ABOUT DYNATRAC 393 LOCK-IN AMPLIFIER

DYNATRAC 393 measures signals obscured by noise, at signal levels from picovolts to volts, frequencies from .1 Hz to 200 kHz and selectable bandwidths from ±.001 Hz to 100 Hz. Unlike conventional lock–in amplifiers there are three simultaneous outputs: A (amplitude), Acosϕ, and Asinϕ, where ϕ is the phase angle between the signal and a coherent reference to which the instrument is synchronized. When you use the A output, no phase adjustments are required. Unlike new competitive instruments that use crystal filter heterodyning or pulse width modulation (PWM), our DYNATRAC and vector features are always there, do not require mode selection and matching of channels, and operate over the full .1 Hz to 200 kHz frequency range.

Lock–in amplifiers have long been used by scientists and research engineers to detect signals buried in noise or other electrical interference. DYNATRAC 393 is an extension of this technology that eliminates both the phase* and harmonic sensitivities of conventional lock–in amplifiers. This adds convenience, performance, and accuracy to traditional measurements and extends the applications of the instrument. With options, the 393 also measures phase angle, narrowband noise, or the ratio of its output to a second dc voltage (for use in double beam optical systems). Remote preamplifiers are available to adapt to any signal source and provide up to 100 times more sensitivity.

This lock–in amplifier responds only to those signals that are coherent with a reference frequency that can be established by a) an external reference signal, or b) an internal manually set oscillator. It will track the frequency of an external reference with neither amplitude nor phase errors. The effective signal bandwidth can be made almost arbitrarily narrow.

* Vector Sum Output

HETERODYNING* – Why it works better

Users know that lock–ins are suppose to detect signals in a lot of noise. Most do a creditable job in ordinary applications. A few do an outstanding job, but at the expense of complexity, cost, and lots of knobs – usually for setting filters to eliminate what the detector can't handle, such as harmonic signals and overloading interference.

DYNATRAC instruments use an old idea in a new way – heterodyning – to eliminate these problems, without expensive options, without extra knobs, and with outstanding performance in the really crucial applications.

Most lock–ins today have tracking phase shifters and reference circuits. DYNATRAC (which is derived from heterodyne and tracking) also has a pre-detection tracking filter that "strips off" harmonics and interference early in the instrument over the full operating frequency range. Amplitude and phase response are unaffected by frequency change and no manual filter setting is required (or provided).

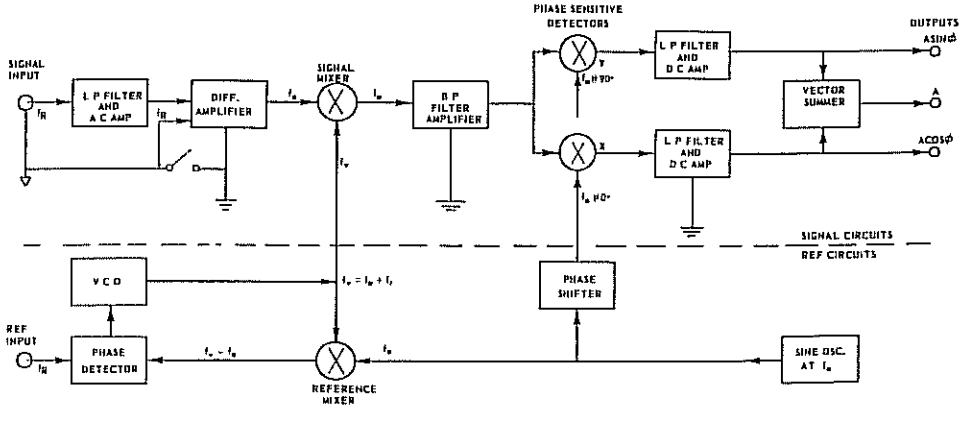
*Heterodyning is a technique used commonly in ordinary radios whereby the input signal is translated or "mixed" to a fixed intermediate frequency before the signal is detected.

How DYNATRAC 393 works

The input signal is amplified and passed through a 24 dB/octave low pass filter set just above the highest frequency for that range. The amplified signal is mixed with a signal f_o, thus translating any coherent input (i.e. at the reference frequency f_r) to the constant IF frequency f_o. This signal goes through a differential amplifier to the band pass amplifier centered at f_o, which removes harmonically related side band signals and further restricts the bandwidth, thus reducing overload interference outside this bandwidth.

There are two phase sensitive detectors (PSD) and output amplifiers operating in quadrature with each other. A vector sum circuit takes these two outputs and creates an output that is independent of phase. Conventional lock–ins have a single PSD, which means phase controls must be used to maximize the signal – a time consuming and error producing operation. With DYNATRAC you use the phase controls only if you want to.

In the EXT mode, the phase lock loop, consisting of the phase detector, voltage controlled oscillator (VCO) and reference mixer, phase-locks the reference mixer output to the external reference signal. A fixed frequency sine oscillator generates f_o, which is an input to both the reference mixer and, via the phase shifter, the phase sensitive detector. The fact that the phase shifter always operates at the same frequency results in outstanding phase-tracking accuracy.



DESCRIPTION

TIME CONSTANT/BANDWIDTH CONTROL

This control determines the effective bandwidth of the instrument. For most measurements, the high out band attenuation rate of –12 dB/octave is desirable. However, when the lock–in amplifier is used in a feedback loop, a –6 dB/octave rolloff is necessary to maintain stability. A rear panel switch allows selection of either the –6 dB/octave or –12 dB/octave rolloff characteristics. For convenience, the noise bandwidth expressed in Hertz is also displayed on the Time Constant Switch. Calibration is for the –12 dB/octave rolloff characteristics.

INPUT AND SENSITIVITY CONTROL

Unique, floating, guarded input stage provides differential performance with a single-ended connection to signal source. Eliminates ground loops and provides exceptional noise performance. If your signal source is floating, connect source ground to chassis ground with front panel switch. If your source is grounded, use "isolate" position. If true differential input is required (as in bridge balancing), use Model 168 Preamplifier. Sensitivity range 100nV to 3V without optional preamplifier.

REFERENCE MODE CONTROL

INTERNAL – an internal oscillator provides both an internal reference signal and a sine output at the oscillator output BNC connector. The frequency of the oscillator is determined by the Range switch and the calibrated multi–turn vernier Frequency control. Oscillator output amplitude is determined by the Osc Level control.

The Internal mode can also be used without a reference by tuning manually until the signal is found. The signal must remain within the bandwidth of the output filter setting (Time Constant control).

EXTERNAL – The instrument automatically synchronizes to and tracks an external reference signal.

EXTERNAL 2f – The same as External, except the instrument responds to input signals of twice the reference frequency.

SIGNAL TRACKING – The instrument automatically phase locks to the input signal, and does not require a reference. This mode should be used only when a suitable reference signal is not available.

OVERLOAD LIGHT

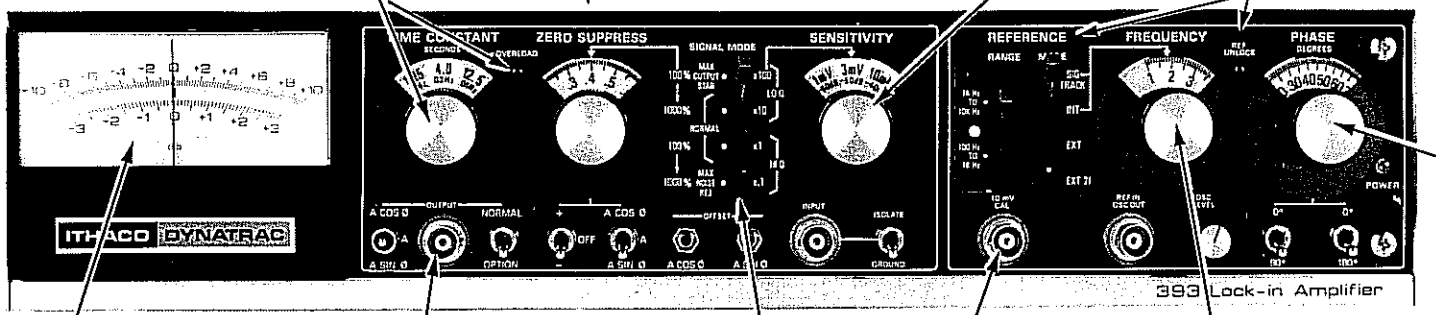
Indicates overload conditions at any point in the instrument.

ZERO SUPPRESS

Multiple turn vernier control gives output zero suppress of up to 100% or 1000% of full scale depending on the signal mode. Switches determine which output signal is suppressed (Acos ϕ, Asin ϕ or A) and the polarity.

REF UNLOCK LIGHT

Indicates that the internal oscillator has not locked to the external reference input.



PHASE CONTROLS

Multi–turn vernier phase control gives 0–100° adjustable phase shift. Phase steps of 0°, 90°, 180°, and 270° are provided by toggle switches.

METER

1% accuracy and linearity. Voltage, dB, and ratio scales. As Phasemeter, (Option 03), full scale corresponds to 100°.

OUTPUT

The front panel output connector and meter are selected by a pair of switches. In the "Normal" position select Acosϕ, Asinϕ, or A (amplitude). The "Option" position selects optional functions such as phase, noise, or ratio.

Rear panel connectors provide simultaneous Acosϕ, Asinϕ, A, and option outputs.

CAL

BNC output provides a precision 10mV square wave signal for instrument calibration.

SIGNAL MODE CONTROL

This control facilitates trading off output dynamic range for input overload capability at a given sensitivity. For the great majority of applications, the Normal – HI Q mode should be used. Use other modes only if a specific need arises.

	SIGNAL MODE	SENSITIVITY 1–3–10 SEQUENCE	OUTPUT STABILITY [1]	OUTPUT DYNAMIC RANGE [2]	INPUT OVERLOAD RANGE [3]	ZERO SUPPRESS RANGE	COMMENTS
LO Q	MAX OUTPUT STABILITY	100μV–3V	.001%/°C	>100 dB >100,000	10 × FS to 280 × FS	0–→±100%	Expand selected output instantaneously by a factor of 10 even when zero suppress is used
LO Q	NORMAL	10μV–1V	.01%/°C	>80 dB >10,000	100 × FS to 2800 × FS	0–→±1000%	
HI Q	NORMAL	1μV–100mV	.01%/°C	>80 dB >10,000	100 × FS to 2800 × FS	0–→±100%	Expand selected output instantaneously by a factor of 10 even when zero suppress is used
HI Q	MAX NOISE [4] REJECTION	100nV–10mV	.1%/°C	>60 dB >1,000	1000 × FS to 28000 × FS	0–→±1000%	

1 For Blue Card Set, multiply by 5. For Green Card Set, multiply by 15.

2 This is the full scale output voltage divided by the peak output noise at constant temperature, 1 Hz bandwidth and lowest sensitivity.

3 This is the ratio of the rms value of a sine wave that just overloads the instrument to the rms value of a coherent sine wave that produces full scale output. See Figure 1, page 6. For 1 volt full scale output, multiply by 10.

4 Not recommended for Green Card Set.

FREQUENCY

The instrument will operate at frequencies from .1 Hz to 200 kHz. Color coded plug–in cards determine the operating frequency range. A typical card set covers a 400:1 range in two switch selected 40:1 ranges. See table below. Frequency range cards may be changed by the operator with no recalibration of the instrument.

CARD SET COLOR CODE	OPERATING FREQ RANGES EXT MODE [1] (Hz)	OPERATING FREQ RANGES INT MODE (Hz)	I F FREQ (Hz)	APPROX I F BW (Hz) HI Q	MAX SETTLING TIME	MAX SWEEP RATE Hz/Sec	MIN SWEEP TIME f TO 10 f (Sec)
BROWN	.1 – 2 .5 – 20	.1 – 1.1 1 – 11	55	4	15 min 100 sec	7×10^{-4} .007	13000 1300
RED	.5 – 20 5 – 200	1 – 11 10 – 110	550	40	100 sec 10 sec	.007 .7	1300 130
ORANGE	5 – 200 50 – 2K	10 – 110 100 – 1.1K	5.5K	400	10 sec 1 sec	.7 70	130 13
YELLOW	50 – 2K 500 – 20K	100 – 1.1K 1K – 11K	55K	4000	1 sec .1 sec	70 7K	13 1.3
BLUE	1.5K – 60K	3K – 33K	165K	12K	.03 sec	63K	.4
GREEN	5K – 200K	10K – 110K	465K	34K	.01 sec	700K	.13

1 In EXT 2F mode, the instrument detects a signal at twice the operating frequency up to a maximum of the highest frequency listed for this card set.

REAR PANEL

SPECIFICATIONS

SIGNAL CHANNEL

SENSITIVITY: 100 nanovolts to 3 volts for full scale (10 volts) output in 1–"3"–10 sequence, also calibrated in dB below 1 volt in 10 dB steps.*

INPUT: Single ended, floating, guarded, input stage may be grounded either at the instrument or at the signal source. Maximum dc resistance between input circuit ground and instrument ground should not exceed 1000Ω.

INPUT IMPEDANCE: 100 megohms shunted by 40 picofarads.

COMMON MODE REJECTION: Greater than 120 dB up to 10 kHz at highest sensitivity. Maximum peak common mode voltage between input stage ground and instrument ground is ±5 volts.

MAXIMUM INPUT: ±200 volts dc, ±5 volts peak non–coherent AC.

INPUT FILTERING: Tracking bandpass filter tracks over 40:1 range in frequency with no manual controls. Center frequency is determined by external reference signal or by internal oscillator.

NOISE: Less than 5 nanovolts/$\sqrt{Hz}$, and less than .03pa/$\sqrt{Hz}$, at 1 kHz. See Figure 4.

GAIN ACCURACY: ±1%

GAIN STABILITY: ±.05%/°C

HARMONIC REJECTION: >55 dB for both even and odd harmonics under all operating conditions.

OUTPUTS: Signal amplitude (A), A cosϕ, and A sinϕ are simultaneously available on rear panel BNC connectors. Any one of these can be switch selected for front panel BNC connector and meter.

OUTPUT LEVEL: **Front Panel:** BNC ±10V full scale in all modes. **Rear Panel:** BNC ±10 volts full scale for "Normal Hi Q" and "Maximum Output Stability" modes, ±1 volt full scale for "Normal Lo Q" and "Maximum Noise Rejection" modes.

OUTPUT IMPEDANCE: 1kΩ ±1%

METER: 3½" meter, ±1% accuracy and linearity. Volts, dB, and ratio scales.

OVERLOAD: LED's monitor overload at all points.

OUTPUT FILTER TIME CONSTANT/BANDWIDTH: Selectable from 1.25 milliseconds to 125 seconds in 1.25–4–12.5 sequence. This corresponds to bandwidths from ±100 Hz to ±.001 Hz in 10–3–1 sequence. Rear panel switch selects 6 dB/octave or 12 dB/octave rolloff in all positions of the front panel time constant switch.

MAXIMUM NON-COHERENT SIGNAL WITHOUT OVERLOAD: See Figure 1.

REFERENCE CHANNEL

FREQUENCY RANGE: Operating frequency range .1 Hz to 200 kHz with plug–in card sets. (See Table on page 4)

INTERNAL MODE: Internal sine oscillator provides both a reference to the instrument and a manually variable output (0–1V rms, 1kΩ output impedance, 2% harmonic distortion) at the frequency determined by the frequency dial.

EXTERNAL MODE: Automatically locks to external reference signal between 250mV and 20V peak to peak that crosses mean value twice per cycle.

EXTERNAL 2f MODE: Same as external mode except instrument responds to input signals of twice the reference frequency.

SIGNAL TRACKING MODE: Instrument automatically phase locks to the input signal.

PHASE ADJUSTMENT: High resolution multiple turn calibrated 0–100° phase control with ±.2 degree resolution. Dial accuracy is<2°. 0–90° and 0–180° phase switches accurate to ±.2 degrees.

PHASE RESPONSE: See Figures 2 and 3.

GENERAL

AMBIENT TEMPERATURE: Operating 15°C to 45°C.

AC POWER REQUIREMENT: 90–130V or 195–260V selectable on rear panel, 50 watts, 50–400 Hz.

PREAMP POWER OUTPUT: Regulated ±16V dc at 25 ma rear panel XLR connector for remote preamp only.

SIZE AND WEIGHT: 17" x 3½" x 19" bench top or rack mounting. Rackmounting hardware included. 20 lbs.

OPTIONS

NOISE OPTION 01: Permits measuring narrowband noise simultaneously with coherent signal. See page 8.

RATIO OPTION 02: Permits taking the ratio of the instrument output and an external dc voltage. Facilitates double beam optical measurements. See Page 9.

PHASE OPTION 03: Permits measuring phase angle between input signal and coherent external reference over full 360°. See page 9.

REMOTE PANEL OPTION 04: Permits use of 01, 02, and 03 Options simultaneously with a single lock–in.

POWER OPTION 17: Permits operation at 180–260V, 50–400 Hz.

* Note that although the meter is correctly calibrated for a ±3 scale, the actual output voltage runs in a 1, $\sqrt{10}$, 10 sequence, where $\sqrt{10} = 3.16$ = "3".

TYPICAL PERFORMANCE DATA

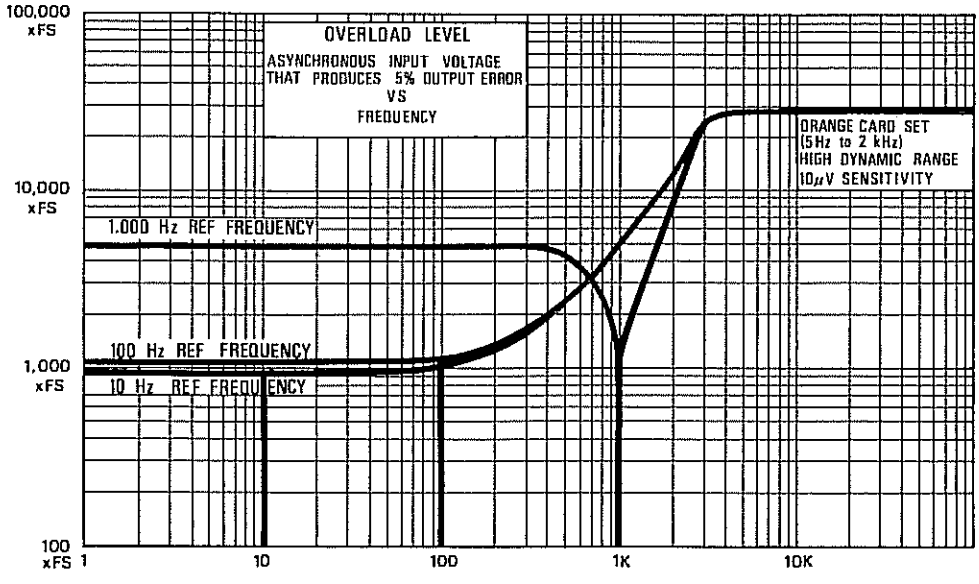


FIGURE 1 MAXIMUM INTERFERING SIGNAL WITHOUT OVERLOAD

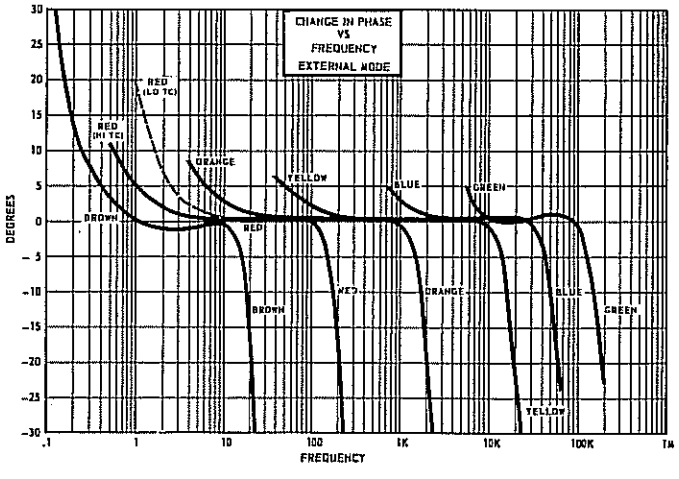


FIGURE 2 PHASE RESPONSE – EXTERNAL MODE

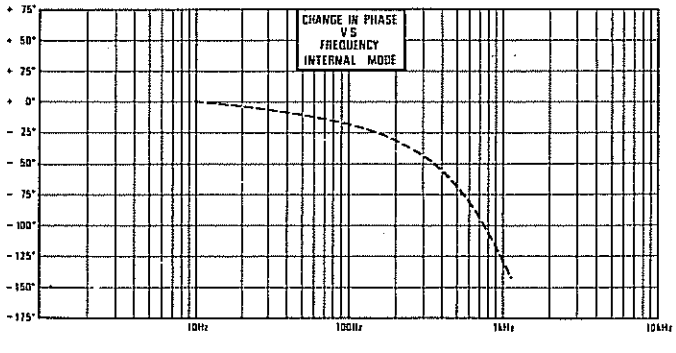


FIGURE 3 PHASE RESPONSE – INTERNAL MODE

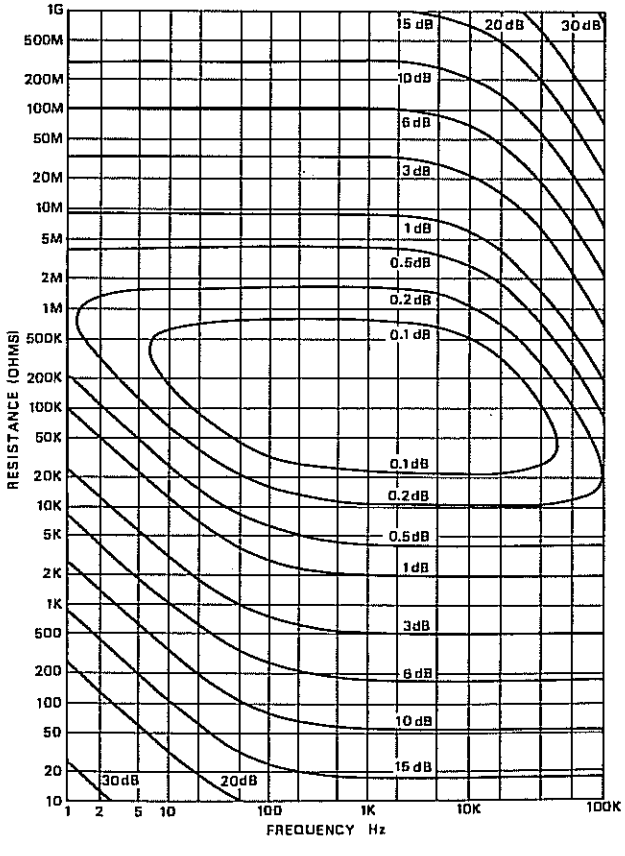


FIGURE 4 NOISE FIGURE CURVES FOR BUILT–IN FLOATING PREAMPLIFIER

SPECIFICATIONS

SIGNAL CHANNEL

SENSITIVITY: 100 nanovolts to 3 volts for full scale (10 volts) output in 1–3–10 sequence, also calibrated in dB below 1 volt in 10 dB steps.*

INPUT: Single ended, floating, guarded, input stage may be grounded either at the instrument or at the signal source. Maximum dc resistance between input circuit ground and instrument ground should not exceed 1000Ω.

INPUT IMPEDANCE: 100 megohms shunted by 40 picofarads.

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PHASE ADJUSTMENT: High resolution multiple turn calibrated 0–100° phase control with ±.2 degree resolution. Dial accuracy is<2°. 0–90° and 0–180° phase switches accurate to ±.2 degrees.

PHASE RESPONSE: See Figures 2 and 3.

GENERAL

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PREAMP POWER OUTPUT: Regulated ±16V dc at 25 ma rear panel XLR connector for remote preamp only.

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OPTIONS

NOISE OPTION 01: Permits measuring narrowband noise simultaneously with coherent signal. See page 8.

RATIO OPTION 02: Permits taking the ratio of the instrument output and an external dc voltage. Facilitates double beam optical measurements. See Page 9.

PHASE OPTION 03: Permits measuring phase angle between input signal and coherent external reference over full 360°. See page 9.

REMOTE PANEL OPTION 04: Permits use of 01, 02, and 03 Options simultaneously with a single lock–in.

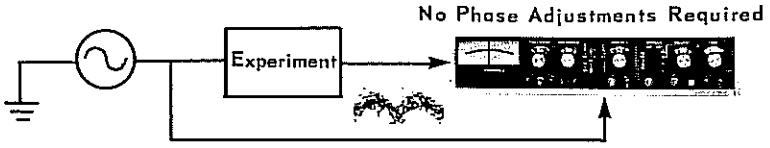
POWER OPTION 17: Permits operation at 180–260V, 50–400 Hz.

* Note that although the meter is correctly calibrated for a ±3 scale, the actual output voltage runs in a 1, $\sqrt{10}$, 10 sequence, where $\sqrt{10} = 3.16$ = "3".

APPLICATIONS

LOCK-IN AMPLIFIER

Detect signals that may be obscured by noise or interference. With DYNATRAC 393, unlike other lock–in amplifiers, no phase adjustments are required, a great convenience when:



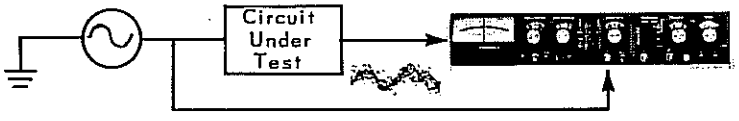
- the time constant must be long (have you tried to adjust phase when the time constant is 3 sec or longer? It is irritating to do even at 1 sec).
- the phase of the signal with respect to the reference changes during the measurement.
- you don't want to worry whether phase is set correctly.

Typical scientific applications where this feature is a particular convenience include:

- soft X–ray analysis
- bridge balance null detection
- low level NMR, EPR, and ESR
- circular dichroism spectroscopy
- magnetic susceptibility measurements
- retarding beam Auger spectroscopy
- Cochlear potential measurements
- Opto–acoustic modulation spectroscopy
- polarized luminescence measurements
- precision double beam optical systems

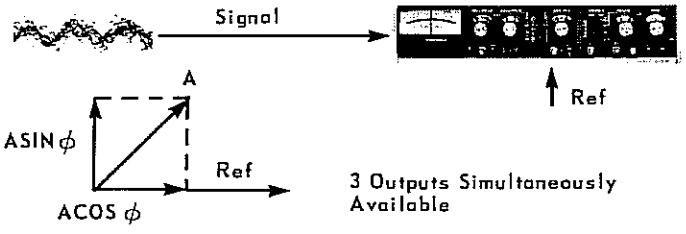
AC VOLTMETER

In the electronics laboratory, measure cross talk, power supply rejection, and other low level coupling phenomena. The instrument tracks the signal source while maintaining a constant narrow bandwidth.



VECTOR VOLTMETER

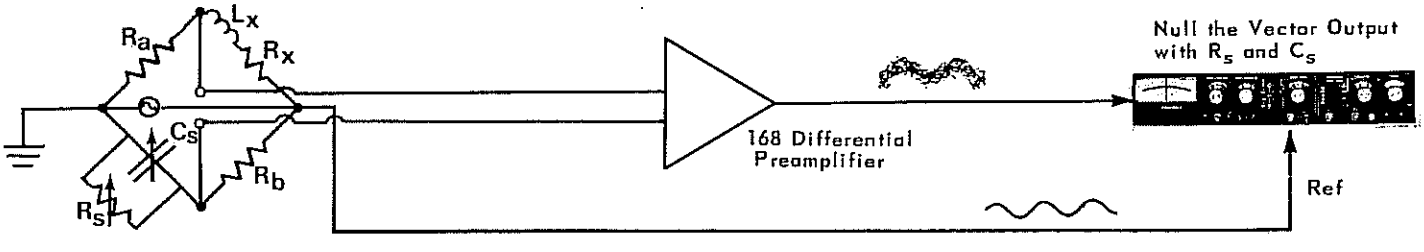
DYNATRAC 393 makes simultaneous in–phase, quadrature, and amplitude measurements of signals obscured by noise. Internal calibrated phase adjustments provide a continuous 360° phase offset capability to facilitate phase nulling to a resolution of less than .1°.



BRIDGE BALANCE NULL DETECTOR

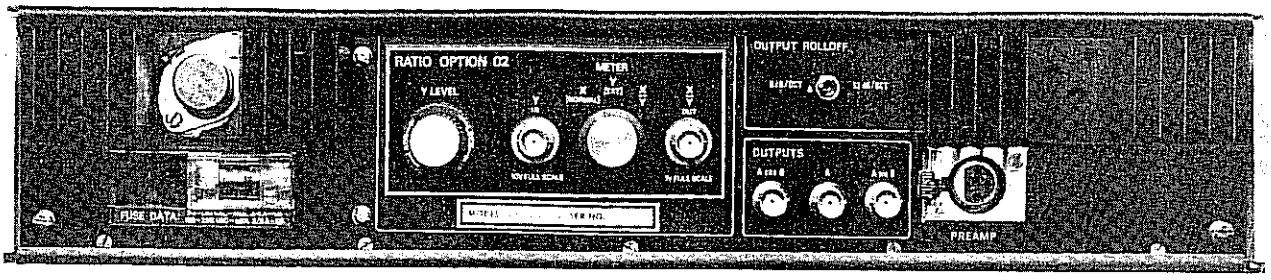
The vector output simplifies bridge balance by making it unnecessary to use the phase controls, unlike conventional or two–phase lock–in amplifiers often used in this application. The excellent harmonic rejection of DYNATRAC 393 is essential to many complex impedance bridge measurements because many such bridges are frequency sensitive, and therefore very small harmonic distortion components in the signal source will be greatly accentuated when the fundamental is nulled.

For bridge balancing the 168 Differential Preamplifier is available that provides a balanced 100mΩ input and excellent common mode rejection.



Eliminates effects of Phase Shift, Noise, and Harmonic Distortion

RATIO OPTION 02 (OPTIONS NOT AVAILABLE SIMULTANEOUSLY IN MAINFRAME)



With this option, an $\frac{X}{Y}$ output is provided, where X = normal lock–in output (+ only)

Y = control voltage (+ only)

Accuracy (25°C ±5°C): ±2% (Ext. Input 0.1 to 10VDC)

Where full scale = ratio of 1.00 = +1.00 volts of rear panel ratio output = positive full scale on lock–in meter

If both X and Y are proportional to the same variable (such as source intensity in a double beam optical system) the effect of this variable is eliminated.