the secondary as shown in Figure (A). This can result in an output even if $E_1 = E_2$. This effect is minimized if a secondary shield is used, connected as shown in Figure (B).

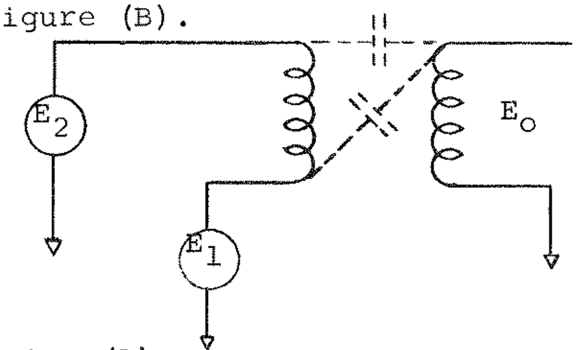


Fig. (A)

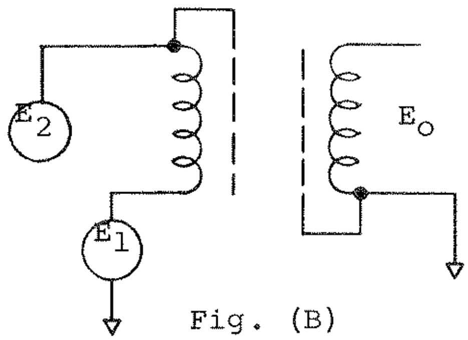


Fig. (B)

The other source of error is capacity to ground, phase shifting the signal from a source with a finite source impedance as shown in Figure (C).

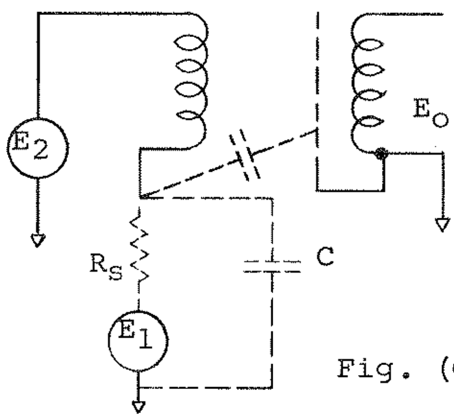


Fig. (C)

This effect is minimized if a double shielded wire and a primary shield is used as shown in Figure (D). This will connect the capacity from the inner conductor to the inner shield across the transformer which, when nulled, introduces no error. Capacity from the inner to outer shield and capacity from the primary shield to secondary shield is across E_2. If E_2 has a low source impedance, this will introduce no error.

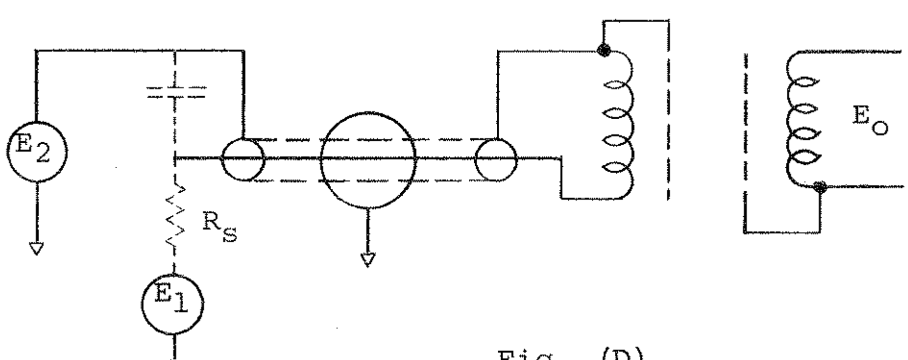
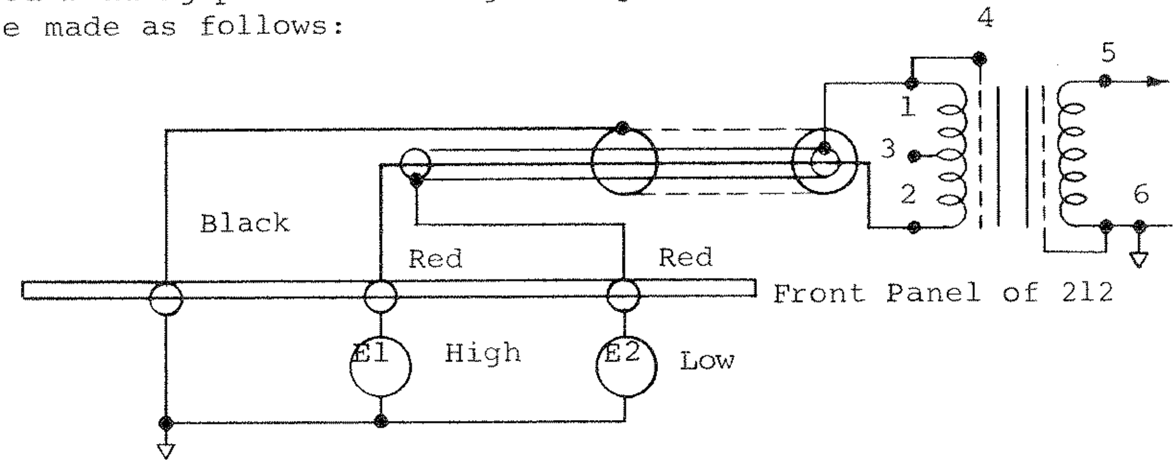


Fig. (D)

Therefore, for maximum accuracy in making differential measurements, the lowest impedance source should be connected to the No. (1) pin of the signal isolation transformer (available at the right hand red binding post of the signal input terminals). Connections should be made as follows:



Instruments which have rear M.S. connectors are wired as follows:

Pin A to Pin 1 of transformer
Pin B to Pin 2 of transformer
Pin C to ground

Input connections should be made as above.

THEORY OF OPERATION

4.1 INTRODUCTION

The block diagram of Figure 4.1 will serve to illustrate the principles of operation of the Phase Angle Voltmeter. The Phase Angle Voltmeter is a multi-function instrument and the following will describe each of these functions.

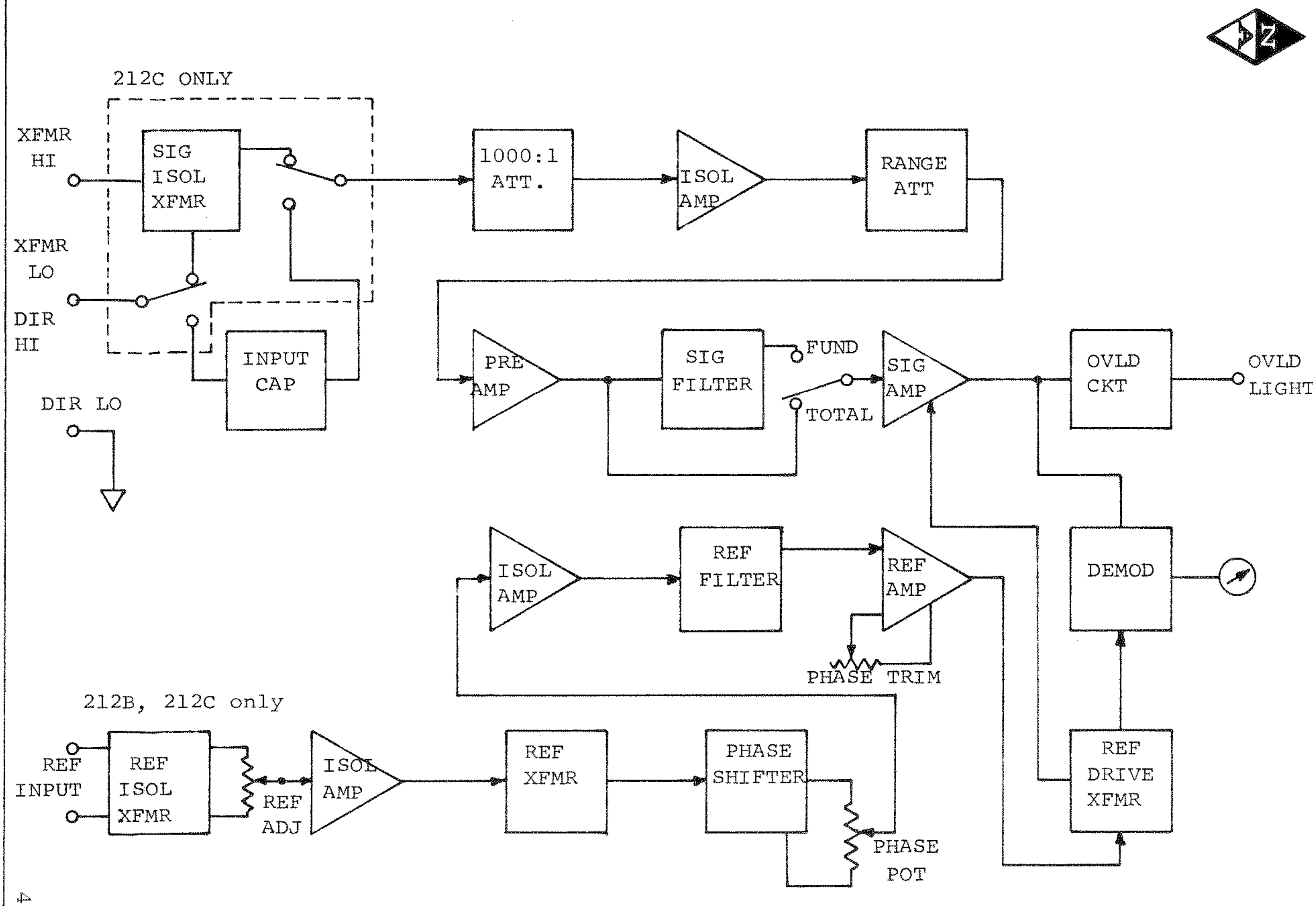
4.2 VOLTMETER

When operating as a Total and Fundamental voltmeter, the instrument uses only the Signal Channel circuitry. The Signal Amplifier, in conjunction with the Range Attenuators, functions in a similar manner to a good quality AC Electronic Voltmeter. The signals applied to the input are amplified and fed to the meter recifier circuit and indicated on the meter.

As a Fundamental Voltmeter, a harmonic filter is switched into the circuit and the meter will read only those frequencies within the pass band of the filter. See Figure 4.4 for filter characteristics.

As a Phase Angle Voltmeter, the Reference Channel is activated. The reference signal is amplified and phase shifted by the reference circuitry. The reference channel output serves to gate the demodulator portion of the meter circuit. The relationship of this gating voltage to the signal being measured will determine the magnitude and the polarity indicated on the meter.

For those signals which are in-phase, a signal of maximum amplitude will be indicated and for those signals which are 90° out-of-phase (in Quadrature) a minimum signal will be read. Where the instrument is being used to read quadrature signals, these signals may exceed the indicated range by up to 10 x without over-loading the signal amplifier circuits. This capability provides a means for much more accurate measurements of quadrature voltages and computation of phase angles.



MODEL 212 PHASE ANGLE VOLTMETER BLOCK DIAGRAM
FIGURE 4.1

4.3 SIGNAL INPUT ATTENUATOR

The amplifiers of the Model 212 always operate with the same basic sensitivity (300uv). This requires attenuators for reducing higher level voltages to this range. The input attenuator actually consists of two separate voltage divider networks. The first provides a 1000:1 reduction for voltages one volt and above. The second provides six attenuator ranges from 3:1 to 1000:1. This latter attenuator provides attenuation for signals up to and including 300mv and is added to the attenuation of the 1000:1 divider for signals between 3 volts and 300 volts.

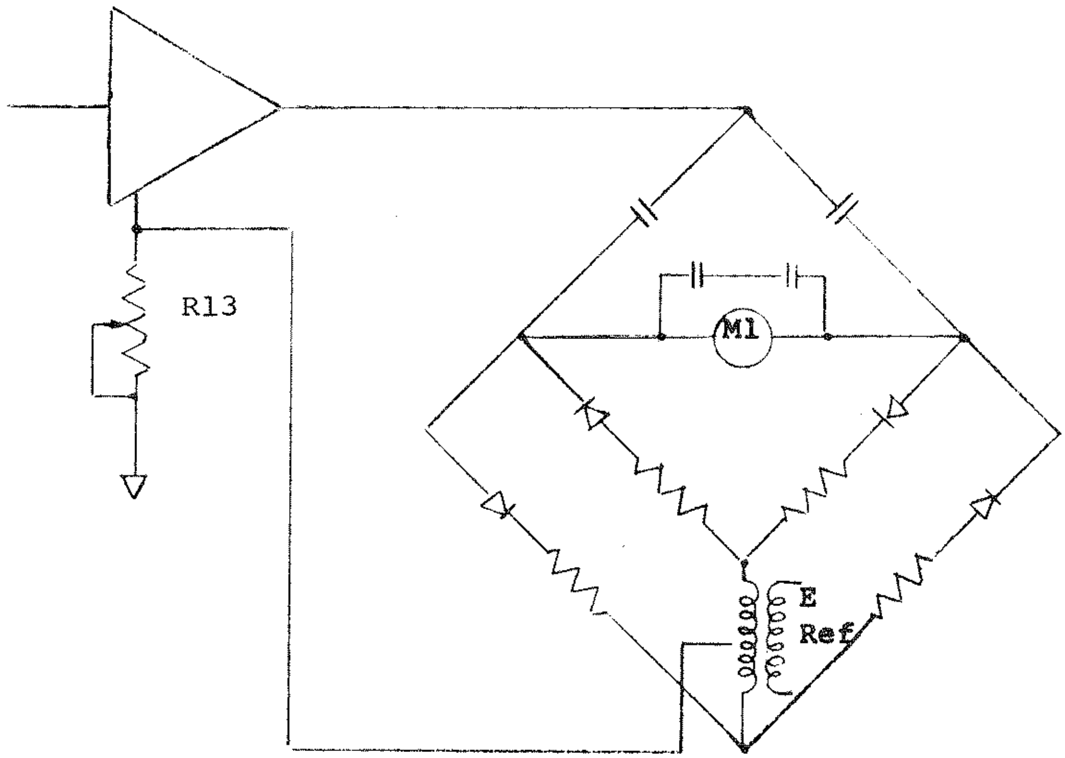
At low frequencies, the 1000:1 attenuator ratio is determined soley by the resistors employed. At higher frequencies, capacitive compensation is necessary to compensate for circuit strays. This converts the attenuator to a capacitive divider at high frequencies. The crossover from resistive to capacitive attenuation occurs at approximately 600Hz. This attenuator when properly adjusted not only provides proper attenuation at both high and low frequencies but also has essentially zero phase shift over the rated frequency range. See Alignment Procedure, Section V, for proper alignment.

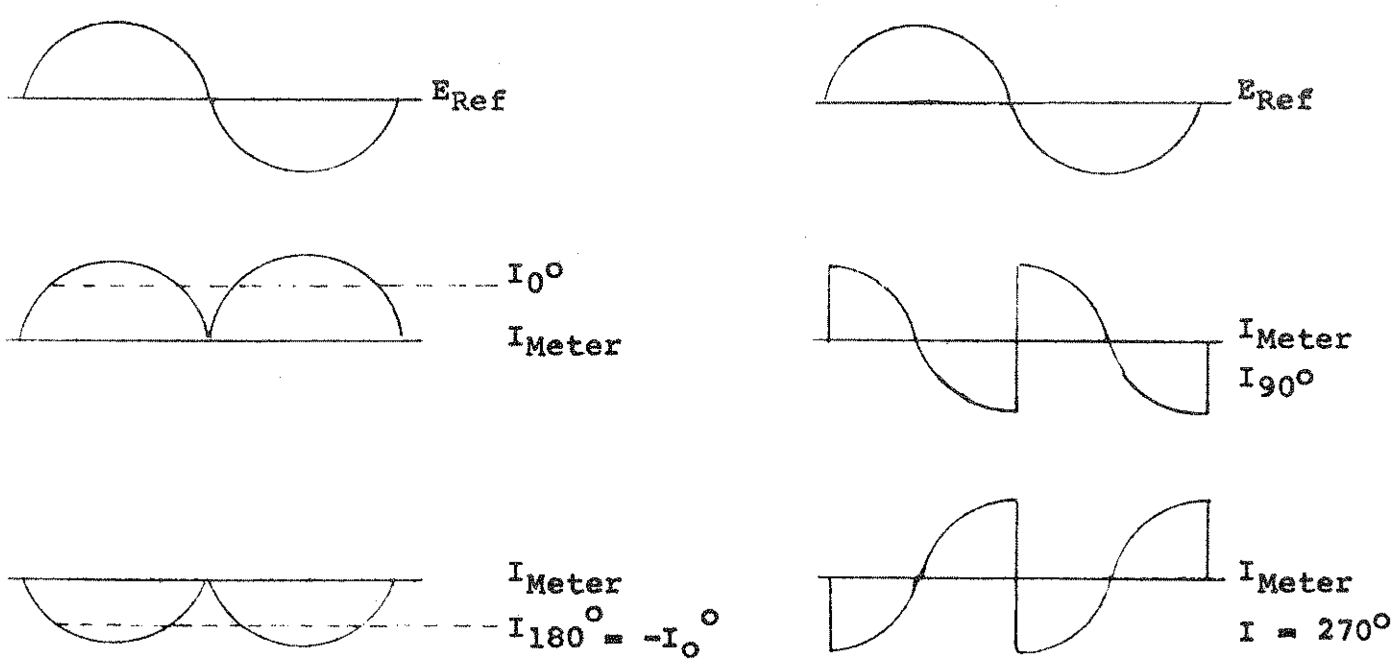
4.4 AMPLIFIERS

The amplifiers used in the Model 212 Phase Angle Voltmeter are silicon transistorized. All designs are based on the use of components well below maximum manufacturer's ratings to insure long-life and trouble-free operation. The individual amplifiers are described in the following paragraphs.

Isolation Amplifiers - There are three isolation amplifiers located on the large printed circuit board. These amplifiers contain very similar circuitry, each being modified slightly for a specific function. The basic function of this amplifier is to provide an accurate gain of unity, a high input impedance to the

SIMPLIFIED PHASE SENSITIVE DEMODULATOR





IN PHASE ($0^o/180^o$)
(A)

QUADRATURE ($90^o/270^o$)
(B)

Fig. 4.2

circuitry preceding it in order to prevent loading, and a low output impedance to the circuits which follow. The design of this amplifier is based on techniques using low noise field effect transistors.

Signal Pre-Amplifier - The Signal Pre-Amplifier is contained within the A1 Module, NAI #782251. This Amplifier provides a stable gain of 10 which is necessary for the 300uv sensitivity of the instrument. Large amounts of negative feedback are used so that its gain is controlled soley by stable precision resistors internal to the module. Its design is such that it provides a wide band frequency response with minimal phase shift and low noise.

Signal Amplifier - The Signal Amplifier (A2 Module, #782245) is a circuit designed to have a very high gain bandwidth product resulting in a low phase shift and high power gain. Its output drives the meter demodulator circuit. Large amounts of negative current feedback are used to eliminate the effects of diode non-linearities. The meter demodulator circuit is located partly within the A1 Module and partly on the Function Switch.

The Demodulator's phase-sensitive operation (See Figure 4.2) can be likened to that of a set of commutating switches. The reference signal alternately connects one side of the meter to ground through resistor R13 and then the other end on the reverse cycle of the reference. The signal is, therefore, synchronously rectified through the meter movement. When the reference and signal are in-phase (Figure 4.2A) the average value will be maximum and the meter will read a maximum. When the signals are 90° apart (Figure 4.2B) the average will be zero and no reading will result. The equation governing this is:

I Meter (avg) = $K\ E \cos \theta$

Where K = proportionality constant

E = RMS of signal

θ = angle between signal and reference.

Demodulator saturation effects will limit this characteristic equation to the designed levels for the instrument. Under special conditions, such as are described in the appended Application Notes, the reference level is increased to improve accuracy for high signal levels. Measurements at the quadrature null point ($\theta = 90^{\circ}$) are relatively unaffected by saturation.

The response of the phase sensitive detector is limited to signals at the reference frequency as well as to odd order harmonics. Response for this type detector to odd order harmonics will never be greater (usually less depending upon phase angle) than the fundamental response multiplied by a factor 1/n where n is the order of the harmonic. Where a Signal Channel filter is used, there is, of course, essentially no response to harmonics in the signals.

All other frequencies are rejected except for signals very near to the reference frequency and its odd harmonics. Here, the meter movement will oscillate between 0 degrees in-phase and 180 degrees out-of-phase and at a frequency proportional to the difference between the input frequency and the fundamental or third harmonic of the reference signal. Response of this nature is limited to frequency differences of about 5Hz (meter pass band).

The effect of reference harmonics is much less important than that of signal harmonics because the harmonic content can never do more than shift the point at which the diodes start to conduct. Expressed otherwise, there is an equivalent error in degrees which results from harmonics in the Reference Channel. For measurements using the phase shifter, the error can be removed by trimming. For measurements using E cos θ characteristic, the effect is small because the meter reading as a function of current integrated over an entire cycle and the small error produced by distortion has a correspondingly small effect on the total current.

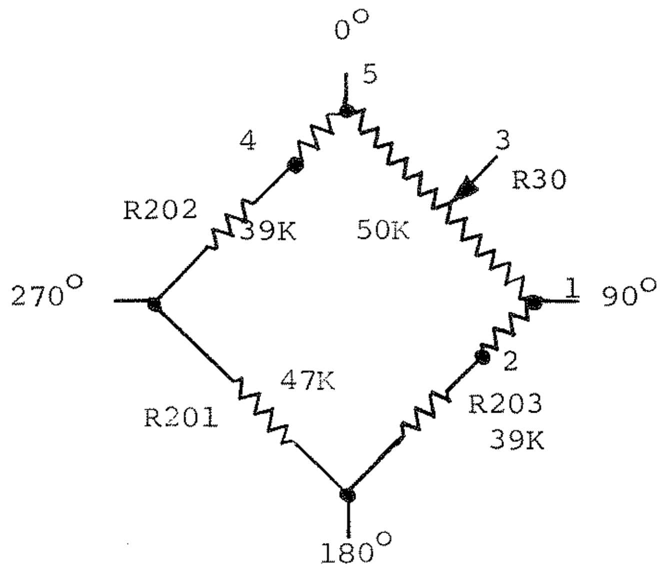
When used as a conventional voltmeter the phase-sensitive rectifier is switched to a full wave rectifier configuration. Operation is identical to that of a full wave bridge power supply in which the meter movement acts as the load.

Effects of Distortion - The current through the meter in the latter circuit is proportional to the average value of the voltage waveform applied. Calibration of the meter in RMS is based on a ratio between the average and effective values of a true sinesoidal voltage. Deviation from a true sinewave may cause errors in the meter indication. Table I lists the range of possible errors due to the 2nd and 3rd harmonic distortion.

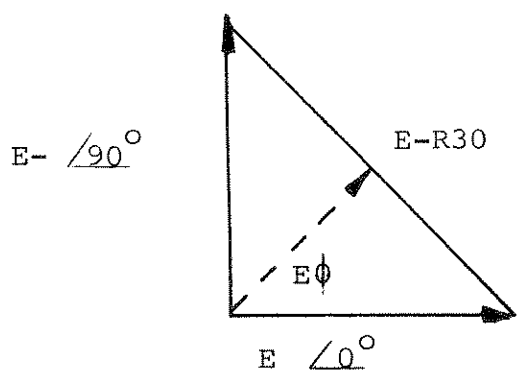
TABLE I - Errors Due to Harmonics in a Typical Average Detector

Harmonic Order	Harmonic Content	Error
2nd	10%	Nil
2nd	20%	0 to +2%
2nd	50%	0 to +10%
3rd	10%	-4% to +4%
3rd	20%	-6% to +8%
3rd	50%	-10% to +16%

The signal also drives the Overload Detector Circuit. The Overload Detector Circuit is designed to operate as a switch. When the signal level out of the Signal Amplifier Module (A2) exceeds a level of approximately 11 x full scale, the circuit will switch turning on the Overload indicator. The signal amplifiers will operate up to and including a 10 x overload. The indicator is set to light above this level and ordinarily measurements may not be made as long as the indicator is lit. The amplifiers, however, have the capability of operating with large signals without distorting.



PHASE SHIFT BRIDGE



$$E\angle 0^\circ = E\angle 90^\circ$$

$$\theta = \theta \text{ Max} \frac{\text{Tan } \phi}{1 + \text{Tan } \phi}$$

ϕ = Electrical Phase Angle

θ = R30 Shaft Angle

VOLTAGE VECTOR AT PHASE POTENTIOMETER

The voltage E-R30 appears across the Phase Potentiometer R30 between the taps, terminals 1 and 5. When $E\angle 0^\circ$ is set equal to $E\angle 90^\circ$, the electrical angle $E\angle\phi$ is a non-linear function of the potentiometer shaft angle. This is compensated by a non-linear phase dial This function is described by the equation shown.

The 90° angular rotation is shifted to any quadrant by the four corners of the bridge being rotated to cause the desired quadrant voltage to appear across the potentiometer. This is performed by the function switch.

Fig. 4.3

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Phase Bridge Network - The Phase Bridge Network is required to generate the precision phase shifts in the Reference Channel. These networks are designed for specific frequencies as required by the individual user. An output of 0°, 90°, 180° and 270° is provided and is selected by the Function Switch. Angles in any quadrant are determined by connecting the phase potentiometer to any two adjacent points through the Function Switch. This provides a phase shift capability of 0° to 360° as determined by the Function Selector setting plus the Phase Dial (phase potentiometer) setting. (See Figure 4.3)

Reference Amplifier (A3 Module, NAI #782246) - It is the function of this module to accept the phase shifted signal from the reference filter and to convert it to a push-pull driving signal. This driving signal, coupled through the Reference Drive Transformer performs the ultimate operation of gating the demodulator. The amplifier is designed to provide the necessary power gain while maintaining a minimal phase shift. It has in its feedback network a phase control (R43) which provides small leading and lagging phase shifts. This control is used to align the phase shifts between the signal and reference channels to 0°.

Power Supply - This circuit contains three +30V DC sources. Two of these 30V sources are well regulated, well filtered, and are used individually to supply the Signal and Reference Channels. The third 30V source is zener regulated and is used to supply the overload circuitry.

4.5 FILTERS

The filters used are low pass types and are operated in a restricted portion of the pass band. This is to maintain over this band the amplitude gradient within the instrument's specifications and to restrict the phase variation. Figure 4.4 is a typical filter response. F_m designates the geometric mean frequency of the usable band. The upper frequency

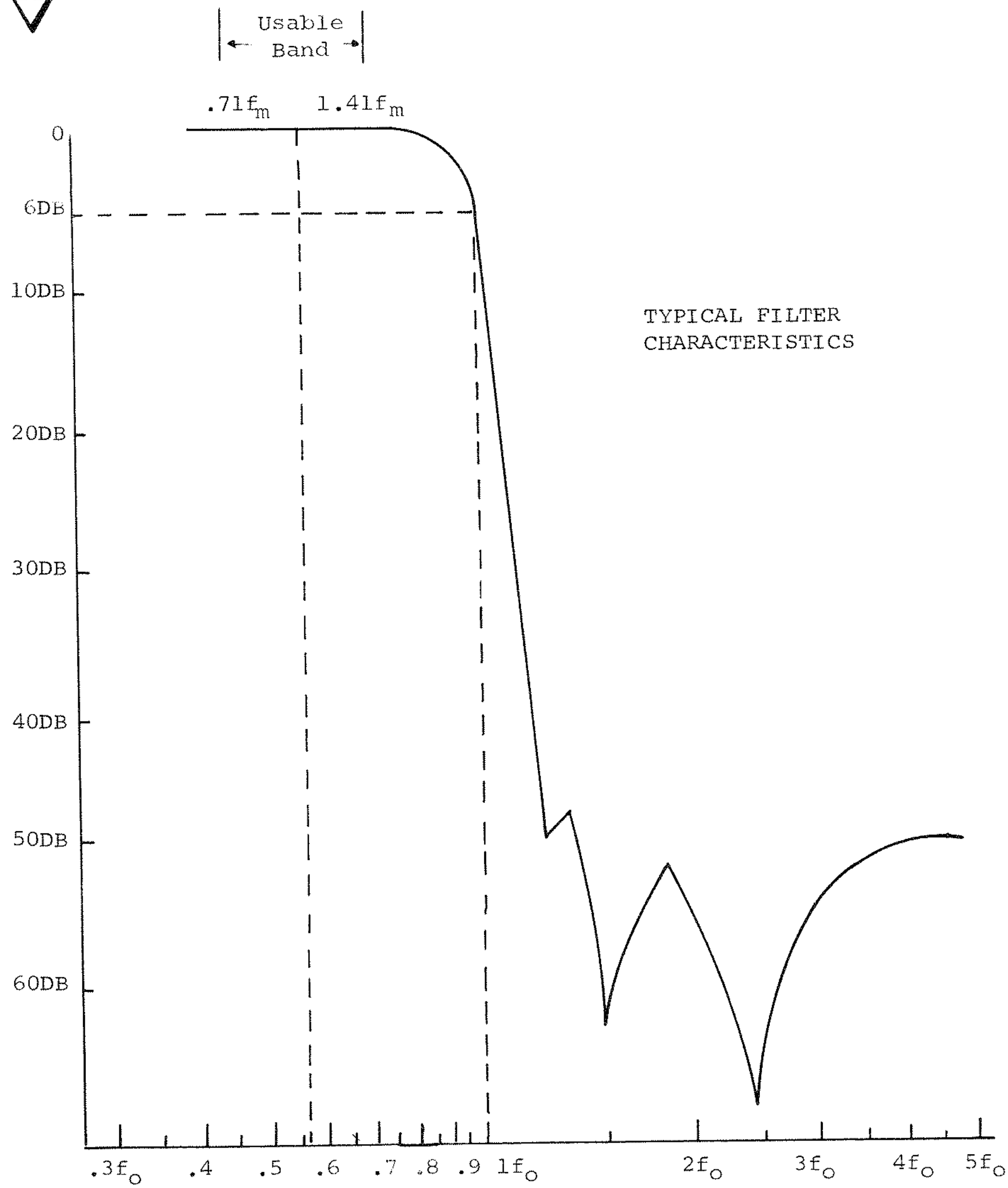
Usable
Band
.71f_m
1.41f_m
0
6DB
10DB
20DB
30DB
40DB
50DB
60DB
TYPICAL FILTER
CHARACTERISTICS
.3f_o
.4
.5
.6
.7
.8
.9
1f_o
2f_o
3f_o
4f_o
5f_o

Fig. 4.4

limit is determined by the amplitude vs frequency characteristic. Lower Frequency limit is determined by the amount of rejection of the third harmonic of this frequency.

NOTE: When making phase sensitive measurements, the detector circuit inherently has a high second harmonic rejection (approx. 55DB) and 10DB additional rejection of the third harmonic. This additional harmonic rejection is individually added to the filter rejection when operating in any phase-sensitive mode.

4.6 ISOLATION TRANSFORMERS - Model 212B (REF) and 212C (SIG and REF)

The 212B is characterized by the inclusion of an isolation transformer in its Reference input. This will allow a common reference signal to be connected to the instrument without creating a ground loop.

The 212C is characterized by the inclusion of an isolation transformer in its signal input, as well as containing the above mentioned Reference Isolation Transformer. The DIR/TRANS Switch provides a means of switching this transformer in and out of the input as desired. The transformer may be used for making single ended as well as differential measurements.

SECTION V

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

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5.1 MAINTENANCE

The following section contains instructions for the general maintenance of the Phase Angle Voltmeter. Performance testing, alignment procedures, and troubleshooting are described here.

WARNING: High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to avoid shock hazard.

5.2 COVER REMOVAL

In order to service, it is necessary to remove the top cover of the instrument via the removal of 5 screws. For additional troubleshooting and maintenance, it may become necessary to remove the bottom cover of the instrument which may easily be accomplished by removing 5 screws.

5.3 REPLACEMENT OF MODULES

With the top cover removed, loosen the screws which clamp the module to its hold down bracket and remove it from its socket. Care must be exercised to insure that a module is replaced with the same type.

5.4 REPLACEMENT OF P.C. BOARD COMPONENTS

There are a number of components which are mounted directly to the "Mother" P.C. Board, all of which are easily accessible. In the event that any of these must be replaced, normal precautions consistent with good manufacturing practice should be followed.

There are also a number of components which are mounted to switch assemblies. In the event there is a failure in any of these components, it is recommended that the switch wafer be replaced as a complete assembly.

5.5 REPLACEMENT OF FUSE

A power fuse is mounted on the rear panel of the unit and may easily be replaced by removing the fuseholder cap. This fuse will normally be a .5 amp fuse, type 3AG, for those instruments which operate with 230V power source, this fuse should be a .25 amp, type 3AG.

5.6 PERFORMANCE EVALUATION PROCEDURE

It is the purpose of this procedure to assist a qualified technician in the recalibration of the Model 212 Phase Angle Voltmeter. Under normal circumstances, this instrument, due to the use of solid-state circuitry, should require a minimum of service and recalibration.

The Test Procedure portion of Section V may be used for incoming acceptance test or for periodic calibration checks. It is recommended that the initial periodic check be made every 3 months and future checks be expanded to 6 months or yearly checks.

The Alignment Procedure portion of Section V may be used for recalibration in the event there is a failure which requires the replacement of any module or component in the instrument.

5.6.1 EQUIPMENT REQUIRED TABLE II

TEST EQUIPMENT	CAPABILITY/TYPE	APPLICATION
Variable Voltage Source	Frequency Accuracy: ±5% Frequency Range 10Hz to 100KHz (e.g., - Elin AD0102	Voltage & freq. response calibration

TEST EQUIPMENT	CAPABILITY/TYPE	APPLICATION
Scale Voltmeter, Monitor	Accuracy: ±0.5% calibrated full scale - 400Hz	Voltage Calibration
Voltmeter, Monitor	Flat Freq. Response: ±0.5% 10Hz to 100KHz (e.g., Hewlett-Packard Model 739R)*	Frequency Response
AC Ratio Box	NAI Model RB-503	Voltage Calibration
** Phase Generator	NAI Model 350	Phase Calibration

*A Hewlett-Packard K02-738BR VTVM calibration system may be used in place of the above voltage calibration equipment.

**See Paragraph 5.6.2.7 for alternate methods of Phase Angle Generation.

5.6.2 PROCEDURE

5.6.2.1 Preliminary Checks

A. Before turning on equipment, check mechanical zero of the meter and rezero if necessary.

B. Ground Isolation Check (instrument turned off)

1. Check resistance between chassis ground and circuit ground at the signal input terminals. (Link must be removed) This should read open.

C. Noise Check (instrument on, chassis connected to house ground, ground link in place):

1. Short Signal Input terminals, apply a 100V Reference Signal, and set reference to red line.

2. Reading on the meter should not exceed 15uv on any range in the TOTAL and FUND Modes. In the PAV (Phase Sensitive Modes) the meter indication should be less than 2uv.

5.6.2.2 Voltage Check - Connect instrument as shown in Figure 5.4A

A. Set controls as follows:

Function Switch - Total

Trans/Dir Switch - Dir (Model 212C only)

B. Apply a voltage to the Signal input terminals corresponding to the full scale indication at each position of the Range Switch. The accuracy of the input voltage should be ±0.5%. The Model 212 should indicate these values ±2% of full scale.

1. Set Range Switch to 300uv.

2. Apply a 300uv ±0.5%, 400Hz to the Signal input terminals

3. Meter should now read 300uv ±2%

4. Set Range Switch to lmv.

5. Apply a lmv, ±.5%, 400Hz to the Signal input terminals.

6. Meter should now read lmv ±2%.

7. Set Range Switch to 3mv.

8. Apply a 3mv ±.5%, 400Hz to the Signal input terminals.

9. Meter should now read 3mv ±2%.

10. Set Range Switch to 10mv.

11. Apply a 10mv ±.5%, 400Hz to the Signal input terminals.

12. Meter should now read 10mv ±2%.

13. Set Range Switch to 30mv.

14. Apply a 30mv ±.5%, 400Hz to the Signal input terminals.

15. Meter should now read 30mv ±2%.

16. Set Range Switch to 100mv.

17. Apply a 100mv ±.5%, 400Hz to the Signal input terminals.

18. Meter should now read 100mv ±2%.

19. Set Range Switch to 300mv.

20. Apply a 300mv ±.5%, 400Hz to the Signal input terminals.

21. Meter should now read 300mv ±2%.

22. Set Range Switch to 1V.

23. Apply a 1V ±0.5%, 400Hz to the Signal input terminals.

24. Meter should now read 1V ±2%.

25. Set Range Switch to 3V.

26. Apply a 3V, ±0.5%, 400Hz to the Signal input terminals.

27. Meter should now read 3V ±2%.

28. Set Range Switch to 10V.

29. Apply a 10V ±0.5%, 400Hz to the Signal input terminals.

30. Meter should now read 10V ±2%.

31. Set Range Switch to 30V ±2%.

32. Apply a 30V ±0.5%, 400Hz to the Signal input terminals.

33. Meter should now read 30V ±2%.

34. Set Range Switch to 100V.

35. Apply a 100V ±0.5%, 400Hz to the Signal input terminals.

36. Meter should now read 100V ±2%.

37. Set Range Switch to 300V.

38. Apply a 300V ±0.5%, 400Hz to the Signal input terminal.

39. Meter should now read 300V ±2%.

C. Switch the Function Switch to Fund and repeat B (signal input must be at the operating frequency of the instrument).

D. (Model 212C instruments only)

Switch the Trans/Dir Switch to Trans. With Function Switch in Fund position and a signal at the operating frequency of the instrument repeat Step B.

E. Linearity Check - Set the Frequency Switch to any convenient frequency and inject a full scale signal into the Signal input terminals. Switch the Function Switch to Fund. Change input Signal down scale in discrete steps. Meter should indicate corresponding levels as follows (±2%):

Range	Input	Meter X Full Scale
1V	1V	1
1V	.8V	.8
1V	.6V	.6
1V	.4V	.4
1V	.2V	.2
1V	.1V	.1

5.6.2.3 Frequency Response - Total Mode, (Dir only in Model 212C)

A. Set Function Switch to Total
Set Range Switch to 0.1V
Set Trans/Dir Switch to Dir (Model C only).

B. Using a wideband oscillator, inject a signal equal to 0.09V at 400Hz. Monitor this input voltage with a meter which has a known frequency response which is flat to within 0.5% over a range of 10Hz to 100KHz.

C. Sweep the input signal from 10Hz to 100KHz. Meter should indicate 0.09V ±2%. 20Hz to 50KHz and ±5% 10Hz to 100KHz.

D. Switch Range Switch to 1.0V. Reset input level to 0.9V at 400Hz and repeat Step C. Meter should indicate 0.9V ±2% 20 Hz to 50KHz and ±5% 10Hz to 100KHz.

5.6.2.4 Sig and Ref Channel Phase Alignment

A. Turn Function Selector to REF ADJ and adjust reference level for "red line" value on the meter scale.

B. Set Range Selector to .010 and connect 90° signal source to signal input terminals. Adjust input voltage until a full scale reading on Phase Angle Voltmeter is obtained. (See Fig. 5.4B)

C. Set Phase Dial to 0°.
Set Function Selector to 0°.
Set Range Selector to .001 (approx. 10 x overload)

D. Adjust R43 (back panel control) for zero reading on meter.

NOTE: Signal and ref channel are now phase aligned. The 0° Function Selector and Phase Dial position are now calibrated.

5.6.2.5 Phase Check

The following checks should be made at the operating frequency of the instrument. For methods of generating phase angles, see paragraph 5.6.2.6.

A. Using a 10V voltage level into the Reference input terminals, set Function Switch to REF ADJ position and Reference Adjust Control to cause the meter to read "red line" (red mark at half scale on meter).

B. Set Function Switch to 90°.
Set Phase Dial to 0°.
Set Range Switch to 0.001V.

C. Inject a 0.010V (10 x overload) 0° signal into the

Signal input terminals.

D. Adjust Phase Dial to cause the meter to read a null (0). The indicated angle should be $\pm 1^{\circ}$ of the input angle (i.e. - with a 0° input, the Phase Dial should read between -1° and $+1^{\circ}$).

E. Repeat Steps C and D <u>in 10° increments</u> to 90°. The Phase Dial readings should all be within $\pm 1^{\circ}$ of the input signal angle.

5.6.2.6 Overload Check

A. Inject a Reference signal at the frequency of operation and adjust the reference level as in IV-A.

B. Set the Function Switch to 90°.
Set the Range Switch to 0.1V.

C. Inject a 0° signal into the Signal input terminals at approximately 1V level (10 x overload). Meter will indicate zero.

D. Gradually increase the input signal until overload light comes on. This should occur at approximately 11 x overload (1.1V).

5.6.2.7 Phase Angle Generation

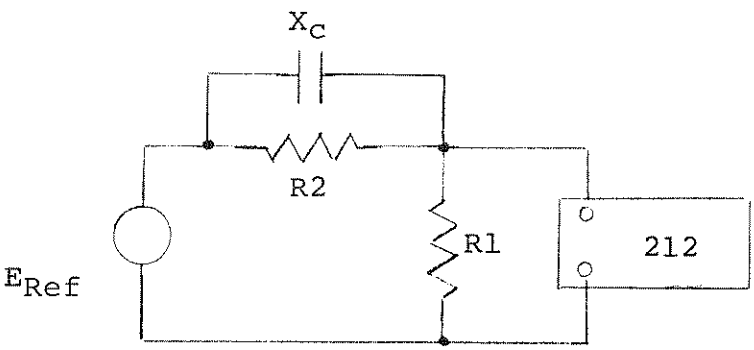
The test procedure required that phase angles other than 90^{o} or 0^{o} be used for some checks. Commercially available phase angle generating equipment may be used to perform these tests. However, if commercial equipment is not available, it is suggested that the following methods be used.

RC Passive Phase Shifter - Precise phase angles can be generated using the circuit configuration shown below. These networks are very useful and are simple to construct. They do require, however, accurate measurement of component values. They may be constructed with the aid of the design equations shown below. The components should be high quality, stable devices; such as, mica, or polystyrene capacitors, and metal film or deposited carbon resistors.

$$\text{Attenuation} = \frac{R_1}{|Z|}$$

Providing $R_1 // |Z|$

$$\text{Phase Shift} = \text{Tan}^{-1}\frac{R_2}{X_C}$$



$$Z = \frac{R_2}{1 + j\frac{R_2}{X_C}}$$

$$|Z| = \frac{R_2\, X_C \sqrt{X_C^2 + R_2^2}}{X_C^2 + R_2^2}$$

Fig. 5.1

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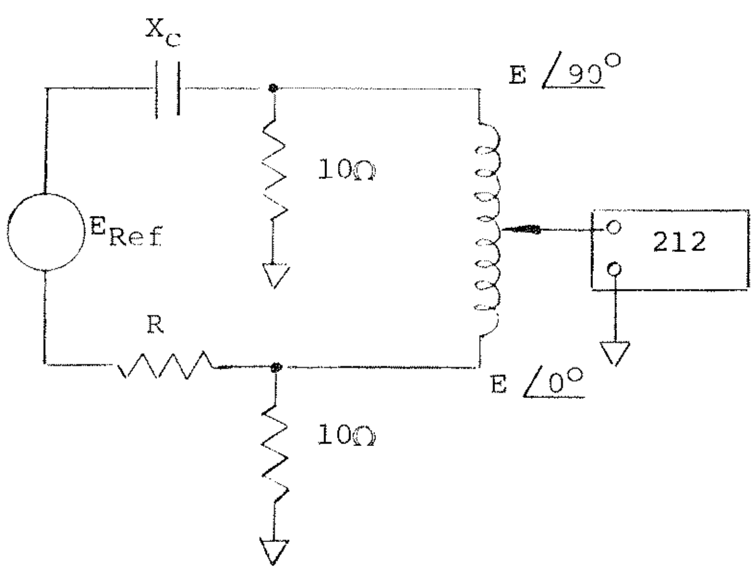
Ratio Box Phase Shifter - This circuit is somewhat less complicated than the previous circuit in that it requires only a precise 0° and 90° signal be generated by use of passive networks but it does require that a high quality Ratio Box which is accurate at the operating frequency be used. The components again must be high quality and drift free. It may be seen that any angle between 0° and 90° can be selected depending on the setting of the Ratio Box. It should be noted, however, that the amplitude of the 0° and 90° signal should be set equal to each other. The output amplitude will vary through a minimum of 0.707 of the 0° and 90° signals at 45° (Ratio Box setting of 0.5).

Phase network component values and Ratio Box settings are determined by the equation shown.



$$\frac{X_c}{10} \gg 1000$$

$$R = X_c$$

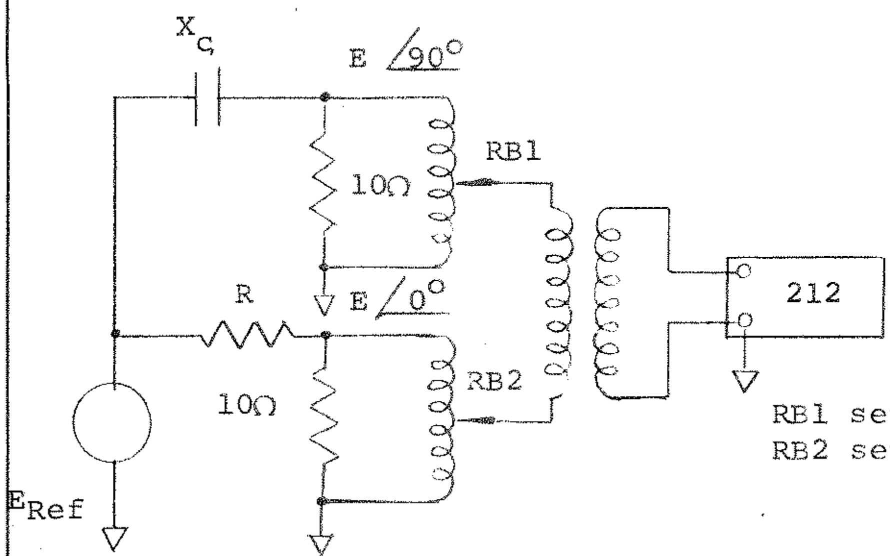
E $\angle 0^{\circ}$ and E $\angle 90^{\circ}$ must be set equal within 1/4%.

Ratio Box setting =

$$\frac{1}{1+\operatorname{ctn}\theta}$$ where θ is desired phase shift

Fig. 5.2

Resolver Simulator Phase Shifter - The third system is that of the resolver simulator phase shifter. This circuit very closely simulates the performance of the resolver in that the phase angle generated is between 0° and 90° at a constant amplitude. The same passive networks as above are used to generate the 0° and 90° and also as above their amplitudes must be set equal to each other. Two Ratio Boxes are used to drive a bridging transformer. The 0° and 90° signals of varying amplitudes as set by the Ratio Boxes are then summed vectorally in the bridging transformer and the resultant output is fed to the Model 212. Phase network component values and Ratio Box settings are determined by the equation shown.



$\frac{X_C}{10} \gg 1000$

$R = X_C$

$E \angle 0^\circ$ & $E \angle 90^\circ$ must be set equal within 1/4%.

RB1 setting = $\sin \theta$
RB2 setting = $\cos \theta$
where θ is desired phase shift.

Fig. 5.3

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NAI Model 350 Phase Generator - The Model 350 Phase Generator uses the same technique as the latter above mentioned system, packaged in one convenient instrument. Front panel controls, calibrated in phase angle permit direct selection of phase angles, avoiding the necessity for computing component values and ratio box settings. The frequency range of the instrument is 50Hz to 12KHz.

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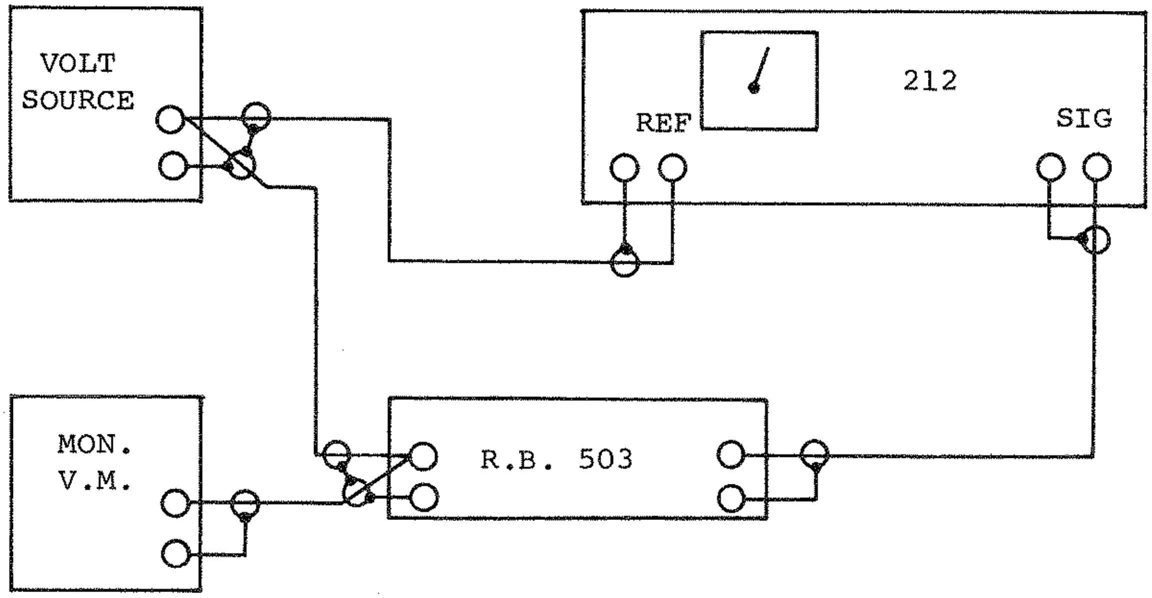

Figure 5.4A

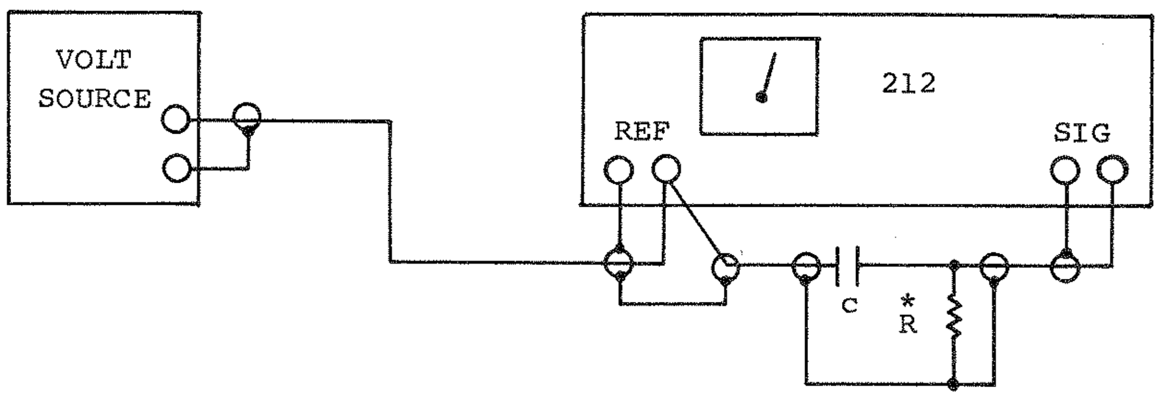

Figure 5.4B

400Hz

C = 500pf

R = 80Ω

For other frequencies

X_C approx. 10000 times R

R less than 200Ω

TEST CONNECTIONS

*See page Phase Angle Generator

5.7 ALIGNMENT PROCEDURE

5.7.1 Preliminary Checks

A. Before turning on equipment, check mechanical zero of the meter and rezero if necessary.

5.7.1.1 Ground Isolation Check

A. Check resistance between chassis ground and circuit ground at the signal input terminals (link must be removed). This should read open.

5.7.1.2 Power Supply Check - Instrument turned on (Range Switch on 300V Range)

A. Check 30V-A, 30V-B, 30V-C. Each should read +30V ±1.5V.

B. Check ripple with Hewlett-Packard voltmeter. Should not exceed the following:

30V-C	7mv RMS or P.P.
30V-B	7mv RMS or P.P.
30V-A	85mv RMS or P.P.

5.7.1.3 Noise Check

A. Short Signal input terminals, apply a 100V reference signal.

B. Reading on the meter should not exceed 15uv on any range in the Total and Fund modes. In the PAV (Phase Sensitive) Mode, the meter indication should be less than 2uv.

5.7.2 Voltage Alignment - Connect as in Figure 5.3a.

The following adjustments are for the purposes of calibrating the basic voltage gain of the instrument, plus setting the transfer of the filter in the Fund mode. It also incorporates the "broadband" adjustment of the 1000:1 standard input attenuator and the Total Mode frequency response trim.

A. FUND Adjustment

1. Set Range Switch to 0.1V, Function Switch to Fund.

2. Apply 0.1V at operating frequency to the Signal input terminals.

3. Adjust Fund Adj. Pot (R13) for full scale indication on the meter.

B. TOTAL Adjustment

1. Rotate Function Switch to Total position. Apply 0.1V at 400Hz and adjust Total Adj. Pot (R57) for a full scale reading on the meter.

C. 1000:1 Input Attenuator Adjustment

This attenuator must operate over the entire frequency range of the instrument in the Total Mode. Therefore, it must be adjusted for a "flat" amplitude characteristic and a minimum shift over this range. Two different methods may be used to adjust this attenuator.

1. For instruments which operate at a frequency between 160Hz and 1KHz (Connect instruments as shown in Figure 5.5a)

a. Set voltage source for precisely 10V as measured on the Monitor Voltmeter at a frequency corresponding to the Model 212 operating frequency.

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b. Set Ratio Box to 0.01V (.001000).

c. Set Function Switch to REF ADJ. Set reference adjust control for "red line."

d. Set Range Switch to 0.001V, Function Switch to 90°, and Trans/Dir Switch to Dir.

e. Rotate Phase Dial until meter reads precisely zero.

f. Set Range Switch to 10V position and Function Switch to Fund.

g. Set Ratio Box for 10V (1.00000).

h. Adjust R103 for full scale reading on 212 meter. See Figure 5.5.

i. Set Function Switch to 90° and Range Switch to 1V (10 x overload).

j. Adjust C101 for zero reading on 212 meter. See Figure 5.5.

k. Repeat Steps f through j until best results are obtained. This is required due to the interaction of the two controls.

2. <u>For instruments which do not operate at frequencies between 160Hz and 1KHz</u>

a. Set the Range Switch to the 1V position and the Function Switch to Total. Set Reference Adjust control to "red line". (In the Model 212C instruments, Dir/Trans Switch to Dir).

b. Apply a 1V ±0.5%, 50Hz signal to Signal input terminals. Monitor with meter which has a frequency response flat within ±0.5%.

c. Adjust R103 for full scale reading on the meter. See Figure 5.5.

d. Reset the signal input to 10KHz, 1V ±0.5%.

e. Adjust C101 for a full scale reading on the meter See Figure 5.5.

f. Recheck Steps b through e, readjusting as necessary The 1000:1 input attenuator is now "broadbanded" and will have minimal phase shift.

D. Frequency Response Trim (Total Mode)

The Frequency Response of the 212 in the Total Mode should not require retrimming unless an amplifier is replaced. (Note that in the Model 212C instruments, in the Trans position of the Dir/Trans Switch, the frequency response is limited to that of the transformer.)

1. Set the Function Switch to Total, the Range Switch to 0.01V, and in Model 212C instruments, set the Dir/Trans Switch to Dir.

2. Using the wide band voltage source, inject a 0.009 volts signal (90% of full scale) at 400Hz. Note reading.

3. Check this reading at 50 KHz and 100 KHz.

4. If the errors observed exceed ±2% of full scale @ 50KHz ±5% of full scale @ 100KHz correct by selecting a new value for C28.

5.7.3 Phase Dial Alignment on Phase Shifter Pot, R30 (This should be checked before proceeding with Phase Alignment

The following is a procedure for mechanically aligning the Phase Dial on the shaft of the phase shifter pot (R30). This is necessary in the event that a Phase Dial, phase pot, or both are disassembled or replaced. The 0° and 90° points on the Phase Dial must be aligned to coincide with the taps of the pot.

CAUTION: Use only a high impedance ohmmeter (i.e. - H.P. 412) as damage to the precision phase pot can occur if excessive voltage is applied.

A. Turn power off.

B. Set Function Selector to any phase sensitive position.

C. Use an ohmmeter to place the wiper of R30 exactly on the ccw tap point. Loosen dial clamping screws and rotate Phase Dial until dial reading is exactly 90° . Tighten clamping screws. Reconnect ohmmeter to cw tap point and rotate Phase Dial until wiper of R30 is on cw tap point. Dial should now read zero degrees. If not, reposition dial so as to achieve the best compromise reading between the two taps. For example, if the zero degree point reads low, the 90° point should read high by the same amount. Fully tighten set screws and re-check to make sure dial has not slipped during tightening.

5.7.4 Phase Alignment

This alignment will adjust the instrument for zero phase shift between the signal and reference channels.

A. Connect the Model 212 as shown in Figure 5.4b. This will require a precise 90° phase shifted signal which may be generated as indicated in this figure.

B. Set the Function Switch to REF ADJ, inject 100V at the frequency of operation into the Reference input terminals. Adjust Reference Adjust control for "red line" on the meter.

C. Set Function Switch to 0°, Phase Dial to 0°, and Range Switch to 0.01V.

D. Connect the precise 90°, 0.01V signal to the Signal input terminals.

E Set Range Switch to 0.001V (10 x overload) and adjust R43 (See Figure 5.5) to cause the meter to read 0.

F. Set Function Switch to 90° and Phase Dial to 90°.

G. Meter should read zero. If an error exists, readjust R43 to divide the error between Steps E and F.

5.7.5 Phase Bridge Alignment
(Be sure to perform 5.7.4 before proceeding)

A. Using a 10V Reference level into the Reference input terminals, set Function Switch to REF ADJ position and Ref adjust control to cause meter to read "red line".

B. Set Function Switch to 90°
Set Phase Dial to 0°
Set Range Switch to 0.001V

C. Inject a 0.010V (10 x overload) 0° signal into the Signal input terminals.

D. With the AC VTVM measure the voltage across C15 and note. Measure the voltage across R26 and note. These voltages should be balanced to within .05 volts. If they are not, adjust R26 to cause them to be balanced. (Note: Be sure the high side of the AC VTVM is connected to the junction of C15, R26 to avoid common mode errors.)

E. At this point meter should be reading 0. If not adjust R27 to cause a 0 reading.

F. Set Function Switch to 90° and Phase Dial to 0°. Meter should read 0. If not adjust R27 for best compromise between steps E and F.

5.8 TROUBLESHOOTING TABLE

A troubleshooting table for the Phase Angle Voltmeter is presented in Figure 5. The troubleshooting table lists TROUBLE indications, denotes the PROBABLE CAUSE of trouble based on the observed symptons, and recommends a REMEDY to clear the trouble.

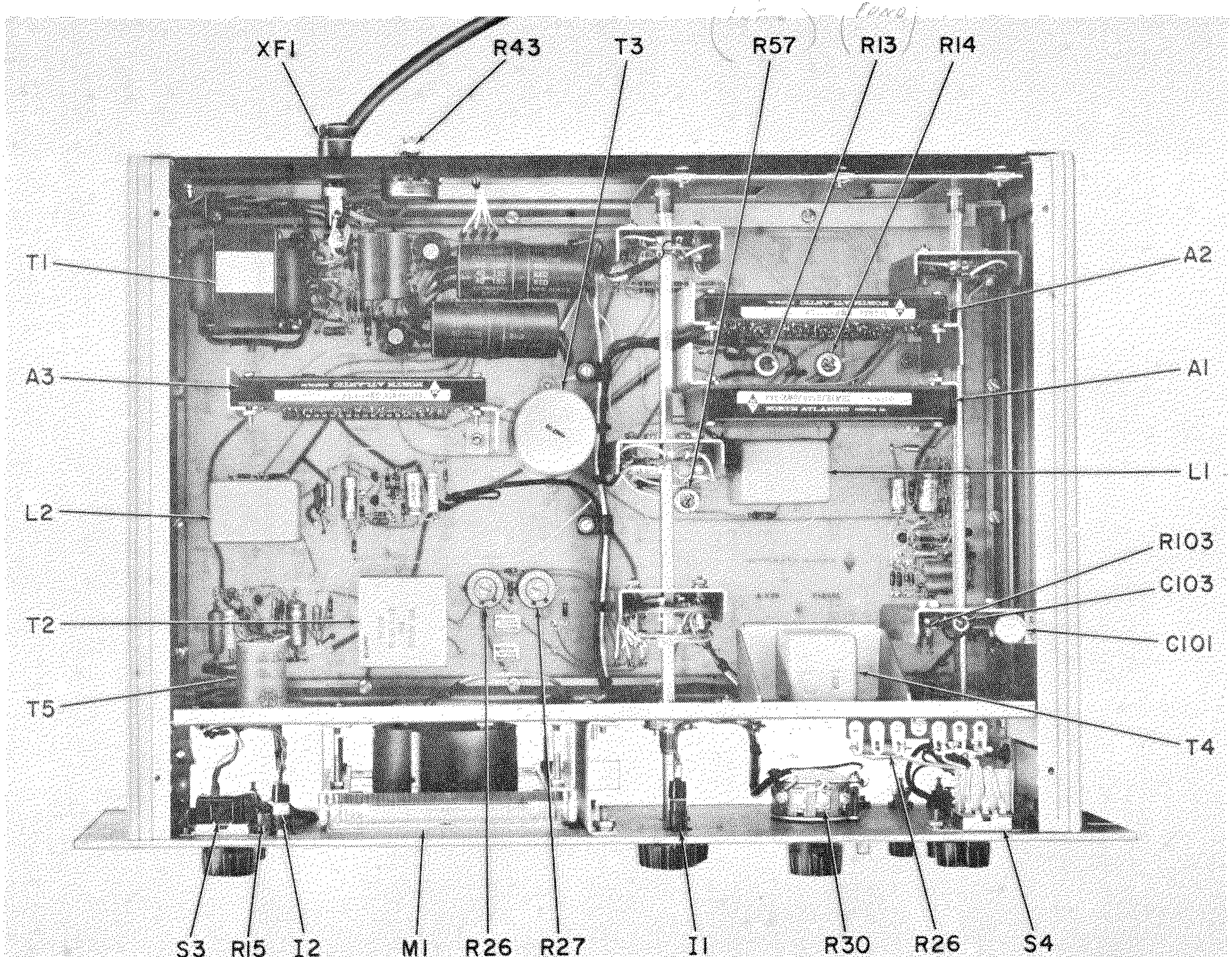
To support troubleshooting operations, see the following maintenance diagrams: schematic diagram is shown in Figure 4.6 and a parts location and identification diagram is shown in Figure 4.5. (Refer to the Parts List in Section VI for replacement part data.)

TABLE III

TROUBLE	PROBABLE CAUSE	REMEDY
Power lamp I1 does not light when power is applied from external control switch	Lamp I2 Fuse F1	Check fuse and/or lamp. Replace defective unit.
Secondary power at +30V DC is absent or abnormal. Off-set errors	Power supply Zener Diode - CR17, CR18, or CR19 Transistor Q7,Q8 Filter Caps C24 or C25 Rectifier diodes - CR13,CR14,CR15, or CR16	Check for defective component (s) and replace.
No meter indication in Total or Fund mode	Signal channel amplifier module A1 or A2	Replace modules in turn until trouble is cleared.
	Signal Isolation Amplifier	Check for and replace defective component.
Offset errors	Electrostatic charge on meter	Discharge meter face by wiping glass with mild detergent solution.
Failure in Fund mode only	Filter L1 or or associated resistor (s)	Check resistor (s) and replace if defective or replace filter.
Failure in Total mode only	Total Resistors R57,R58, or R60	Check for and replace defective resistor (s).

TROUBLE	PROBABLE CAUSE	REMEDY
Inaccurate meter readings on all ranges	Signal channel amplifier module A1 or A2; Signal Isolation Amplifier	Replace module in turn until trouble is cleared.
	Diodes CR5, CR6, CR7, or CR8	Check and replace defective diode.
	Meter M1	Replace meter
Inaccurate meter readings on one or more specific ranges or high range failure above 300mv	Range attenuator resistor (s) on switch S1 associate with defective ranges (s) as observed, or input attenuator	Check applicable resistor (s) in group R108-R114 and replace defective unit (s) Check input attenuator and replace defective component.
Failure of low range, 300mv and below	Range attenuator resistors R108-R114	Check resistors and replace defective unit.
Phase Sensitive mode errors or erratic meter readings in both 0 and 90 degree positions	Reference channel components, including module A3, ref.isol. amps., phase shift network, phase pot R30, Ref. filter L2, Transformer T2, T3, Phase trim components R43, R44, R45, C22	Replace modules in turn until trouble is cleared. If trouble is not in module, check in turn resistors, capacitors, and transformers until defective unti is found. Replace to clearn trouble.

TROUBLE	PROBABLE CAUSE	REMEDY
Overload lamp remains lit or does not light	Lamp I1	For a lamp that does not light, check lamp I1 and replace if defective.
	Overload Circuit of Module A1	Replace module A1 if lamp I1 is not defective.
	Resistor R14	Check and replace if defective



MAJOR COMPONENT AND CAL. ADJ. LOCATOR. FIG 5.5

ITEMS NOT CALLED OUT, ARE IDENTIFIED ADJACENT TO OR UNDER THE COMPONENT.

⚠1 SELECT AT TEST.
⚠2 USED IN 212A ONLY.
⚠3 CHANGE LOCATION OF S2G IN MODEL 212C

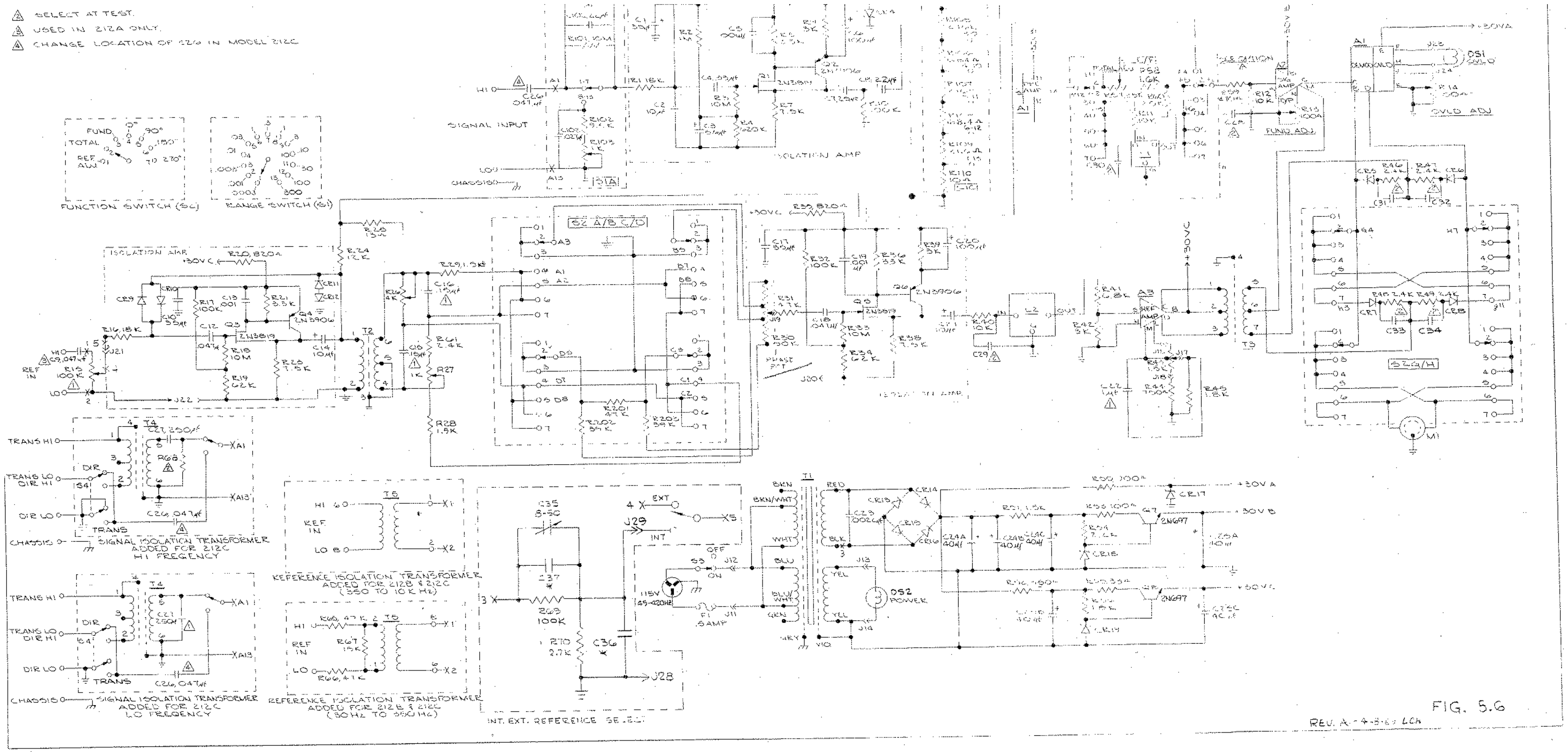


FIG. 5.6

REV. A

NOTES:
⚠ THESE VALUES ARE FOR 400 Hz ONLY.

SECTION VI

R E P L A C E M E N T   P A R T S   L I S T

REPLACEMENT PARTS LIST

PHASE ANGLE VOLTMETER MODELS 212A, 212B, 212C

Reference Designation	Description	NAI Part No.	Total Qty.
A1	Signal Ampl. Assy.	782245	1
A2	Pre-Amp/Demod/Ovld Assy.	782251	1
A3	Reference Ampl. Assy.	782246	1
C1, C10, C17	Capacitor, Fixed, Elec. 35 μf, 50V, -10 +75%	803291	3
C2	Capacitor, Fixed, Mica 10 μμf, 500V, ± 10%	802422	1
C3	Capacitor, Fixed, Elec. 5.6 μf, 35V, ± 10%	802391	1
C4	Capacitor, Fixed, Film .33 μf, 80V, ± 20%	803008	1
C5, C13, C19	Capacitor, Fixed, Film .001 μf, 200V, ± 5%	802316	3
C6, C20	Capacitor, Fixed, Elec. 100 μf, 6V, -10 +75%	801517	2
C7	Capacitor, Fixed, Elec. 25 μf, 25V, -10 +75%	803342	1
C8	Capacitor, Fixed, Elec. 6.8 μf, 6V, ± 20%	803456	1
C9, C26	Capacitor, Fixed, Film .047 μf, 400V (C9 - 212A ONLY)	802395	2
C12, C18	Capacitor, Fixed, Film .047 μf, 100V, ± 10%	801011	2

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

PHASE ANGLE VOLTMETER MODELS 212A, 212B, 212C
(Continued)

Reference Designation	Description	NAI Part No.	Total Qty.
C14, C21	Capacitor, Fixed, Elec. 10 μf, 20V, ± 20%	800802	2
C15, C16	Capacitor, Fixed, Paper .15 μf, 200V (400 Hz)	B-800720	2
C22	Capacitor, Fixed, Elec. 1 μf, 35V, ± 20% (400 Hz)	801343	1
C23	Capacitor, Fixed, Film .0022 μf, 400V, ± 20%	803177	1
C24A,B,C, C25A,B,C	Capacitor, Fixed, Elec. 3 x 40 μf, 150V	804509	2
C27	Capacitor, Fixed, Mica 250 μμf, 500V, ± 10% (212C ONLY)	803193	1
C28, C31, C32, C33, C34	Capacitor, Fixed, Mica (Select at Test)		5
C30, C29	Capacitor, Fixed, Film (Select at Test)		2
C101	Capacitor, Variable 3-12 μμf	801512	1
C102	Capacitor, Fixed, Polystyrene 22 μμf, 500V, ± 5%	802572	1
C103	Capacitor, Fixed, Polystyrene .027 μf, 100V, ± 5%	802571	1
CR1, CR2, CR9, CR10	Diode, 1N625	800114	4
CR3, CR4, CR11 CR12	Diode, 1N758	800658	4

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REPLACEMENT PARTS LIST

PHASE ANGLE VOLTMETER MODELS 212A, 212B, 212C
(Continued)

Reference Designation	Description	NAI Part No.	Total Qty.
CR5, CR6, CR7, CR8	Diode, 1N3069	802924	4
CR13, CR14, CR15, CR16	Diode, 1N645	800323	4
CR17	Diode, 1D30B	801203	1
CR18, CR19	Diode, 1N972B	803205	2
DS1	Light Cartridge (Red)	804507	1
DS2	Light Cartridge (White)	804508	1
F1	Fuse, .5 Amp.	802900	1
L1, L2	Filter (Pair) (400 Hz)	203516	1 pr
M1	Meter	A-203593	1
Q1	Transistor, 2N3819 (Special)	202837	1
Q2, Q4, Q6	Transistor, 2N3906	803661	3
Q3, Q5	Transistor, 2N3819	803662	2
Q7, Q8	Transistor, 2N697	804403	2
R1, R16	Resistor, Fixed, Wirewound 18K, 5W, ± 3%	801362	2
R2	Resistor, Fixed, Comp. 1 Meg., 1/4W, ± 5%	802730	1
R3, R18, R33	Resistor, Fixed, Comp. 10 Meg., 1/4W, ± 10%	803292	3
R4	Resistor, Fixed, Comp. 620 K, 1/4W, ± 5%	802087	1

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REPLACEMENT PARTS LIST

PHASE ANGLE VOLTMETER MODELS 212A, 212B, 212C

(Continued)

Reference Designation	Description	NAI Part No.	Total Qty.
R5, R21, R36	Resistor, Fixed, Comp. 3.3K, 1/4W, ± 10%	801400	3
R7, R23, R38	Resistor, Fixed, Comp. 7.5 K, 1/4W, ± 5%	801984	3
R8, R20, R35	Resistor, Fixed, Comp. 820 Ω, 1/4W, ± 10%	801402	3
R9, R39, R42	Resistor, Fixed, Comp. 3K, 1/4W, ± 5%	801406	3
R10, R17, R32	Resistor, Fixed, Comp. 100K, 1/4W, ± 10%	803222	3
R11, R12, R40	Resistor, Fixed, Dep. Carbon 10K, 1/4W, ± 1%	802716	3
R13, R14	Resistor, Variable 100 Ω	804592	2
R15	Resistor, Variable 100 K, 2W	800005	1
R19, R34	Resistor, Fixed, Dep. Carbon 62 K, 1/4W, ± 5%	802082	2
R24	Resistor, Fixed, Comp. 12K, 1/4W, ± 10%	803228	1
R25	Resistor, Fixed, Comp. 13 Ω, 1/4W, ± 5%	804589	1
R26	Resistor, Variable 4 K	804527	1
R27	Resistor, Variable 1 K	804594	1

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200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

PHASE ANGLE VOLTMETER MODELS 212A, 212B, 212C

(Continued)

Reference Designation	Description	NAI Part No.	Total Qty.
R28, R29	Resistor, Fixed, Comp. 1.5 K, 1/4W ± 5%	802232	2
R30	Resistor, Variable 50 K	B-201568	1
R31	Resistor, Fixed, Comp. 4.7 K, 1/4W, ± 10%	801373	1
R41	Resistor, Fixed, Comp. 6.8 K, 1/4W, ± 5%	802189	1
R43	Resistor, Variable 1.5 K, 2W	803440	1
R44	Resistor, Fixed, Comp. 750 Ω, 1/4W, ± 5%	803229	1
R45	Resistor, Fixed, Comp. 1.8 K, 1/4W, ± 5%	804004	1
R46, R47, R48, R49, R61	Resistor, Fixed, Comp. 2.4 K, 1/4W, ± 5%	801408	5
R50	Resistor, Fixed, Wirewound 900 Ω, 7W, ± 5%	804591	1
R51	Resistor, Fixed, Comp. 1.5 K, 1W, ± 10%	803208	1
R52	Resistor, Fixed, Wirewound 350 Ω, 7W, ± 5%	804590	1
R53	Resistor, Fixed, Comp. 100 Ω, 1/2W, ± 5%	800631	1
R54	Resistor, Fixed, Comp. 2.2 K, 1/2W, ± 5%	800829	1

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

PHASE ANGLE VOLTMETER MODELS 212A, 212B, 212C
(Continued)

Reference Designation	Description	NAI Part No.	Total Qty.
R55	Resistor, Fixed, Comp. 33 Ω, 1/2W, ± 5%	800413	1
R56	Resistor, Fixed, Comp. 1.8 K, 1/2W, ± 10%	800499	1
R57	Resistor, Variable 2.5 K	804593	1
R58	Resistor, Fixed, Metal Film 1.6 K, 1/4W, ± 1%	803253	1
R59	Resistor, Fixed, Comp. 470 Ω, 1/4W, ± 10%	803223	1
R60	Resistor, Fixed, Metal Film 2K, 1/4W, ± 2%	803449	1
R65, R66	Resistor, Fixed, Comp. 47K, 1/2W, ± 5%	800870	2
R67	Resistor, Fixed, Comp. 15K, 1/2W, ± 5%	800647	1
R68	Resistor, Fixed, Comp. (Select at Test)		
R101	Resistor, Fixed, Metal Film 10 Meg., 1/2W, ± 3%	803633	1
R102	Resistor, Fixed, Metal Film 9.5 K, 1/2W, ± 1%	803634	1
R103	Resistor, Variable 1 K	803341	1
R104	Resistor, Fixed, Metal Film 6.84 K, 1/8W, ± 1/4%	801474	1

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REPLACEMENT PARTS LIST

PHASE ANGLE VOLTMETER MODELS 212A, 212B, 212C
(Continued)

Reference Designation	Description	NAI Part No.	Total Qty.
R105	Resistor, Fixed, Metal Film 2.16 K, 1/8W, ± 1/4%	801475	1
R106	Resistor, Fixed, Metal Film 684 Ω, 1/8W, ± 1/4%	801476	1
R107	Resistor, Fixed, Metal Film 216 Ω, 1/8W, ± 1/4%	801477	1
R108	Resistor, Fixed, Metal Film 68.4 Ω, 1/8W, ± 1/4%	801478	1
R109	Resistor, Fixed, Metal Film 21.6 Ω, 1/8W, ± 1/4%	803431	1
R110	Resistor, Fixed, Metal Film 10 Ω, 1/8W, ± 1/4%	803000	1
R201	Resistor, Fixed, Comp. 47 K, 1/4W, ± 5%	801638	1
R202, R203	Resistor, Fixed, Dep. Carbon 39 K, 1/4W, ± 1%	803238	2
S1 A/B	Switch, Wafer (Range)	B-203592-1	1
S1 C/D	Switch, Wafer (Range)	B-203592-2	1
S2 A/B	Switch, Wafer (Function)	B-203591-2	1
S2 C/D	Switch, Wafer (Function)	B-203591-3	1
S2 E/F	Switch, Wafer (Function)	B-203591-4	1
S2 G/H	Switch, Wafer (Function)	B-203591-4	1
S3	Switch, Power	804586	1
S4	Switch, Transformer In/Out	A-202730	1

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REPLACEMENT PARTS LIST

PHASE ANGLE VOLTMETER MODELS 212A, 212B, 212C
(Continued)

Reference Designation	Description	NAI Part No.	Total Qty.
T1	Transformer Power	C-202819	1
T2	Transformer, Reference	800549	1
T3	Transformer, Reference Drive	B-202348	1
T4	Transformer, Sig. Isolation	B-201562	1
T5	Transformer, Ref. Isolation	800050	1
	Binding Post, Black	800120	2
	Binding Post, Red	800119	3
	Binding Post	800546	1
	Dial Assy., Phase Angle	500498	1
	Knob, Large Rd.	B-201724	1
	Knob, Large, Pointer	B-201837	2
	Line Cord	800502	1
	Link Shorting	800339	1
S1	Switch Mechanism	B-203590-1	1
S2	Switch Mechanism	B-203590-2	1
	Window, Meter	B-202561	1
XDS1, XDS2	Connector Cartridge	804544	2
XF1	Fuseholder (1)	800117	1

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SECTION VII

A P P E N D I X

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

WARRANTY

North Atlantic Industries, Inc. warrants its products against defects in material and workmanship for one year from the date of the original shipment. Our liability is limited to repairing or replacing products (except fuses and electron tubes) which prove to be defective during the warranty period.

North Atlantic Industries, Inc. is not liable for consequential damages or for any damage or injury to persons or property resulting from the operation or application of any of its equipment.

Warranty is voided if there is evidence that the product has been operated beyond its design range, improperly maintained, or physically mistreated.

In the event of a malfunction in a product under warranty, the purchaser should notify his local Sales Representative or the Sales Department of North Atlantic Industries, Inc. giving full details of the defect and providing the model and serial number of the instrument. Service data or shipping instructions will be forwarded promptly. There is no charge for warranty repair of products, except transportation charges.

North Atlantic Industries, Inc. reserves the right to make changes and improvements in its products without any liability for incorporating such changes or improvements in any products previously sold.

No other warranty expressed or implied is offered other than the foregoing.

Estimates of charges for out of warranty repairs or other service work will be supplied before work begins. Out of warranty repairs will only be made following the receipt of purchaser's authorization of applicable charges.

Claims for Damage in Shipment

The purchaser should inspect and functionally test the product in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or, if insured separately, with the purchaser's insurance company.

(turn over for Shipping Instructions)

Shipping

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in heavy paper or a plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.

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APPLICATION NOTES

FOR

SERIES 200

PHASE ANGLE VOLTMETERS

The North Atlantic Industries Series 200 Phase Angle Voltmeter is a truly unique, multifunctional instrument which will function as a sensitive voltmeter, a phase angle meter, a meter measuring in-phase signals ($E \cos \theta$), and quadrature signals ($E \sin \theta$), a phase sensitive null indicator, an impedance meter, and a power factor meter.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

TABLE OF CONTENTS

I - INTRODUCTION

The following notes will acquaint the user of the 200 Series Phase Angle Voltmeter with the many ways in which these versatile instruments can be used.

By virtue of the instrument's ability to measure the two basic characteristics of any signal; namely, magnitude and phase angle, measurements are now possible which previously either required extensive associated equipment or could not be made at all.

The principle of operation is illustrated in Figure (1).

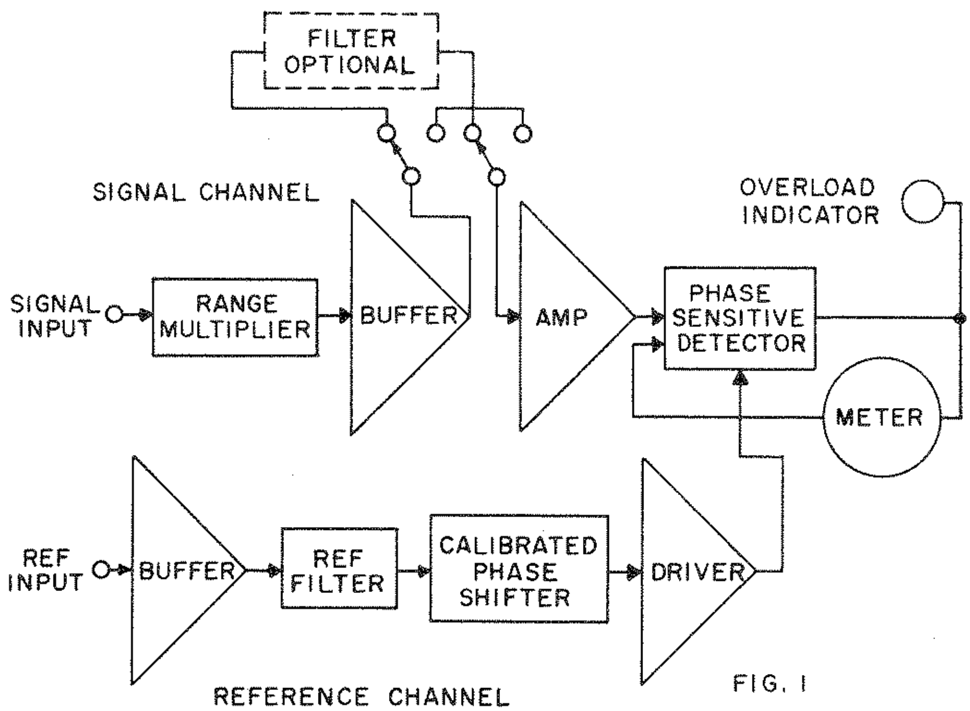

FIG. I

An input signal is first attenuated by the range multiplier. The high gain amplifier drives a phase sensitive detector which in turn drives the indicating meter. The meter output is recombined to form an AC signal which is fed back to the amplifier input thus making the instrument independent of diode characteristics and tube ageing. A reference signal is also amplified and its phase angle shifted by the calibrated phase shifter. This signal driving the phase sensitive detector results in the phase angle characteristics shown in Figures (5) and (6).

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The sections to follow describe the many ways in which this instrument is being used. Block diagrams illustrate typical measuring set ups.

II - GENERAL NOTES ON GROUNDING TECHNIQUES

Successful measurement with any high input impedance voltmeter is dependent upon the elimination of all unwanted or extraneous signals from the measurement circuit.

The most common sources for extraneous signals are the following:

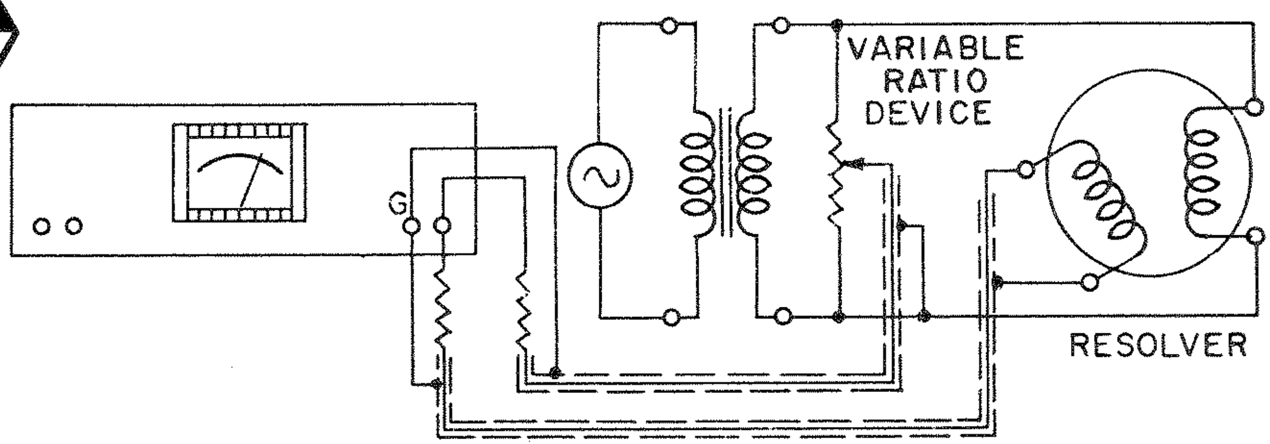
a) Internal noise
b) Electrostatic pickup
c) Inductive pickup
d) Common ground runs

Internal noise has been minimized by design and is equivalent to less than 5 microvolts for a high impedance circuit (1.0 megohm).

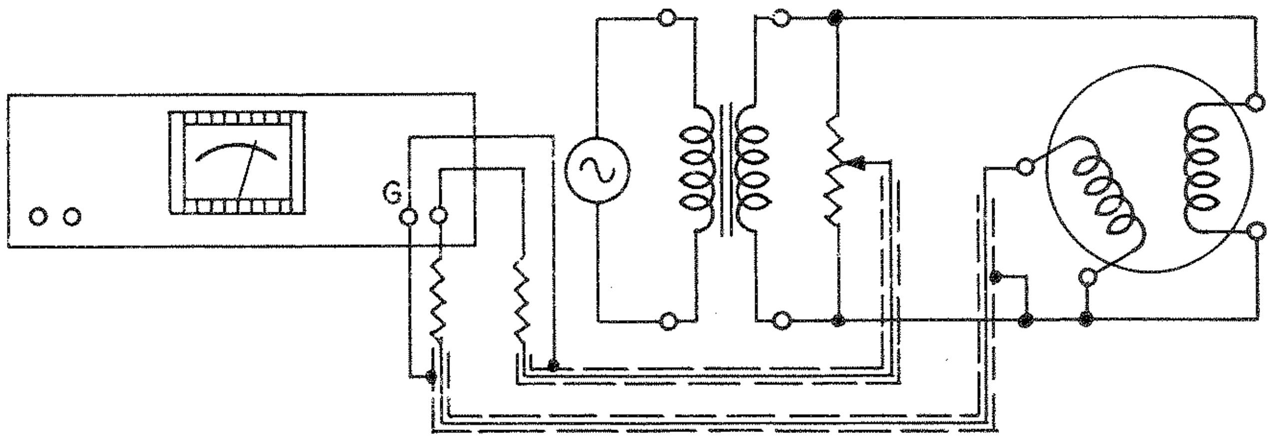
Electrostatic pickup, frequency a problem in high impedance circuits, is easily eliminated by shielded cable or twisting leads one of which is at ground potential. Care must be taken, however, to avoid loading the signal source by the cable capacitance.

Inductive pickup is generally less often encountered than electrostatic pickup and possibly for that reason, methods for minimizing it are not frequently employed. Both twisted and shielded leads are effective in reducing this form of pickup because they minimize the effective area through which extraneous electromagnetic flux can pass. This is true in the case of a shielded lead, only if the shield, for example, is the return circuit for the signal.

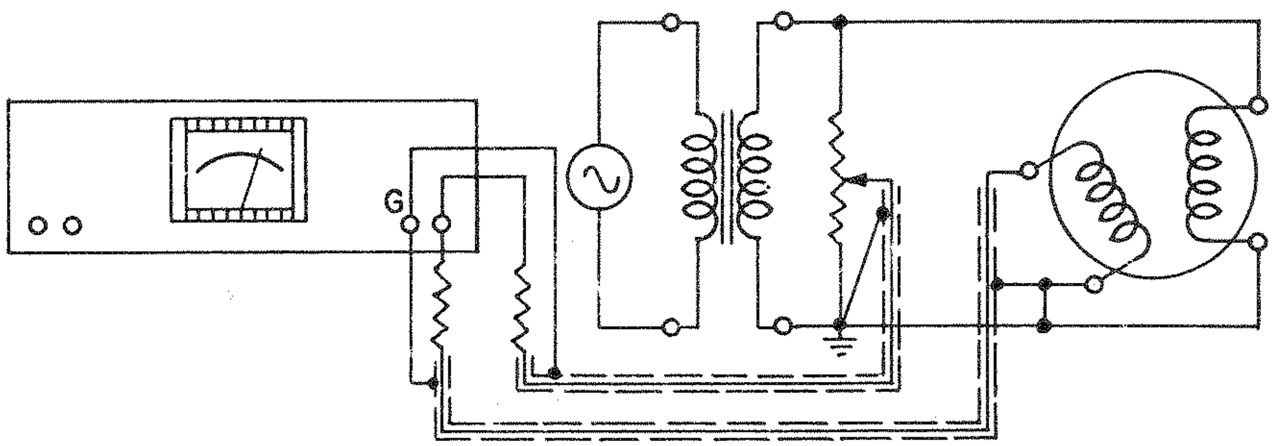
Inductive pickup in ground leads can and does occur with multiple point grounding systems. The effect of these ground loops frequently can be reduced by bundling cables together, again so as to minimize loop areas. A better method is to eliminate the ground loops altogether especially those in the signal system or that portion of a circuit where a measurement is being made. Figure (2) shows several workable methods for using the voltmeter as a phase sensitive null detector when making transformation measurements. All methods can be made to work by minimizing stray fields and bundling cables together. However, Figure (2A) is the most advantageous arrangement and is not at all critical to lead runs. Figures (2B) and (2C) both have loops which can be potential trouble spots. Note also that grounds other than those shown in Figure (2) can exist due to chassis contact, line cord ground, and reference grounds. All must be considered when setting up the measuring system.



(a)—GOOD, NO LOOPS



(b)—ONE LOOP, PICK-UP POSSIBLE



(c)—POOR—ONE SIGNAL LOOP AND ONE GROUND LOOP

FIG. 2—RATIOMETER WITH SERIES SUMMING

Common ground runs are sources of extraneous signals by virtue of voltage drops in the voltmeter input which arise from ground current other than the signal ground current. Figure (3) is a sketch of a typical arrangement wherein the power ground lead is in part that of the shield on the signal input. A portion of the load current as well as power supply leakage current to ground go through the voltmeter input cable. The voltage drop in the length of common ground is measured in addition to the signal.

Figure (3) also illustrates the internal grounding arrangement. The fact that there are four places in which a ground can be made could mean that isolation transformers are required somewhere in the measuring circuit.

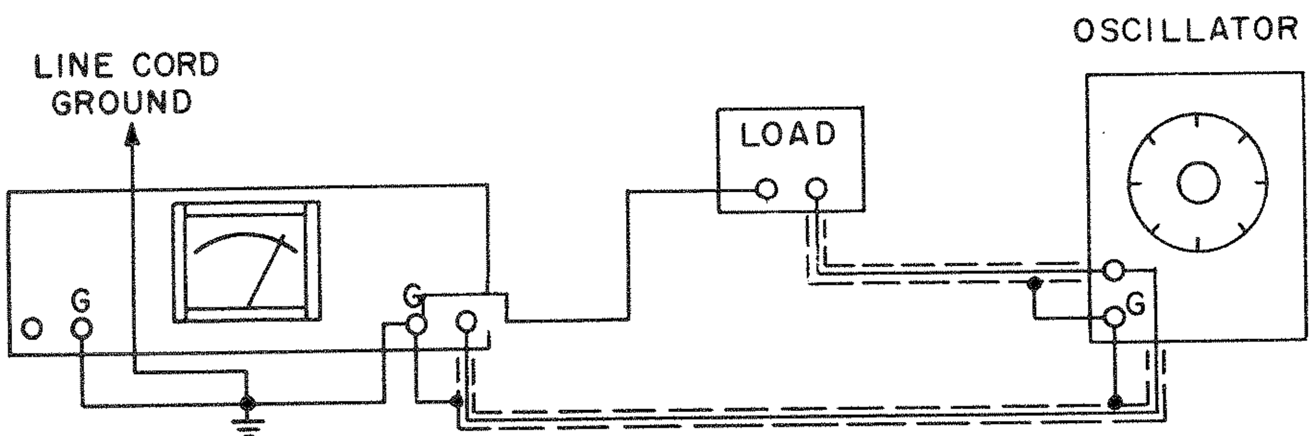


FIG. 3

III - PHASE CHARACTERISTIC

The response of the Phase Angle Voltmeter to the fundamental frequency is given by:

(1) $E\ meter = E\ rms \times \cos\theta$

where E meter = voltage read on the meter
E rms = rms value of the input sine wave
θ = angle between the reference and signal input (Phase shifter at zero degrees)

Response to even order harmonics is theoretically zero, while odd harmonic response varies inversely with the order of the harmonic.

For example, for the 3rd harmonic equation (1) becomes:

(2) $$E\ meter = \frac{E\ rms\ (3rd\ harmonic) \times \cos\theta'}{3}$$

where θ' is the phase angle of the 3rd harmonic with respect to the reference.

Actually response to harmonics departs from equation (2) for a number of reasons. Since calibration of the instrument is at the fundamental frequency, measurements at frequencies other than the fundamental frequency will be somewhat in error.

For instruments having selective filters in the signal and reference channels, harmonic response will in all cases be more than 55DB down. Table I shows typical measured responses. The values shown with filters actually are the sum of the colum I data and the filter characteristic.

TABLE I

FUND (400cps)	No Signal Filter 0DB	With Signal Filter 0DB
2nd Har.	-55DB	-55DB
3rd Har.	-9.5DB	-55DB
4th Har.	-55DB	-55DB
5th Har.	-14DB	-55DB

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Measurements of phase angle using equation (1) are easily accomplished with good accuracy using the setup dhown in Figure (4). The actual phase characteristic used in the measurement is E sin θ for purpose of convenience. The procedure is to adjust accurately the θ = 90 deg. and the θ = 0 deg. point. Measurement than will be a voltage which can be directly translated into degrees using the curves of Figures (5) and (6).

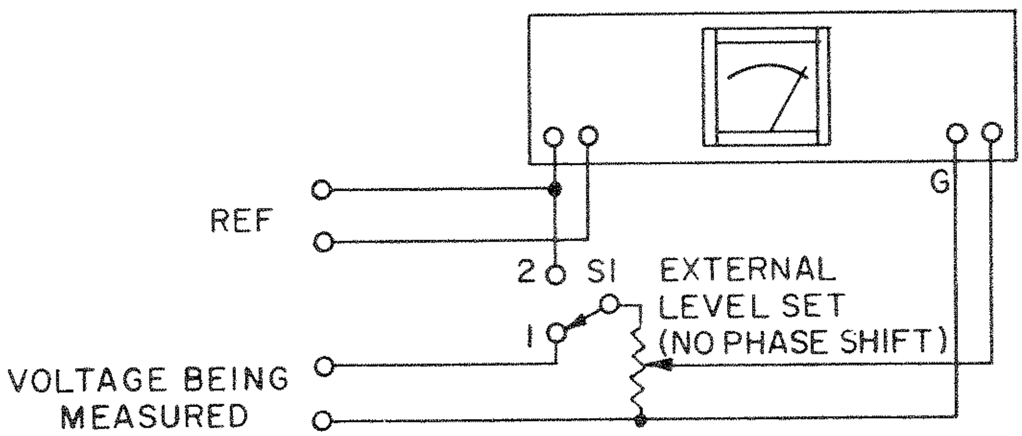


FIG. 4

The step-by-step procedure is:

1. Set reference level to red line value.

2. With meter in "STD VTVM" position and external switch S1 in position 1, select a convenient range and adjust the signal level for full scale deflection. This will insure on-scale readings. (NOTE: Any external level set should be sufficiently low in resistance so as not to introduce phase shift error.)

3. Next switch the reference into the signal channel by switching S1 to position 2 and adjust using the same external level control for full scale deflection.

Switch the instrument to the "PHASE ANGLE VTVM" function and adjust the phase shift dial for zero meter reading. This establishes the $\theta = 0$ deg. point or quadrature null point.

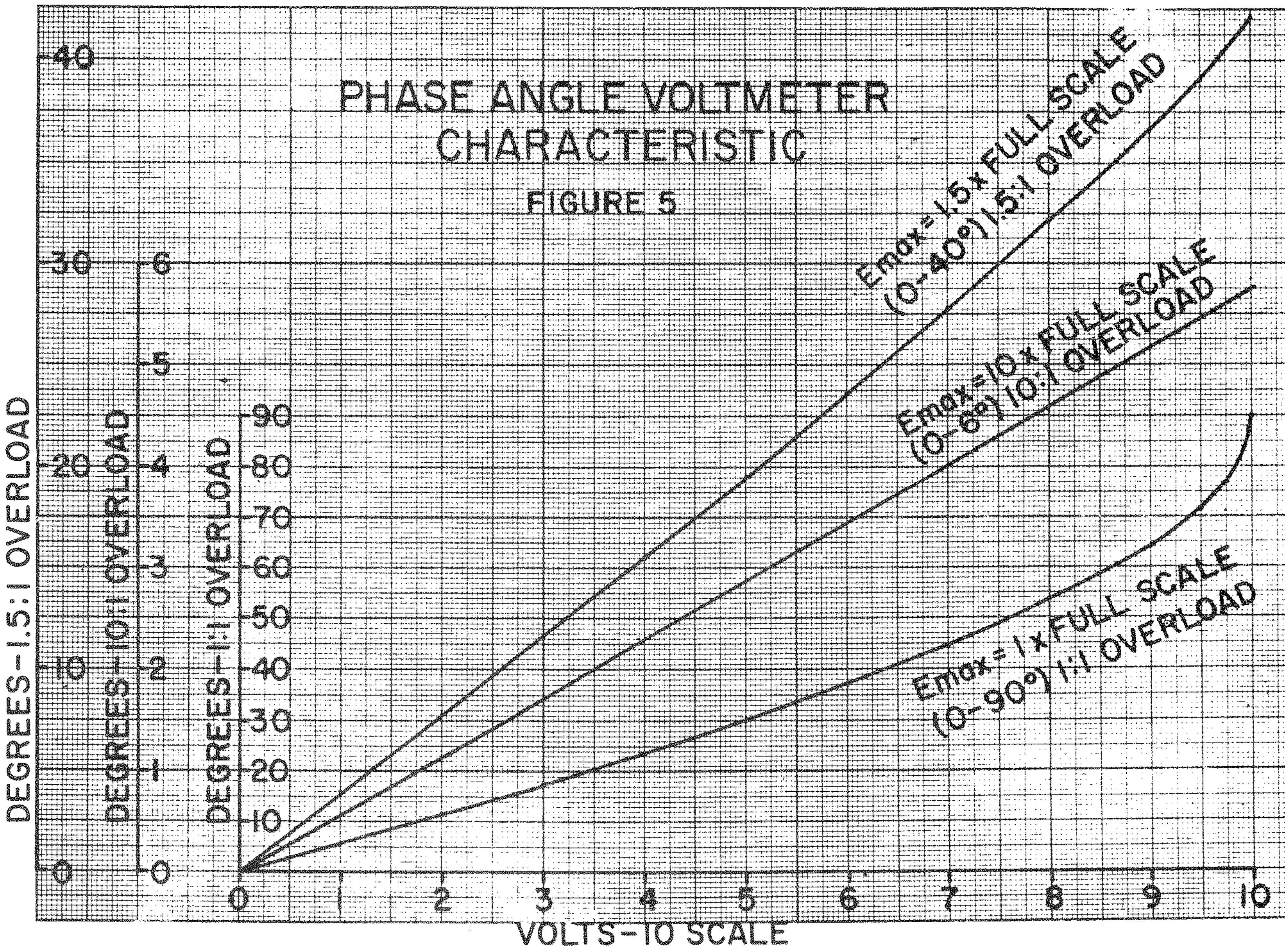
NOTE: FOR MAXIMUM ACCURACY, THIS POINT SHOULD BE RESET WHENEVER THE SCALE IS CHANGED.

4. Return the switch S1 to the signal input and readjust the full scale level with the instrument set as "STD VTVM". This establishes the $\theta = 90$ deg. point (E maximum).

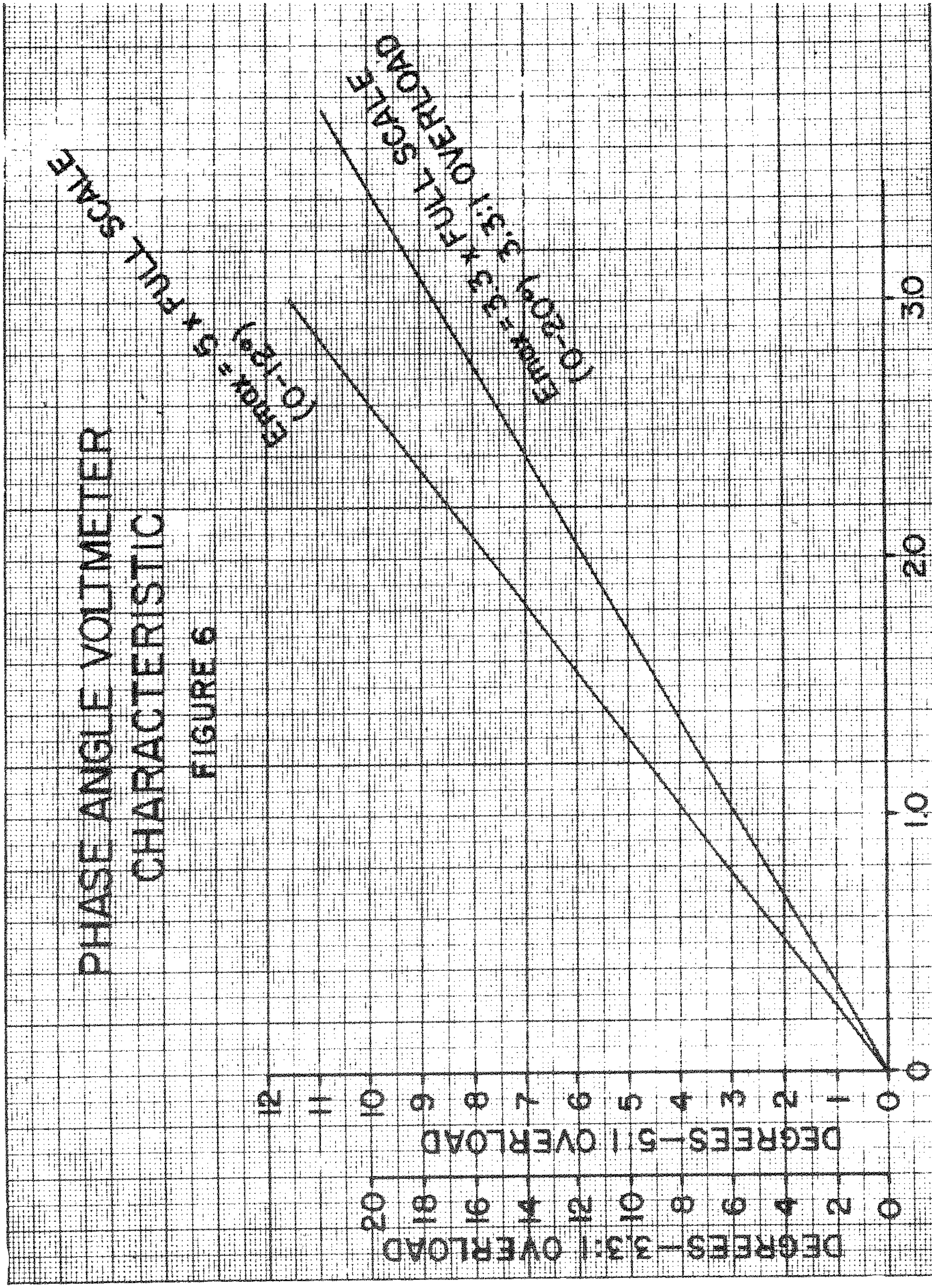
5. Switch back to the "PHASE ANGLE VTVM" position used in (3) above and read the meter. Enter the curves of Figure (5) or (6) to read degrees.

Any full scale range in degrees can be used even down to -6 deg. - 0 - +6 deg, depending upon the full scale limits. For example, if the full scale 90 degree point is set on the 1.0 volt scale and the zero point on the 3.0 volt scale, then the 3.0 volt scale will cover a range of from -17.4deg. - 0 - +17.4 deg. Table II summarizes typical setups and Figures (5) and (6) show curves which can easily be used to convert voltage measurements to degrees. These curves are actually arcsin functions. The angle can also be derived by direct computation from the voltage readings.

Errors in using this type of measurement will be a function of the scale used and the angle. In addition, for large ratios of maximum voltage to full scale values being used, saturation for a portion of each cycle can occur and will result in a small scale error. Obviously, this condition is a function of reference level and for that reason, a level of twice the red line value is recommended when using this technique.



PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 5
Emax = 1.5 x FULL SCALE
(0-40°) 1.5:1 OVERLOAD
Emax = 10 x FULL SCALE
(0-6°) 10:1 OVERLOAD
Emax = 1 x FULL SCALE
(0-90°) 1:1 OVERLOAD
DEGREES-1.5:1 OVERLOAD
DEGREES-10:1 OVERLOAD
DEGREES-1:1 OVERLOAD
VOLTS-10 SCALE



PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 6
Emax = 5 x FULL SCALE
(0-12°)
Emax = 3.3 x FULL SCALE
(0-20°) 3.3:1 OVERLOAD
0 1.0 2.0 3.0
VOLTS-3.0 SCALE
0 1 2 3 4 5 6 7 8 9 10 11 12
DEGREES-5:1 OVERLOAD
0 2 4 6 8 10 12 14 16 18 20
DEGREES-3.3:1 OVERLOAD

TABLE II

Maximum Voltage	Scale for Measuring Degrees	Full Scale Overload Ratio	Degree Range	Max. Error 3%	Figure
1.0	1.0	1:1	90	2.7 deg.	5
1.0	.3	3.3:1	19.5	0.6	6
1.0	.1	10:1*	5.7	.2*	5
1.5	1.0	1.5:1	41.8	1.3	5
1.5	.3	5:1	11.5	.33	6

*NOTE: The overload alarm will be lighted when operated under these conditions. Saturation errors exist and for that reason no error rating is made.

High accuracy Phase Angle Measurements to better than $.01^{\circ}$ can be made using the alternate methods discussed in Section VIII under Small Angle Measurements.

IV - PHASE ANGLE MEASUREMENTS USING CALIBRATED PHASE SHIFTER

The built-in, calibrated phase shifter can be used to measure phase angle directly simply by shifting the reference by an amount equal to the phase angle being measured so as to produce a maximum meter reading in accordance with equation (1). Precise determination of the maximum point is difficult due to the zero slope of the phase characteristic at $\theta = 0$ deg. To avoid this difficulty, the instrument is equipped with four scales 90 degrees apart. Thus, by simply switching the reference 90 degrees, the phase shifter dial can be readily set to a zero point on the meter and then by switching back to the original quadrant the unknown phase angle can be read.

This procedure allows the measurement of phase angles from 0 to 360 degrees. Ambiguity which exists for two quadrants is easily removed by adding 180 degrees to the dial reading if a negative maximum (meter deflection to the LEFT) is used for the measurement. For positive maximums (meter deflections to the RIGHT) the dial scales apply directly.

V - MEASUREMENT OF QUADRATURE AND IN-PHASE COMPONENTS OF A SIGNAL

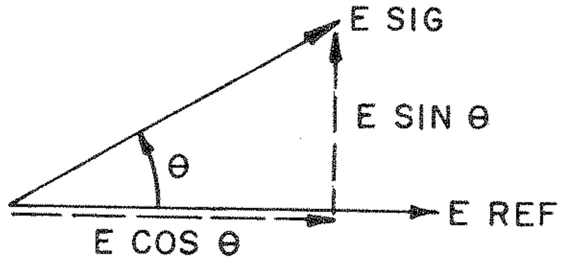


FIG. 7

The quadrature and in-phase components of a signal are defined in accordance with the diagram of Figure (7) as:

In-phase component = $E \cos \theta$

Quadrature component = $E \sin \theta$

Measurement of the in-phase component is made by placing the Phase Angle Dial at zero degrees and reading the meter directly. This voltage will be $E \cos \theta$. (Function Selector must be in one of the PHASE ANGLE VTVM positions). By switching the Function Selector to an adjacent quadrant, the reference is shifted 90 degrees and the meter now reads the quadrature component of voltage $E \sin \theta$. For the greatest accuracy in this type of measurement, the null or 90 degree point should be calibrated on the scale in which the voltage component is to be read. See the section under PHASE CHARACTERISTIC for a description of this type of adjustment.

VI - MEASUREMENT OF POWER FACTOR AND IMPEDANCE ANGLE

Both power factor and impedance angle are defined as the angle which a current vector makes with the voltage reference. This measurement is conveniently accomplished by means of the set up shown in Figure (8). The angle is measured as previously discussed.

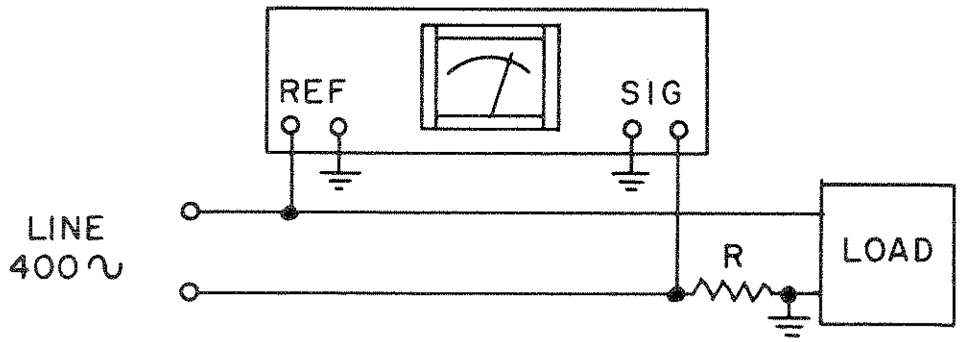


FIG. 8

VII - IMPEDANCE MAGNITUDE

The magnitude of any impedance is measured by using the "STD VTVM" portion of the instrument. Figure (9) illustrates the manner in which the measurements can be made.

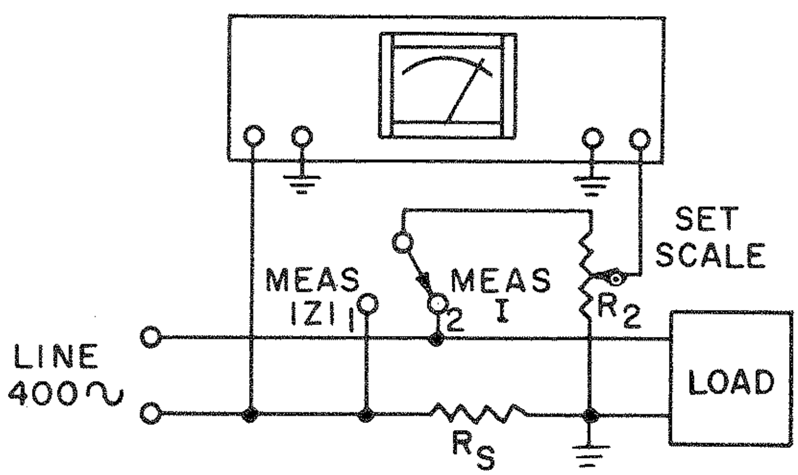


FIG. 9

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Using Table III as a guide, a precision (± 1%) resistor of convenient size is selected for Rs. With S1 in position 1 for measuring current, adjust the scale set potentiometer to read full scale voltage on any 10 scale. Note the actual voltage value. Switch S1 to position 2 for measuring /Z/ and read the meter. This reading will be the impedance magnitude expressed in units of kilohms, ohms, hundreds of ohms, milliohms, etc. depending upon the value of Rs series resistance used per Table III and when divided by the current measurement noted above.

EXAMPLE:

Load impedance = 470K
Rs = 1K
E line = 115 volts

With S1 in position 1 set the level using R2 to a convenient full scale of 10. This might be 0.1 volts. Switching then to position S2 will produce a meter deflection of 47K on the 100K scale (100 volts scale is now 100K per Table III). Dividing this by the current scale of 0.1 will yield 470K. Since the current factor is always set at a multiple of 10, this last correction is simple to accomplish.

TABLE III

Series Resistor	Scale 1V equals	Current Factor
10K	10K	1/volts
1K	1K	1/volts
100Ω	100Ω	1/volts
10Ω	10Ω	1/volts
1Ω	1Ω	1/volts

Measurement of AC Resistance and Reactance

By using the circuit of Figure (9) the real and imaginary components of the impedance can also be measured directly by using the current as a reference and measuring the in-phase and quadrature of the signal measured with the switch in position 2. The in-phase component will be the AC Resistance and the quadrature component will be the reactance with the sign determined as positive for a right hand meter deflection and negative for a left hand deflection.

The following series of block diagrams will illustrate how this instrument can be applied to some of the specific applications noted earlier.

VIII - APPLICATIONS

Precision Ratiometer

In many analog computer systems the process of multiplication, division, addition, and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element. Ordinary nulling system, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure (10) permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

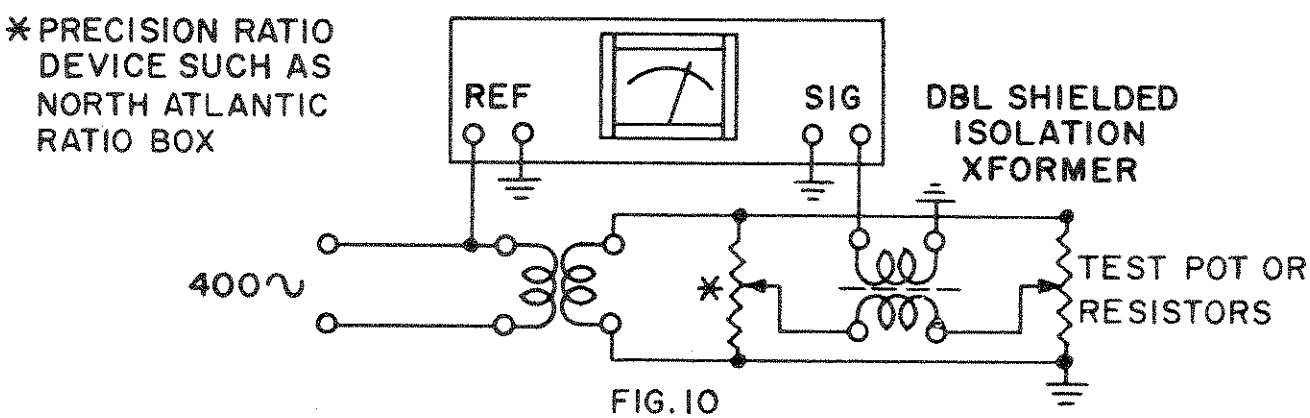

FIG. 10

Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance transformer such as North Atlantic's T-110 should be used. An alternate arrangement would be the circuit of Figure 11, which uses a summing network.

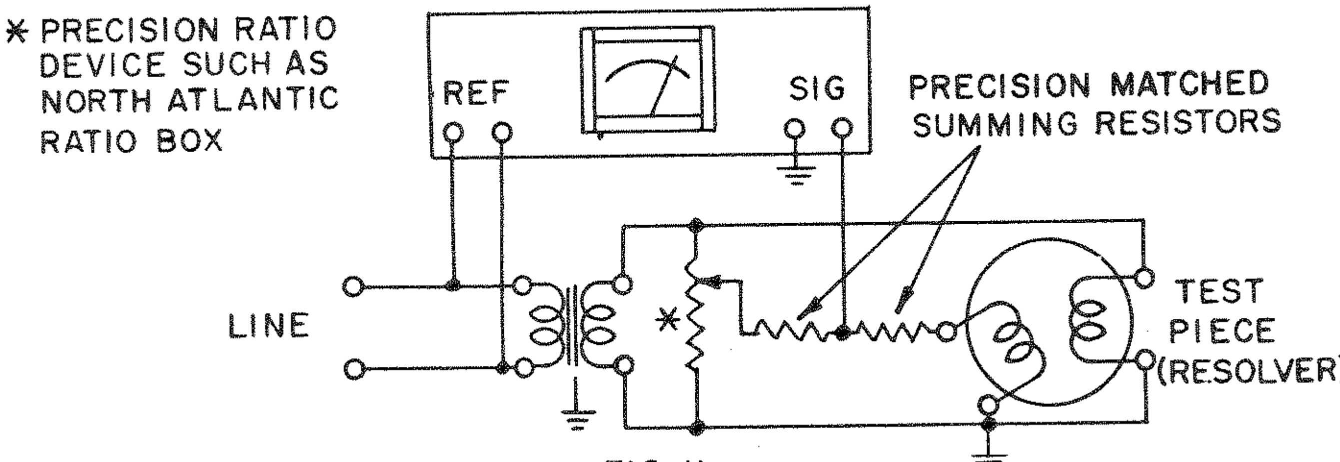

FIG. 11

Transducer Nulling

Applications involving transducers, such as differential transformers or E-Coil pickoffs, are extremely difficult to zero due to the large residual null voltage composed of signal and harmonics from the source as well as harmonics generated in the transducer. Figure (12) shows a system in which a precise in-phase balance can be achieved in the presence of quadrature and harmonics equal to 10 times the full scale sensitivity used. An order greater accuracy in nulling is easily achieved over conventional nulling circuits.

In addition, phase compensation for servo systems or for purposes of linearity compensation are easily accomplished using variations of this same test set-up.

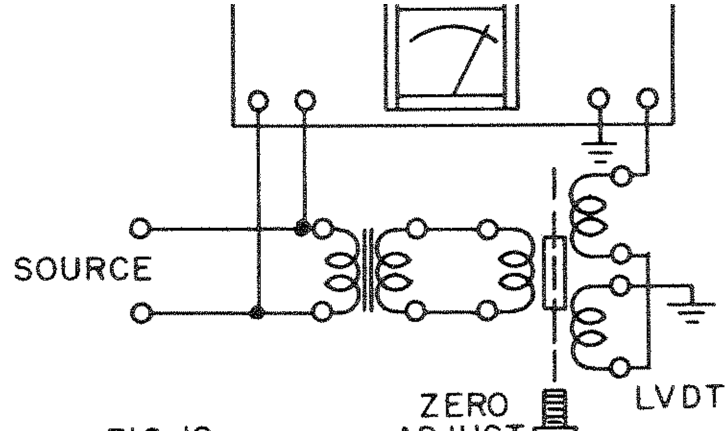

FIG. 12

Synchro Bridge Null Detector

When measuring the electrical errors of synchros, a circuit such as that shown in Figure (13) is used. The phase sensitive characteristics of the Phase Angle Voltmeter as well as the harmonic rejection of the filters and detector makes possible nulls obtainable by conventional instrumentation.

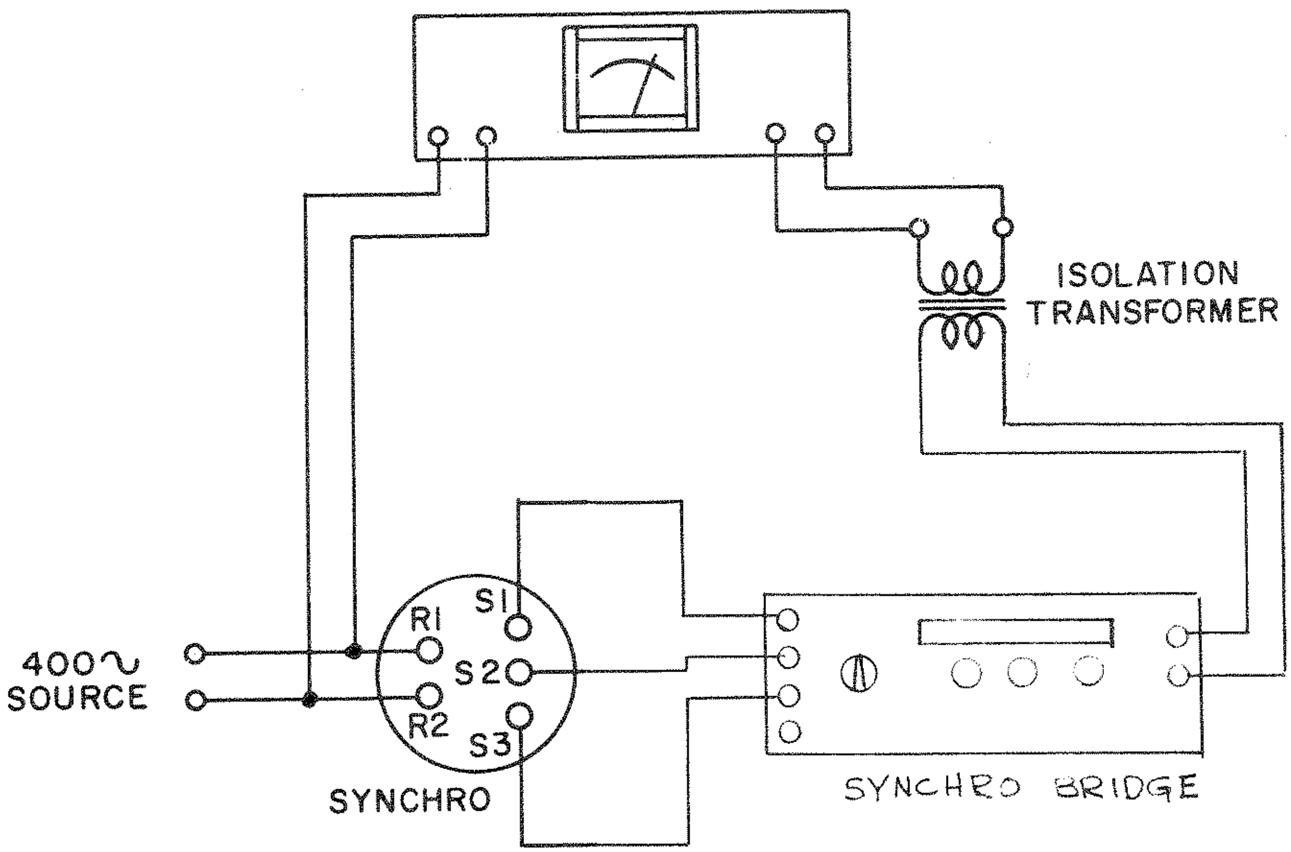

FIG. 13

Magnetic Amplifier and Thyratron Circuit Alignment

Circuits using thyratron power stages or magnetic amplifier stages cannot be monitored using conventional instruments because measurement errors can be prohibitively large due to the chopped waveforms. If the Phase Angle Voltmeter is used to monitor the output of such devices as shown in Figure (14) the task of alignment for maximum torque or output is straightforward since the meter reading is equivalent to motor output.

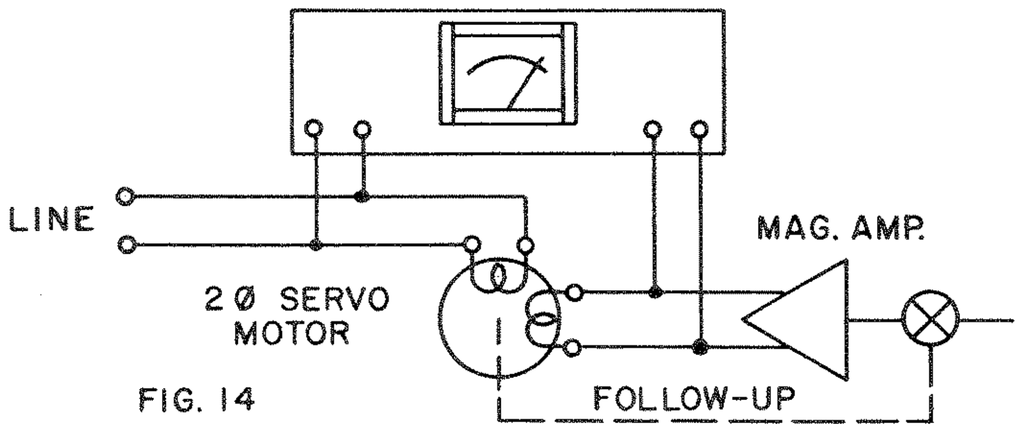

FIG. 14

Carrier Circuits and Amplifiers

Circuits such as those used for phase compensation, summing circuits, amplifiers, etc., must frequently be aligned to reduce quadrature effect to an acceptable minimum and to establish transfer functions at precise values of Phase Angles. Figure (15) is a test setup used to check the phase angle transfer characteristic of a 400 cps carrier amplifier. Switch, S1, is used to adjust exactly the 90 degree point. A precision of trim to a fraction of a degree can be obtained.

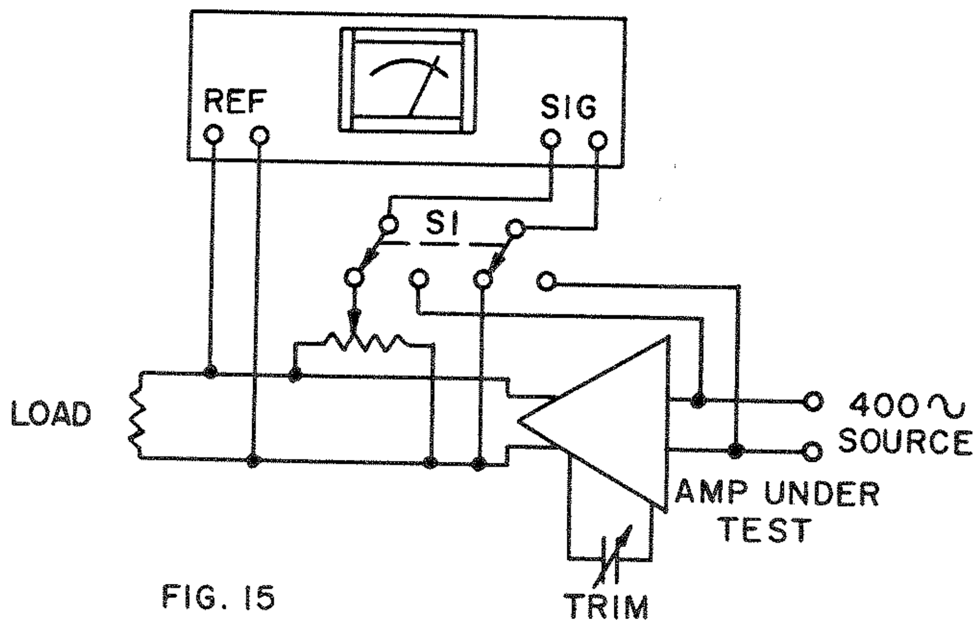

FIG. 15

Transformation Ratio

Numerous circuit arrangements are used in making transformation ratio measurements. Two of the most practical are shown in Figure (16a) and (16b).

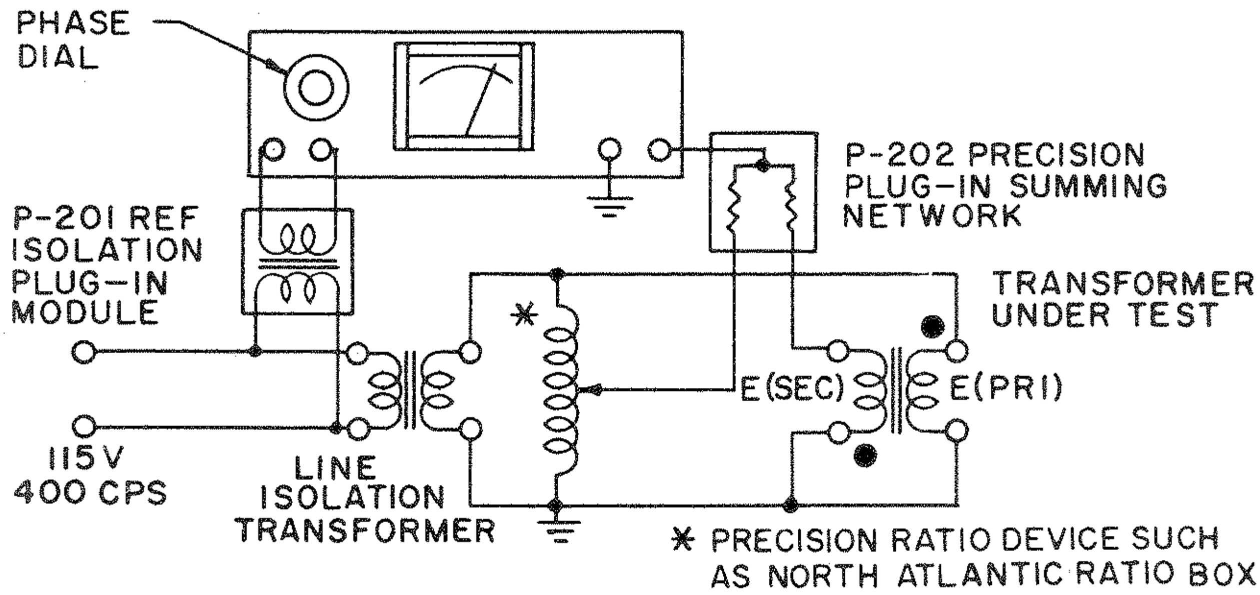

FIGURE 16(a)

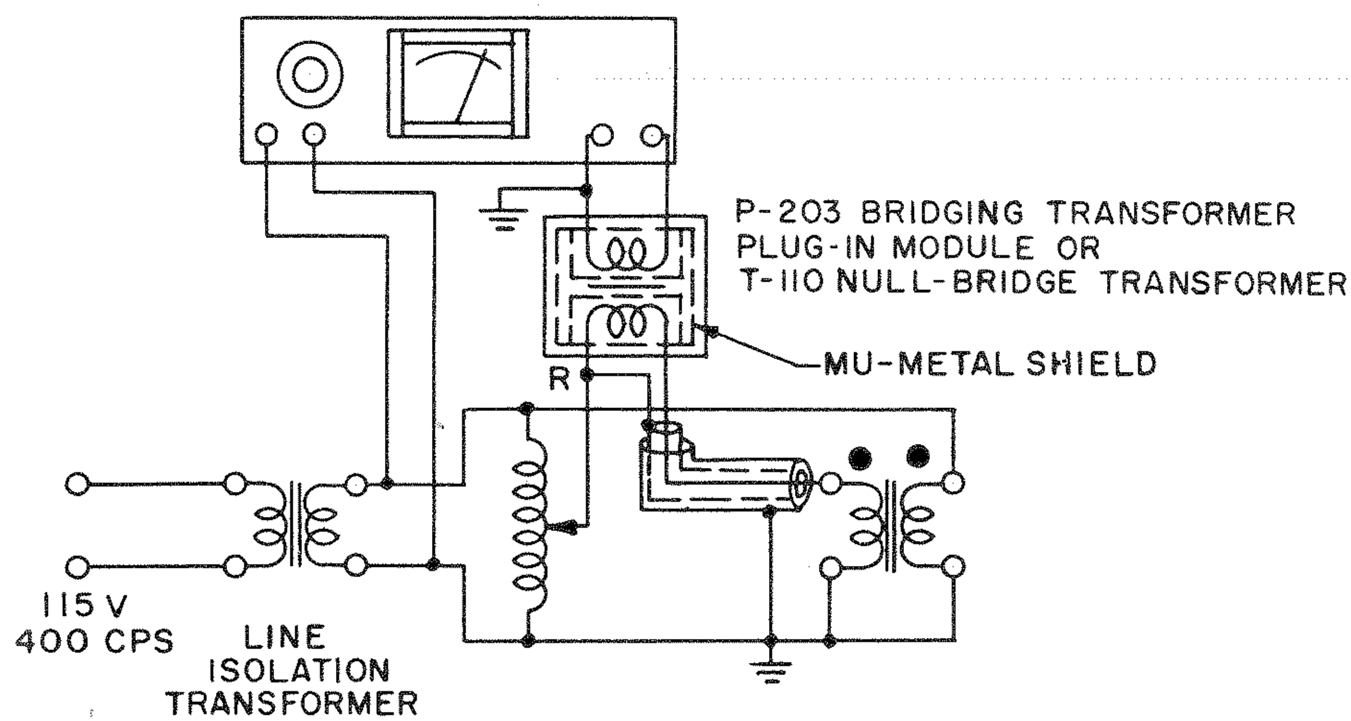

FIGURE 16(b)

I. SUMMING NETWORK TECHNIQUES

In Figure (16a) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors - available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test setup a line isolation transformer is utilized so as to avoid grounding one side of theline. For illustrative purposes the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure (16a) care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure (16b) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common-mode rejection and low input capacitance would suffice.

Measurement errors in Figure (16b) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the Figure.

Common-mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer and the relative values of these impedances. Each setup must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both setups require that the Phase Dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc., This is conveniently done by stepping the ratio device and adjusting the Phase Dial to produce zero output when the Function Selector is in the 90° position. Operation will then be correct when the Function Selector is returned to the 0° position.

Small Angle Measurements

Small angle measurements to better than $.01^{\circ}$ can also be made using the setups of Figure (16). The process consists of making the in-phase null, described in the foreoing, using the precision ratio device. Then, by definition the phase shift angle α is:

$$\alpha = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E sec}|} = \text{Tan}^{-1} \left(\frac{\text{E Input (quadrature)}}{|\text{E pri}| \times \text{Ratio}} \right)$$

By measuring the magnitude of the secondary voltage and the quadrature component of the input signal, the angle α can be determined.

For Example:

$$\text{Measured quadrature} = 30.0 \text{ millivolts}$$

$$\text{Secondary voltage} = 30 \text{ volts}$$

$$\alpha = \text{Tan}^{-1} \frac{0.03}{30}$$

$$\cong \frac{0.03}{30} = 0.001 \text{ Rad}$$

$$\cong 0.001 \times 57.3 = .057 \text{ degrees}$$

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