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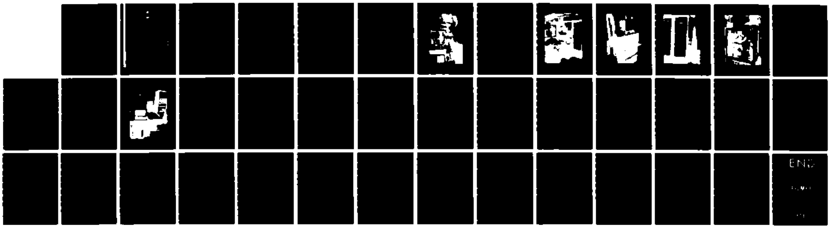

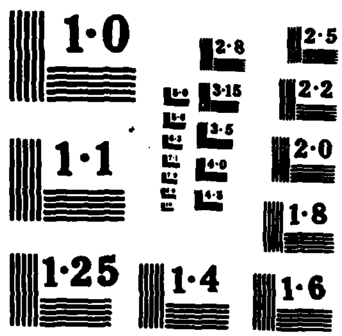
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THE DREO INERTIAL NAVIGATION LABORATORY: DEVELOPMENT AND TEST CAPABILITIES

by

M. Vinnins

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
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ABSTRACT

The DREO Strapdown Inertial Navigation Laboratory is described in detail. Laboratory equipment, much of it custom-designed, is described and specifications are given. Test capabilities are discussed and data acquisition and processing capabilities are detailed.

RÉSUMÉ

Il s'agit d'une description détaillée du laboratorie du CRDO sur le système inertiel non suspendu. On décrit le matériel de laboratoire, qui est en grande partie conçu sur mesure, et en donne les caractéristiques. Il est aussi question des moyens d'essais et de la capacité de collecte et de traitement des données.

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The DREO Inertial Navigation Laboratory: Development And Test Capabilities

1.0 DREO INERTIAL NAVIGATION LABORATORY

The navigation sub-program at DREO was created in 1977 with a mandate to provide technical assistance and advice to DND on all aspects of navigation technology. This has included not only established technologies such as a multitude of radio navigation aids but also satellite position-fixing and strapdown inertial navigation technologies. This latter technology is the basis of the in-house laboratory development at DREO.

The DREO Inertial Navigation Laboratory was developed between 1977 and 1981 as the only complete gyroscope, accelerometer and inertial system test laboratory for the evaluation of strapdown components and systems in Canada. With the aid of a consultant, the laboratory was designed for maximum flexibility; virtually any type of gyroscope can be excited and tested with existing test equipment.

The purpose of such a laboratory is twofold; primarily it provides a test facility for the evaluation of manufacturer's navigation components before procurement of systems but as well it is a flexible, independent facility for experimentation, research and development. More specifically, work within the laboratory has centered upon investigation and characterization of low cost strapdown inertial navigation components and systems. Strapdown technology holds the promise of low cost, long lifetime and ease of maintenance with the mechanical complexity of the traditional gimballed systems being replaced by software computation.

Testing of strapdown gyroscopes is quite different from that of gyroscopes employed on gimballed platforms; a strapdown gyroscope must operate over the entire dynamic range of the vehicle within which it is mounted including not only the possibility of high angular rates but also severe vibration and shock. A photograph of the DREO Gyroscope test station is shown in Figure 1-1. Note that the test platform is a two-axis Goerz motion table which allows both positioning and rate capability about the table axis and positioning capability about the tilt axis.

This report will detail the development, equipment types and specifications, data acquisition capabilities and tests that can be performed in the DREO Inertial Navigation Laboratory.

Figure 1-1 DREO Inertial Navigation Laboratory

2.0 LABORATORY EQUIPMENT

Figures 2-1 to 2-4. show the complement of equipment as it is set up in the laboratory. The necessary equipment can be grouped into the following categories:

- Motion table and associated electronics
- Clocks and frequency sources
- Temperature control and monitoring
- Gyroscope power supplies
- Monitoring equipment
- Recording equipment
- Support equipment

Because the laboratory is designed to accommodate a wide variety of gyroscopes and inertial systems, much of the equipment is custom built to permit flexibility. The following sections will describe in detail the limits of performance for the various equipment groups listed. Some equipment specifications are also attached in the Appendices.

2.1 MOTION TABLE AND ASSOCIATED ELECTRONICS

The laboratory motion table is a Contraves-Goerz Corporation Model 57CD, two-axis table controlled by a 30H MPACS, (Modular Precision Angular Control System) Level III command system. Detailed mechanical and electrical specifications are contained in Appendices A and B.

The table, shown in Figure 2-2 is optically aligned to the earth's axis using Polaris as a reference. Alignment is to within ± 20 arcsec. Mechanically, the table is capable of a position accuracy of ± 1.0 arcsec with a resolution of 0.36 arcsec (0.0001^0) in both axes. Wobble is less than ±3 arc sec. (All bearings are mechanical, ball type). The azimuth axis is capable of rates between 0.001 and 999.9 deg/sec with a resolution of 0.01% and stable to ± 0.1% over 360 degrees. The tilt axis can be used in position mode only with a range of ± 185 degrees.

The table top diameter is 14 inches but a larger top may be used if the environmental chamber is removed. Load capacity is 50 pounds, 6 inches from the table top.

Electrically, the table can be used in 6 modes (azimuth axis) and 2 modes in the tilt axis. The drive modes are:

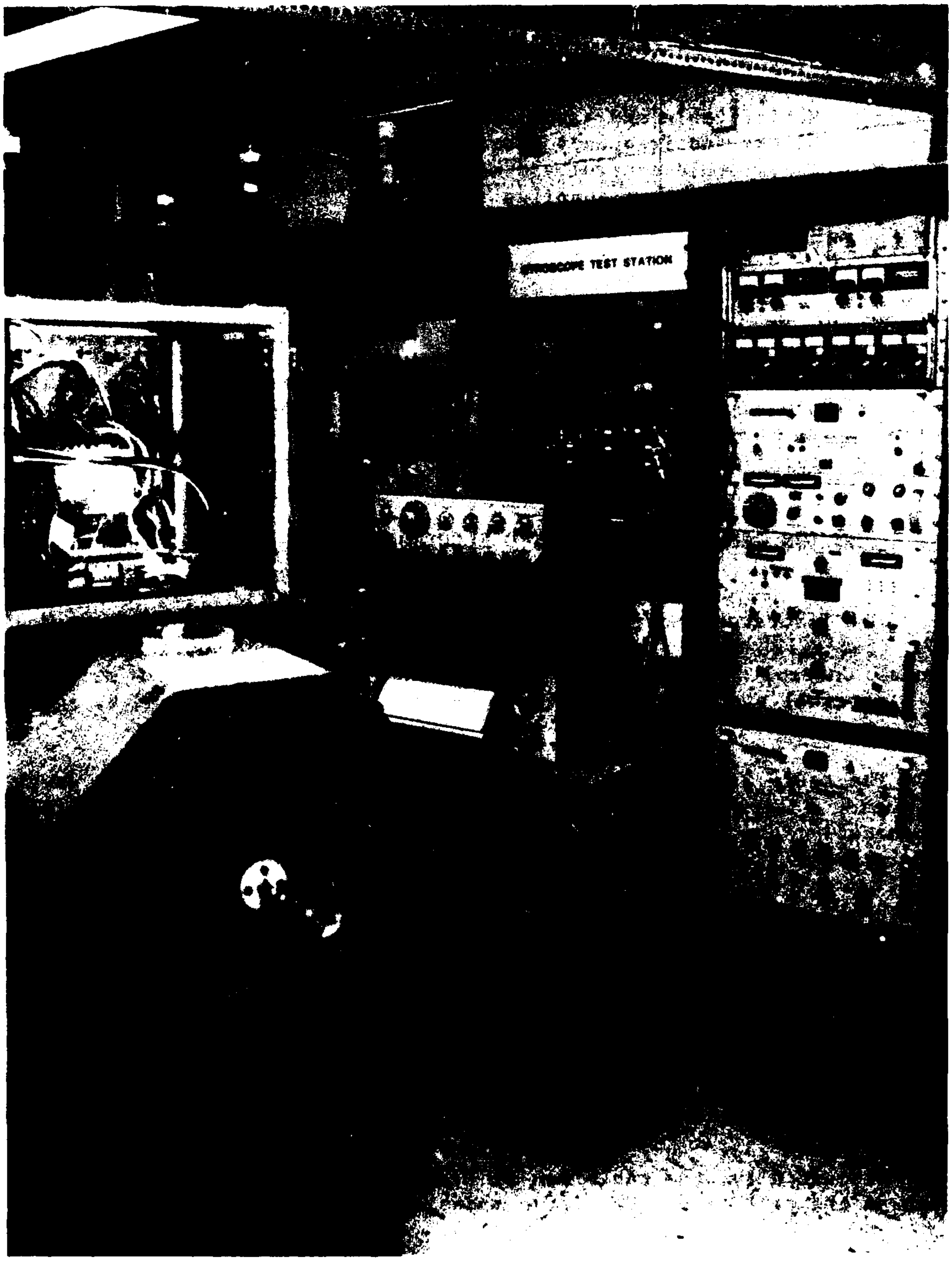


Figure 2-1 Navigation Laboratory Electronics

Figure 2-2 Contraves-Goerz 57CD/30H 2-axis
Motion Table

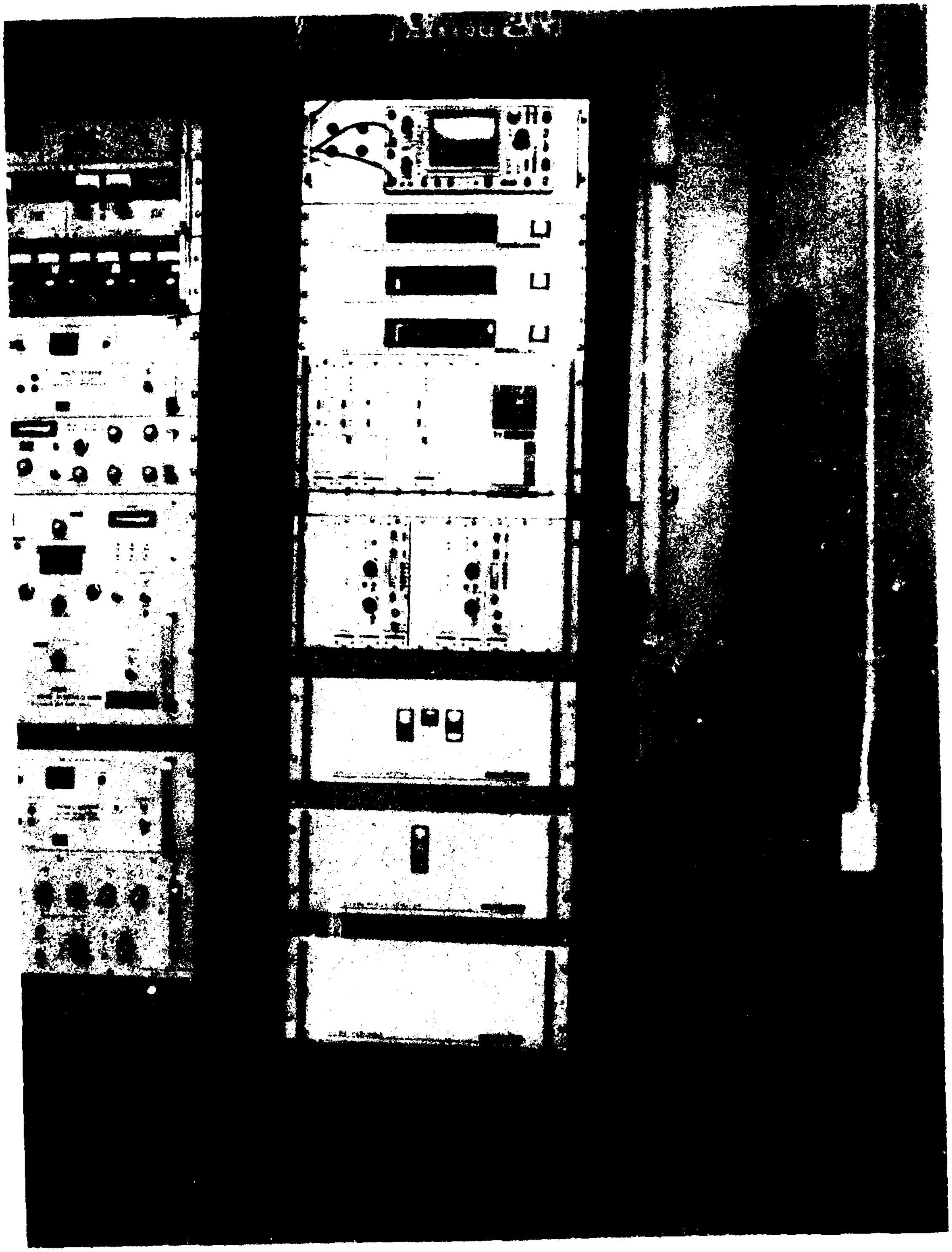


Figure 2-3 Motion Table Control Electronics

Figure 2-4 Table Top Breakouts and Fixturing

- Off Mode
- Position Mode
- Scorsby Mode
- Rate Mode
- Tach Mode
- Gyro Mode

} Azimuth Axis Only

In Off Mode, drift is less than 0.0001 deg/sec. In Tach Rate Mode, the range is 0.001 to 999.9 deg/sec with a resolution of 0.01%. In Position Mode, the range is from 0.0000 to 359.9999 degrees with an accuracy of ± 1.0 arc sec and a resolution of .36 arcsec.

In Digital Rate Mode, the range is 0.0001 to 199.9999 deg/sec with a resolution of 0.0001 deg/sec and an accuracy of 0.001%.

Scorsby Mode is an analog simulate mode which permits remote analog inputs to control table dynamics.

Gyro Servo Mode permits closed loop operation with gyro time constants from 0.1 ms to infinity, gyro gain from 100 mV/mrad to 10,000 mV/mrad and a carrier frequency range of 400 Hz to 10 KHz.

The table is also fitted with a Rate Trip capability which can be operator-adjusted over the entire dynamic range of both axes.

2.2 CLOCKS AND FREQUENCY SOURCES

One of the most important elements in the gyro station is the combination of clocks and frequency sources used to provide the wheel frequency synchronization, pickoff frequency excitation and clocking for data acquisition and test control.

The test station contains a number of frequency sources including:

- Dynamics Research Corp (DRC) Model 4262 Clock/Multiple Frequency Source
- HP 3320B Frequency Synthesizer
- HP 3335A Synthesizer/Level Generator
- Wavetek 184 5 MHz Sweep Generator

The most critical requirement of the main frequency sources is stability. The DRC source has a stability of 1 x 10^{-9} ppm/day and provides, from a single crystal oscillator, synchronization outputs for a wheel supply, signal generator supplies (2) as well as auxiliary frequencies for counters and data acquisition systems. Specifications for the DRC 4262 source, a custom-built piece of equipment, are contained in Appendix C.

2.3 GYROSCOPE POWER SUPPLIES

Two primary power supplies are generally required to excite a spinning wheel gyro. The wheel or spin supply controls the gyro wheel rotation. A microsyn or signal generator supply excites the gyro pickoffs required to sense gyro angular rotation. The power supplies used in the gyro station are custom built supplies obtained from NH Research Corp. in California.

A Model SF1250W-2 Sine/Square Wave Wheel Supply is the main power supply and is capable of both 2 and 3 phase operation, sine or square wave with output voltage from 12.000 to 96.000VRMS L-N in 3 ranges. Output resolution is 1 mV.

Detailed specifications are contained in Appendix D but several important features bear noting. Provision is made for separate start and run modes; start mode permits from 100% to 150% of run voltage to be applied to the wheel on startup under operator control. The output frequency range is 350 Hz to 5 KHz and the phase stability is $\pm$ 0.05°/wk.

The signal generator supply is an NH Model SF2599 power source. Output voltage of 1.0 to 80.0 V RMS is available in two ranges. Accuracy is $\pm$ 1.0% of setting with $\pm$ 0.02% repeatability. The output frequency range is 225 Hz to 50.0 KHz allowing it to be used on virtually all types of signal generators, both inductive and capacitive. Detailed specifications are contained in Appendix E.

It should be noted that both power supplies are synch loss and line power protected preventing overshoot during power supply recovery after failure.

2.4 TEMPERATURE CONTROL AND MONITORING

Thermal control of the instrument under test can be critical, particularly during drift stability and repeatability tests. The gyro test station contains two Dynamics Research Corp. TC-300, 3-channel, proportional temperature controllers. Component temperature can be controlled to better than $\pm$ 0.1 °F. The Block channel permits control of the component fixture, the component channel controls any component-mounted internal heaters and the third channel can be used for monitoring and recording. Both visual and audible alarms indicate off-temperature conditions. The temperature controller provides over 60 watts of block power and over 15 watts of inertial component heater power.

Digital thermometers are also used to monitor block and component temperature visually or record it digitally during data acquisition.

2.5 MONITORING EQUIPMENT

Gyro station monitoring equipment includes oscilloscopes, phasemeters, wattmeters and custom designed signal breakout panels.

Both the wheel and microsyn signals are continuously displayed on monitoring oscilloscopes. Wheel power consumption on start up and after settling is also recorded to observe bearing wear within the inertial components.

The most important aspect of monitoring involves the signal breakout panels. Since a large number of signal lines are required in most cases, wiring and connection errors are difficult to locate. The solution has been to group all signals to central connection/breakout panels in the station and then route them to the table top slip rings. On the table top, the signals are again exposed through breakout panels allowing several access points for debugging purposes. Typical breakout panels are shown in Figures 2-2 and 2-4.

2.6 DATA RECORDING EQUIPMENT

The laboratory data recording system is based on an LSI-11 microcomputer. This is a 16-bit machine addressing 32K of memory. The operating system is RT-11 version 4.0. The data acquisition system is shown in Figure 2-5.

In an attempt to facilitate data access, <u>all</u> instrumentation in the station is equipped with the IEEE- 488 standard bus interface. The LSI-11, through the IEEE-488 bus, controls the Goerz table remotely and reads table states, etc. Data can be recorded on the HP 5150A Thermal Printer, the HP7402 or HP7132A strip chart recorders or digitally on a Kennedy 9832 magnetic tape recorder with a programmable Kennedy 1629 Half Duplex Interface. A very versatile program has been developed which allows the operator to select table states, recording mediums and data during testing. The program is called 'GYRTST' and a flowchart is attached at Appendix F.

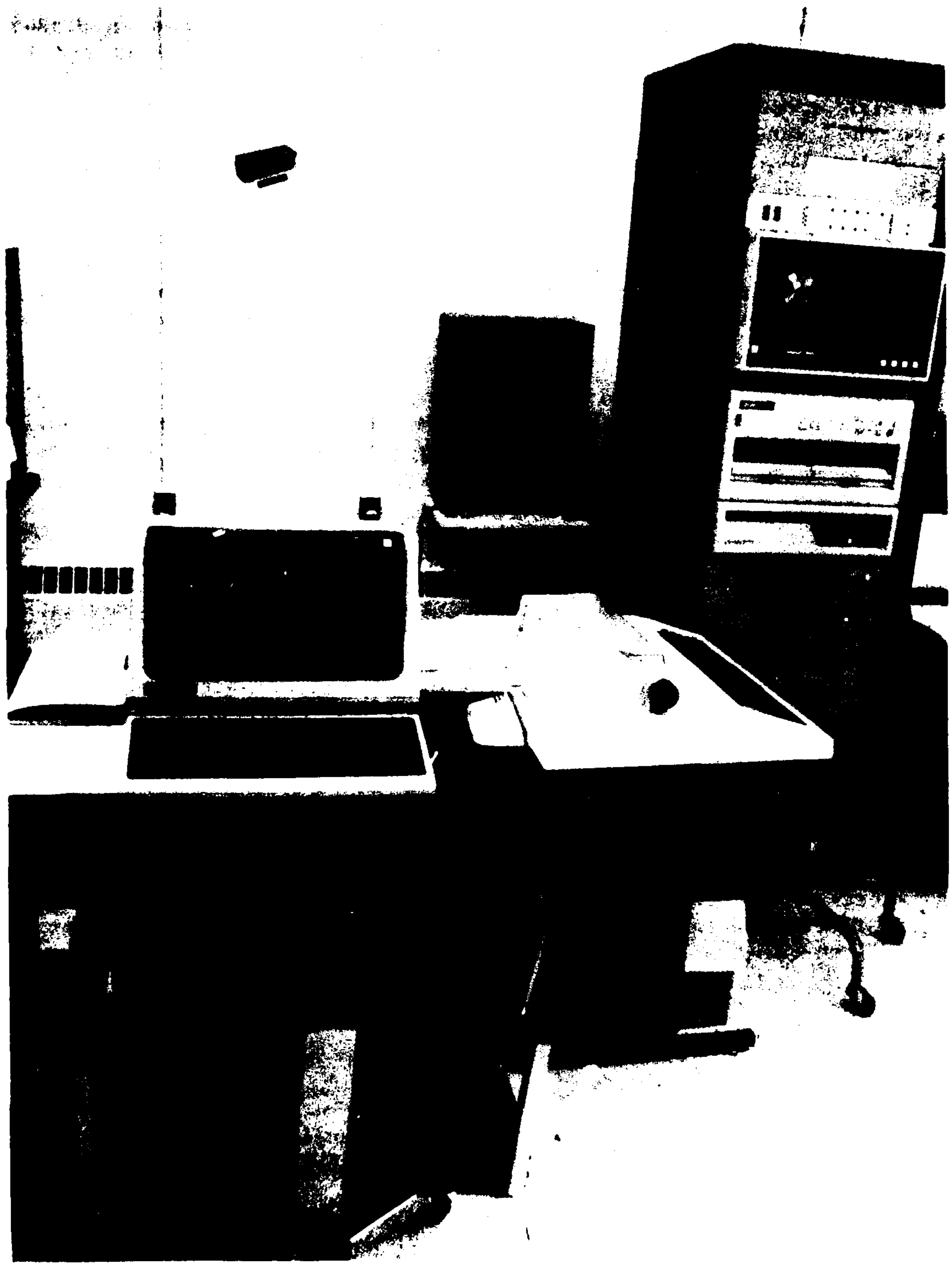


Figure 2-5 LSI-II Data Acquisition System

2.7 LABORATORY SUPPORT EQUIPMENT

Additional support equipment in the laboratory includes an HP5345A Electronic Counter, a Fluke 887A/B/AC/DC Differential Voltmeter and two Datron 1071 multi-function, microprocessor controlled DVMs. The Datron is a high accuracy instrument providing a 6 1/2 digit display (7 1/2 digits in 'averaging' mode for 0.05 ppm resolution). These meters are tied to the data acquisition system on the IEEE-488 bus.

In addition, a North Hills Electronics Ltd. DC Current Source (CS-150) is used as an ultra-stable precision current source for servo testing. The unit provides currents from 0 to ± 150 mA to an accuracy of ± 0.01% of full scale and a stability of ± 1 ppm (of F.S.)/100 hours.

Additional power supplies and meters are installed in the station to provide power to auxiliary electronics which may be necessary during certain tests or to assist in monitoring and debugging system operation.

3.0 TEST CAPABILITIES

With the existing equipment, the DREO Inertial Navigation Laboratory is capable of carrying out characterization tests on almost all classes of single-and two-degree-of-freedom spinning mass gyros with the exception of, perhaps, electrostatic gyroscopes. With modifications to several power supplies, ring laser (RLG) and fiber optic gyros could also be tested.

3.1 TYPES OF TESTS

Tests which can be performed in the laboratory include static (drift) tests, constant rate tests, servo mode tests and a wide variety of strapdown (S/D) tests involving a wide range of dynamics.

A list of possible tests includes:

1) Drift Coefficients

- Bias drift, g-sensitive and g^2-sensitive drift, cross-axis coupling (TDF gyros) and compliance terms.

2) Instrument Integrity Tests

- time constant, run-up and run-down time, pickoff offsets, pickoff scale factor, torquer misalignment, torquer scale factor, tuned speed and Figure-of-Merit (for TRG)

3) Drift Stability and Repeatability Tests

- random drift and repeatability of drift coefficients, turn-on repeatability and transient

4) Thermal Sensitivity Tests

- effects of temperature change on drift coefficients and cool-down sensitivity.

5) Torquer Scale Factor

- linearity (0-1000 deg/sec), repeatability, stability, thermal sensitivity.

6) Rate Transient Effects

- scale factor shifts after rate changes

7) Other Tests

- single axis servo and specialty tests

3.2 GYROSCOPE ALIGNMENT

Before characterization tests can begin on an instrument, it must be accurately aligned to the motion table. A number of flexible, micrometer - adjustable fixtures have been developed to aid in alignment for both single and two-degree-of-freedom instruments. Details on such fixtures can be found in DREO TN 84-5.

4.0 SUMMARY

The DREO Navigation Laboratory has the capability to perform characterization tests on a wide variety of inertial grade gyroscopes including single and two-degree-of-freedom spinning mass instruments as well as ring laser (RLG) and fiber optic gyros.

Future capabilities will include inertial system tests which will require 3-axis positioning capability and expanded data acquisition and recording capability.

At present, all data reduction, plotting and analysis is performed on other site computers but some of this capability will have to be transferred into the laboratory to improve test efficiency.

REFERENCES

A) 'Instruction Manual for a Model 57CD/30H Two-Axes Index Table System', IM-5685', Contraves-Goerz Corporation

B) 'Clock/Multiple Frequency Source Operation Manual, Model 4262', Dynamics Researh Corporation

C) 'Model SF 1250W-2 Rev A, Solid State Sine/Square Wave Wheel Supply', NH Research Corporation

E) 'Model SF2599, Signal Generator/Microsyn Power Source', NH Research Incorporated

Appendix A

A.0 Motion Table Mechanical Specification

A.1 GENERAL

Color	Federal Standard No. 595-25526 Blue
Height of Table, overall	66.25±1 inches
Height of Table Top Surface	50 ±0.5 inches
Height of Tilt Axis	43 ±0.5 inches
Length, overall	45±0.5 inches
Length of Stand at Base	34±0.5 inches
Orthogonality of Axes	5 arc seconds, max.
Leveling Range	1 degree
Leveling Resolution	2 arc seconds
Azimuth Adjust Range	±2 degrees
Shipping Weight	1200 pounds, approximately, including counterbalance weights
Cables	2 cables for connection to control.

A.2 AZIMUTH AXIS

Wobble	±3 arc seconds, max.
Bearing Type	Mechanical, Ball Bearings
Position Resolution	0.36 arc second (0.0001°)
Position Accuracy	±1.0 arc second, RSS, or better
TABLE TOP	
Diameter	14 inches
Material	Stainless Steel
Flatness	0.001 inch TIR
Load capacity, azimuth axis vertical	250 pounds with environmental chamber attached
Load capacity, moment load as measured from table top surface	50 pounds, 6 inches from table top
DRIVE, TABLE AXIS	
Direct coupled 80 ft-lbs DC torque motor	
Continuous Output Torque	80 ft-lbs
Range	Infinite

A.3 TILT AXIS

Wobble	±3 arc seconds, max.
Bearing Type	Mechanical, Ball Bearings
Position Accuracy	±1.0 arc second, RSS
Load capacity (moment load) as measured from tilt axis	Variable up to 70 ft-lbs. (2 adjustable counterweights)
Range	±185 degrees
DRIVE, TILT AXIS	
Direct coupled 22 ft-lbs DC torque motor	
Continuous Output Torque Capacity	22 ft-lbs

A.4 MPACS CHASSIS (2-AXIS)

P/N	D703295
Height	8.75 inches
Width	Fits standard 19-inch rack
Depth	27 inches, overall, including handles requires 26 inches minimum console clearance including rear connectors
Weight	78 pounds
Reference:	For complete description, operational and maintenance instructions, see separate manual IM-7508. 30H/MPACS, 2-Axis

A.5 120-60 CGSM	Switching Power Amplifier
P/N	E702569
Height	7.00 inches
Width	Fits standard 19-inch rack
Depth	24 inches
Weight	50 pounds
Reference:	For complete description, operational and maintenance instructions, see separate manual IM-5607A, 120-60-CGSM Switching Power Amplifier which includes a choke assembly with regenerative energy generator.

A.6 CHOKE ASSEMBLY/R.E.D., 60 AMP

P/N	D702004
Height	7.00 inches
Width	Fits standard 190 inch rack
Depth	20 inches
Weight	60 pounds
Reference	For complete description, operational and maintanance instructions, see separate manual IM-5607A, 120-60-CGSM Switching Power Amplifier

A.7 SERVO POWER AMPLIFIER (TILT AXIS)

P/N	E703273
Height	7.00 inches
Width	Fits standard 19-inch rack
Depth	24 inches
Weight	35 pounds
Reference	This manual contains complete description, operational, and maintenance instructions.

Appendix B

B.0 Motion Table Electrical Specification

B.1 OPERATING MODES AND SPECIFICATIONS

MODE SUMMARY

Drive Modes

A) Off Mode
B) Position Mode
C) Scorsby Mode
D) Rate Mode
E) Tach Mode
F) Gyro Mode

(C–F: Axis #1 Only)

Provision is incorporated for digital commands in the Digital Control Modes to be driven by a computer input using address/multiplex scheme.

Data Readout Capability

In the above drive modes, the Position Readout System provides the following readout capabilities:

A) Position Readout
B) Rate Readout
C) 1/Revolution Pulse
D) 1/Degree Pulse
E) Least Significant Bit Pulse
F) LSB Direction

(B–C: Axis #1 Only)

B.2
DRIVE MODES ELECTRICAL

A. Off Mode — Servoed Stop Mode

Drift ---------- 0.0001 degree/second

B. Tachometer Rate Mode (Axis #1 Only)

Transducer ----- DC Tachometer

Rate Range ----- 0.001 to 999.9 degrees/second

Resolution ----- 0.01% on each range

Data Format----- 4-digit keyboard entry

Accuracy High Rate 0.1% over 360 degrees

Short Term Stability ----- ±1% over 1 degree, ±0.75% over 10 degrees, ±0.1% over 360 degrees

Rate Limit ----- An adjustable rate trip limit is provided to torquer cut-off between preselected rates of 1 and 1000 degrees/second.

C. Position Mode (Axis #1 and #2)

Transducer ------ 720-pole Inductosyn and resolver

Data ------ Manual keyboard input or from data bus

Range ------ 0.0000 to 359.9999 degrees

Resolution ------ 0.36 arc second

Accuracy ------ ±1.0 arc second

Repeatability --- 0.1 arc second

Traverse ------ 0.1 to 30 degrees per second least path adjustable

D. Precision Digital Rate Mode (Axis #1 Only)

Range (low) ------ 0.0001 to 199.9999 deg/sec or ERU (Earth Rate Units)

Data ------ Manual keyboard input or from data bus

Resolution ------ 0.0001 deg/sec or ERU

Accuracy ------ 0.001%

E. Analog Simulate (Scorsby) Mode

The analog simulate mode provides for the remote analog inputs. The position input is summed with the low resolution position error and provides a dynamic range of 100°. An auxiliary rate input can also be utilized to provide rate feed-forward inputs.

F. Gyro Mode

Stiffness (Loop Gain) -- $\geq$6,000 ft-lb/mrad

Gyro Gain (Range) 100mV/mrad to 10,000 mV/mrad

Gyro Time Constant (Range) ------ 0.1 ms to ∞

Bandwidth ------ Variable, limited by gyro constraints

Compensation Network to - Breakpoint Frequencies

Signal Input Circuit Characteristics (Gyro Output Signal)

Impedance ------ >10 KΩ differential floated

Voltage Range --- 0-1V closed loop, 0-5V open loop

Voltage Sensitivity*	<2 microvolts
Carrier Frequency Range	400 Hz to 10 KHz

Reference Signal Circuit Characteristics (Reference Signal generated by Customer)

Impedance	>50 KΩ
Voltage Range	0.5V to 20V RMS
Waveform	Sine
Phase-Shift Capability	0 to ±90 degrees or -45 to +45 degrees
Tachometer Synchronization	Available, may be switched
Rate Limit Circuit	0 degrees per second, 1000 degrees per second

* System equivalent electrical noise will reflect back less than 2 μvolts RMS "in phase" of noise at the gyro output within the servo bandpass. This includes low frequency noise in the DC section of the servo and AC noise centered around the gyro carrier frequency.

Appendix C

Specifications
Model 4262 Clock/Multiple Frequency Source

General Description

The Clock/Multiple Frequency Source is a generator of multiple channel frequencies each digitally derived and in sync from a single crystal oscillator source.

Specifically, the Frequency Source generates four (4) channels of multiply selectable frequencies.

They are:

I. Wheel Frequencies channel -- with a front panel rotary switch to select one of the following ten (10) frequencies; 100, 200, 400, 480, 800, 1200, 1600, 2400, 3200 and 4800 Hertz.

The selected output Wheel Frequency is a square wave and amplitude adjustable 0 to 10 volts.

The selected output Wheel Frequency is available at the front panel at a banana plug and BNC test point, labelled Wheel Freq.; and also at the rear panel on two (2) BNC's wired in parallel and labelled Wheel Freq. Sync.

A capability is provided which digitally phase shifts the selected Wheel Frequency 0^0 to 360^0. This is accomplished by a front panel rotary switch which shifts the phase in 12^0 increments and a $0^0/180^0$ phase toggle switch.

The phase shifted Wheel Frequency output is a square wave and amplitude adjustable 0 to 10 Volts.

The phase shifted Wheel Frequency output is available at the front panel at a banana plug and BNC test point, labelled Wheel Freq. Phase; and also at the rear panel on two (2) BNC's wired in parallel and labelled Wheel Freq. Phase Sync.

II. Microsyn Frequencies Channel - This channel functions the same as channel #1 except that Thirteen (13) selectable frequencies are provided 1600. 2400, 3200, 4800, 6400, 7200, 9600, 12800, 14400, 19200, 38400, and 51200 Hertz.

III.Suspension/Precision AC Frequencies Channel - This channel functions the same as channel #1 except that eleven (11) selectable frequencies are provided 800, 1000, 1200, 1600, 2400, 3200, 4800, 6400, 7200, 9600, and 12800 Hertz.

IV. Auxiliary Frequencies Channel - This channel functions the same as channel #1 except that seventeen (17) selectable frequencies are provided; 100, 200, 400, 800, 1600, 3200, 4800. 7200, 9600, 12800, 14400, 19200, 25600, 28800, 38400, and 51200 Hertz.

A wheel run down time output is also provided. The selected output frequency of the Wheel Frequency is divided by 4 and filtered to a sine wave. This Wheel Run Down time output is also amplitude adjustable 0-10 Volts P-P. It is available on the front panel at the banana plug and BNC test points labelled wheel RDT. The crystal oscillator 1,916,000 Hertz 10 appears at the front panel BNC labelled crystal ÷ 10. Also, a one (1) Hertz pulse 2.0u sec, 0 to 10V amplitude appears at a front panel BNC and also a rear panel BNC, labelled 1.0 sec timing pulse.

All outputs may be short circuited and will recover when short is removed. All output amplitudes are adjustable from 0-10 volts via front panel screw driver adjustable potentiometer.

Operating Instructions

The Clock/Multiple Frequency Source requires only 115 Volt 60 Hertz power. A power connector and 3 AMP fuse are located on the rear panel and an on/off switch and AC power light are located on the front panel.

The unit contains two Lambda Power Supplies. They are Model LND-X-152 with over voltage protection to generate plus and minus 15 volts D.C.; and Model LNS-X-5-OV, also with over voltage protection to generate plus 5 Volts D.C.

The D.C. power enters the Augat circuit board thru plug E1. The crystal oscillator is a Ventron Laboratories, Inc. unit that requires 5 Volt DC for its oven and crystal oscillator. It is model CO-2175A-5 9.216 MHZ.

The specifications for the crystal oscillator are.

Frequency	9,216,000 Hertz
Stability	1 x 10-9 ppm/day
Short term Stability less than	1 x 10-10 ppm/sec
Temp. Stability	$0^0/+50^0$ C $\pm 1 \times 10^{-8}$
Freq. Offset vs:	
Supply ± 5%	$\pm 2 \times 10^{-8}$
Load ± 10%	$\pm 5 \times 10^{-9}$

5 Volt D.C. power is supplied to the oven and crystal oscillator thru plug E1.

With power applied the crystal frequency can be checked at front panel test point labelled Crystal ÷ 10. It is a 921, 600 HZ TTL square wave output.

The 1.0 Sec timing pulse can be checked at its front panel and rear panel banana jack and BNC connectors. It is a 1 HZ less than 2 usec pulse adjustable by its front panel potentiometer from 0 to 10 Volts.

The other four channel frequency and their related phase shifted frequency can be observed at their respective front panel and rear panel and BNC test points. The respective rotary switches can be manipulated to check for the proper frequency and phase. Also the respective amplitude adjustment potentiometer located on the front panel may be adjusted to give the desired amplitude square wave frequency output.

The wheel RDT sine wave signal may also be observed at its front panel banana plug and BNC test point. It's amplitude may be adjusted to ± 10V by its adjustment potentiometer. See layouts for locations and drawings for typical output circuits.

Appendix D

SPECIFICATIONS

MODEL SF 1250W-2 REV A

SOLID STATE SINE/SQUARE WAVE WHEEL SUPPLY

Output Configuration:	4 Wire transformer isolated and floating with 4 wire remote sense.
Phasing (switch selected):	
2 (Sine/Square):	90^{0} (OB lags A)
3 (Sine):	120^{0} Wye
Output Voltage:	
Start Mode:	Adjustable from 100% to 150% of the set run voltage via a separate front panel mounted 10-turn potentiometer.
Run Mode:	12.000 to 96.000V RMS L-N, in three switch selected ranges. Adjustable via a front panel mounted five decade thumb wheel switch
Resolution:	1 mV min.
Slow Rise Control:	Output voltage is front panel adjustable from 0 to 150V via a ten-turn control. This control may be used as a de-mag function
Start-Run Switch:	Front panel mounted
Start-Run Decay:	Wide range of timing is available by selecting an external capacitor which is mounted on binding posts and adjusting a ten-turn potentiometer, both of which are located on rear of instrument.
Waveform:	
A) Sine Wave:	
Distortion:	.1% max THD
B) Square Wave:	
Rise & Fall Time:	15 sec max., 10% - 90%
Overshoot & Ringing:	5% max
Tilt:	2% max

NOTE: Run Mode Only

MODEL 1250W-2 REV A (Cont'd)

Output Current:

2 - - 3 Wire 90^0

Voltage Range	Output Current per phase. Start or Run
12.000 - 24.000	2 amps
24.000 - 48.000	1 amp
48.000 - 96.000	500 ma

3 - - 4 Wire 120^0 Wye

Voltage Range	Output Current per Phase. Start or Run
12.000 - 24.000	1.33 amps
24.000 - 48.000	667 ma
48.000 - 96.000	333 ma

Phase Stability.	$\pm$ 0.05^{0}wk at max voltage
Output Frequency Range:	350Hz to 5 KHz
Frequency Time: (sine Wave Operation only)	The automatic timing circuitry will require 15 seconds maximum to lock on any signal in the given frequency range.

External Input Requirements:

Input Voltage:	5 - 30V RMS or TTL
Input Impedance:	10K single ended
Frequency:	
Sine Wave Mode:	Same frequency as derived output
Square Wave Mode: 2 operation:	4 x the desired output frequency

Load:

Sine Wave Mode:	0.7 lead to 0 lag
Square Wave Mode:	0.7 lead to unity

MODEL SF 1250W-2 REV A (Cont'd)

Amplitude Stability:*

Vs load:	(Sine Wave Mode)	± 0.005%, NL-FS with remote sensing
	(Square Wave Mode)	±0.05%, NL-FL with remote sensing
Vs line:		±0.001% for 115V ±10V line
Vs time:		± 0.0025%/week under constant conditions
Vs temp:		± 0.002%/^{0}C average from 15^{0}C to 40^{0}C
Vs input signal:		±0.001% for specified input

* Measurements made with an average sensing voltmeter in the run mode. Specifications are in percent of the full range voltage as measured L-N.

Ambient Temperature:	0^{0}C to 50^{0}C
Overload Protection:	Output may be short circuited indefinitely, recovery is automatic when short is removed.
Front Panel Test Points:	Voltage and current for both phases. Current is measured via a current transformer with a correlation of 1 amp = 1 volt.
On-Standby Switch:	Output voltage can be turned off without turning off primary power.
On-Calibrate Switch:	Front panel mounted control disconnects output from the rear terminal block and places instrument in internal sense mode. This control may be used for gyro back EMF checks.
Line Power/Sync Loss Protections:	Loss of line power or input sync will not cause overshoot during recovery.
Monitors:	Voltage and Current meters with front panel mounted phase switch.
High Temperature Interlock:	A 28VDC relay is provided to allow power to outputs. Loss of this interlock signal puts supply into standby mode. This interlock may be overridden through a rear panel mounted switch.
Electrical Construction:	All silicon solid state.

MODEL SF 1250W-2 REV A (Cont'd)

Physical:	15 3/4" high, std 19" RETMA panel
Line Power:	115V $\pm$10V, 50/60 Hz
Color:	Off-White, Fed. Code 595-16622

APPENDIX E

SPECIFICATIONS

MODEL SF2599

SIGNAL GENERATOR/MICROSYN POWER SOURCE

Output Configuration:	Single phase, two wire, floating with two wire remote sense
Range I:	1.0-15.99 VRMS in 10MV increments
Range II	10.0-80.0VRMS in 0.1V increments
Voltage Programming:	Front panel mounted, manually set via four thumbwheel switches, and a range switch.
Accuracy:	±.1.0% of setting
Repeatability:	±0.02% of maximum voltage
Output Waveform:	Sine Wave
Output Power:	
Range I:	1.0-15.99VRMS, 10VA (1A max current)
RangeII:	10.0-80.0 VRMS, 5VA
Load Power Frequency:	0.7 lead to 0 lag
Output Frequency:	225Hz - 50.0 KHz (usable to 56 KHz)
External Signal Input Requirements:	
Voltage:	3-30 V PK-PK, Sine or symmetrical square wave
Frequency:	± 0 .25% of operating frequency
Impedance:	10K nominal
Distortion:	Less than 0.2% THD 225Hz = 20 KHz Less than 1.0% THD, 20 KHz = 50 KHz

MODEL SF 2599 (Cont'd)

Amplitude Stability:*	±0.005% NL-FL with remote sense
Vs. line:	±0.001% for +10V line, 110VAC
Vs. time:	±0.005%/wk after warmup
Vs. temp:	±.002%/°C over 15-40°C range
Vs. sync:	±0.001% for any variation within specified limits

* Measurements made with an average sensing voltmeter and are in percent of maximum voltage.

Overload Protection:	Outputs may be short circuited indefinitely, recovery is automatic when short is removed.
Current Test Points:	Front panel mounted, transformer isolated, 1A 1V. Also current meter
Voltage Test Points:	Front panel mounted, test points are connected directly across output
On/Standby:	Front panel switch that turns off the output voltage without turning off primary power
Sync Presence Detector:	Detects sync voltage and turns on supply. If sync is not present, supply will remain in standby mode
Line Power Loss Protection:	Loss and recovery of line power will not cause overshoot of greater than 1%
Line Power:	115V ± 10V 50/60Hz
Electrical Construction:	All silicon solid state
Operating Temperature:	0 - 50°C
Physical:	8-3/4" high, std 19" RETMA rack mount panel

*Addendum to Specification: SF 2599 as of 10/1/79

Addendum - Output frequency changed from 100 Hz -55KHz to 225 Hz-57.6KHz per phone conversation W/M. Vinnins 12/12/79.

Addendum: March 28, 1980 - Specs revised per P. Swartz and M Vinnins

OPERATING INSTRUCTIONS

2.0 CONTROLS

2.0.1 Power Switch: Turns instrument on and off. A power indicator light is included on the front panel.

2.0.2 Fuse: This is the primary power fuse and should be replaced with a 2 1/2 amp slow blow fuse.

2.0.3 ONSTBY Switch: Turns off the output without turning off the main supply. An indicator light is provided which indicates unit is in ON condition.

2.0.4 Sine Voltage Adjust: This is a rear panel control. Refer to Section 5 Calibration.

2.0.5 Sync Presence Indicator: Indicates the presence of a sync signal to the instrument. When the sync signal is absent the instrument reverts to the "STBY" mode and the "ON" indicator lamp is extinguished.

2.0.6 Voltage Programming Switches: Voltage programming is accomplished by 3 1/2 digit switches (BCD) located on front panel.

2.0.7 Range Switch: Selects Range I or II of voltage range program. Range I selects 1.0 - 15.99 VRMS and Range II selects 10.0-80.0 VRMS.

2.1 INSTALLATION

2.1.1 Mounting: The instrument may be mounted in a standard RETMA 19 inch rack panel or may be used as a bench instrument.

2.1.2 Line Power: The instrument requires 105 to 125V, 60 Hz

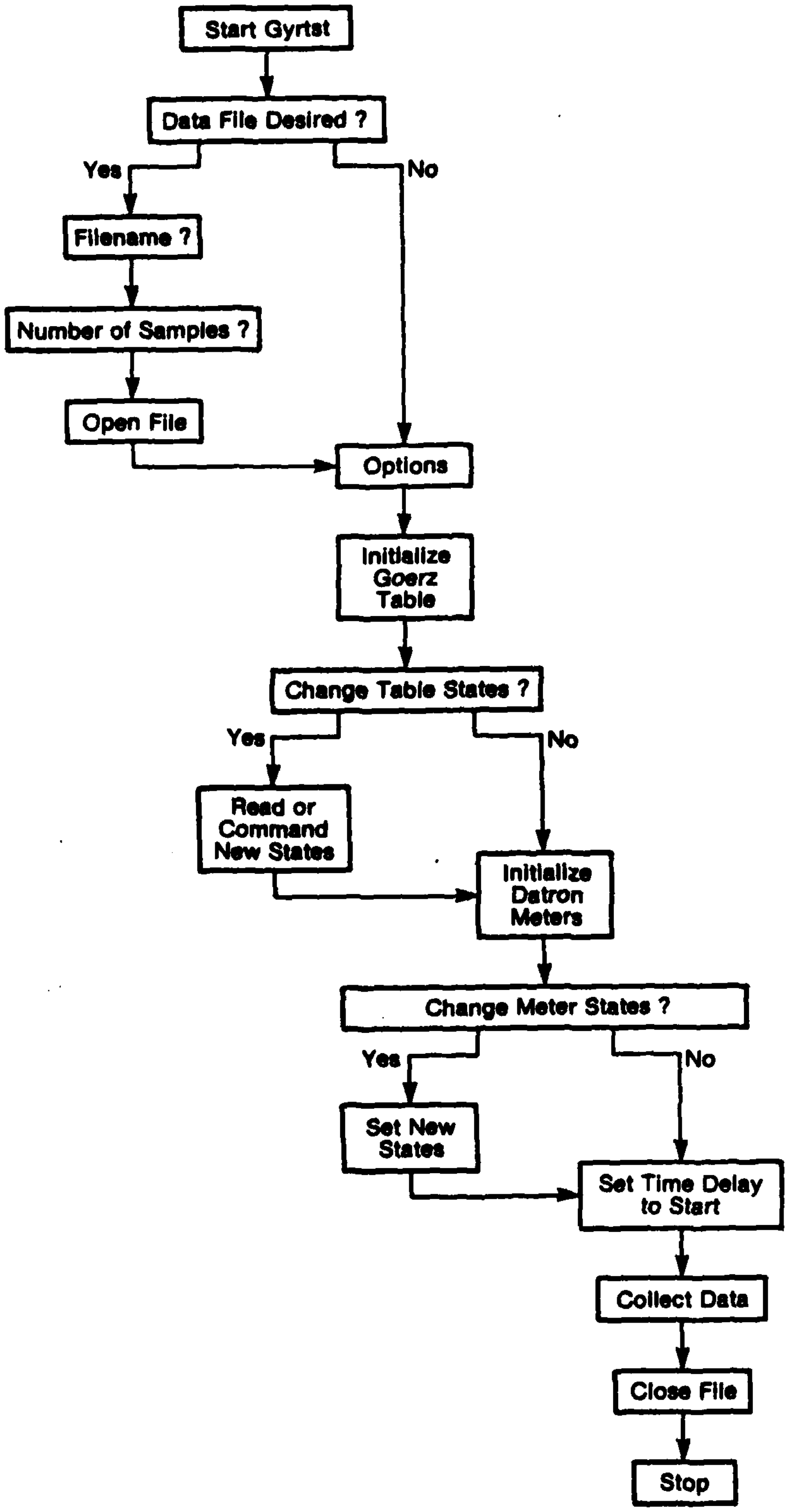
2.1.3 Grounding the Power Output: The power output of the instrument is completely isolated from chasses ground. Wherever possible, it is recommended that the output Lo be strapped to ground at some point in the system.

2.1.4 Output Connections: The output is available at an MS Connector located on the rear panel of the instrument. As with any remote sensed power supply, the remote sense connections are essential for proper operation of the instrument.

2.1.5 Input Signal: A BNC connector is provided on the rear panel for the external input signal.

APPENDIX F

DATA ACQUISITION FLOWCHART



'GYRTST' Data Acquisition Program

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13. ABSTRACT

The DREO Strapdown Inertial Navigation Laboratory is described in detail. Laboratory equipment, much of it custom-designed, is described and specifications are given. Test capabilities are discussed and data acquisition and processing capabilities are detailed.

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KEY WORDS

Inertial Navigation
Motion simulator
Strapdown

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