

Recognized as an
American National Standard (ANSI)

ANSI/IEEE Std 813™-1988(R2011)

IEEE Specification Format Guide and Test Procedure for Two-Degree-of- Freedom Dynamically Tuned Gyros

Sponsor

**Prepared by the Gyro and Accelerometer Panel
of the
IEEE Aerospace and Electronic Systems Society**

Reaffirmed December 7, 2011
Approved August 17, 1988

IEEE-SA Standards Board

Reaffirmed June 7, 2000
Approved May 4, 1989

American National Standards Institute

Copyright © 1989 by

The Institute of Electrical and Electronics Engineers, Inc. 345 East 47th Street, New York, NY 10017-2394, USA

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied “**AS IS.**”

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation, or every ten years for stabilization. When a document is more than five years old and has not been reaffirmed, or more than ten years old and has not been stabilized, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon his or her independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered the official position of IEEE or any of its committees and shall not be considered to be, nor be relied upon as, a formal interpretation of the IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Recommendations to change the status of a stabilized standard should include a rationale as to why a revision or withdrawal is required. Comments and recommendations on standards, and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854
USA

Authorization to photocopy portions of any individual standard for internal or personal use is granted by The Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Foreword

(This Foreword is not a part of ANSI/IEEE Std 813-1988, IEEE Specification Format Guide and Test Procedure for Two-Degree-of-Freedom Dynamically Tuned Gyros.)

This guide was prepared by the Gyro and Accelerometer Panel of the Aerospace Electronics Systems Society of the Institute of Electrical and Electronics Engineers. It consists of two parts.

Part I is a specification format guide for the preparation of a two-degree-of-freedom dynamically tuned gyro (DTG) specification. It provides a common meeting ground of terminology and practice for manufacturers and users. The user is cautioned not to overspecify; only those parameters that are required to guarantee proper instrument performance in the specific application should be controlled. In general, the specification should contain only those requirements that can be verified by test or inspection. Parameters in addition to those given in this standard are not precluded.

Part II is a compilation of recommended procedures for testing a DTG. These procedures, including test conditions to be considered, are derived from those currently in use. For a specific application, the test procedure should reflect the requirements of the specifications; therefore, not all tests outlined in this document need to be included, nor are additional tests precluded. In some cases, alternative methods for measuring performance characteristics have been included or indicated.

The intent is for the specification writer to extract the applicable test conditions and equipment requirements from Section 9. for inclusion in the appropriate sections listed under 4.5. Similarly, it is intended that the writer extract the applicable test procedures from Section 10. for inclusion in the appropriate sections listed under 4.6. Part II can also be used as a guide in the preparation of a separate gyro test specification with appropriate section numbering.

Blank spaces in the text of this document permit the insertion of specific parameter values and their tolerances. Brackets are used to enclose alternative choices of dimensional units, signs, axes, etc. Boxed statements are included for information only and are not part of the specification or test procedures. The terminology used conforms to ANSI/IEEE Std 100-1988, IEEE Standard Dictionary of Electrical and Electronics Terms and ANSI/IEEE Std 528-1984, IEEE Standard Inertial Sensor Terminology. The units used conform to ANSI/IEEE Std 268-1982, American National Standard Metric Practice. The abbreviation of units conforms to ANSI/IEEE Std 260-1978 (R 1985), IEEE Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units). The graphic symbols used conform to ANSI/IEEE Std 315-1975, IEEE Graphic Symbols for Electrical and Electronics Diagrams.

This guide defines the requirements and test procedures for a DTG in terms unique to that gyro. The requirements and tests contained herein cover applications where the gyro is used as an angular motion sensor in navigation and control systems. These requirements and tests apply to the two modes of use: (1) As a strapdown sensor in operating environments typical of aircraft and missile applications, and (2) As a sensor in gimballed platform applications in which the dynamic angular inputs to which the gyro is subjected are benign relative to the accuracy required. The strapdown DTG, because the rotor is captured through two external loops using the two gyro torquers, provides two voltages, currents, or pulse trains proportional to the angular rates about the respective two orthogonal input axes. The gimballed platform DTG provides two output signals proportional to angular displacement of the case about the respective two orthogonal input axes when captured by a servoed platform.

The term two-degree-of-freedom dynamically tuned gyro does not generally include the external electronics. However, in the case of the strapdown DTG, the characteristics of the external capture loops are considered to the extent necessary to define the gyro performance. A model equation is given in 6.3 for reference, to be included in a specification only to the extent necessary.

Appendix A lists various DTG design features for which this format is applicable. The table therein is not intended to make any suggestion regarding the selection of particular design features that might restrict the free choice of manufacturers.

Appendix B shows the DTG open-loop frequency response characteristics, which may be referred to when specifying and evaluating gyro dynamic response. Appendix C presents a guide to the operation of a DTG.

The IEEE will maintain this guide current with the state of the technology.

This publication represents a group effort on a large scale. A total of 141 individuals attended 50 meetings on the Gyro and Accelerometer Panel while this standard was in preparation. The major contributors to this standard were the following:

T.C. Lear, *Chair*

C.H. Barker
S.F. Becka
J.S. Beri
C.E. Bosson
A.T. Campbell *
A. Champsi
J.F. Conroy
J.W. Davies *
H. Diamond
G. Erickson
A.H. Ferraris
K.N. Green
R. Hartzell

M. Hooser
K.J. Klarman
M.G. Koning
E.L. Ladenheim
A.M. Leeking
J.B. Lewis
D.D. Lynch
D.L. Macy
R.D. Marquess
H.D. Morris
G.E.S. Morrison *
G.C. Murray *
J.G. Neugroschl

R.B. Peters
S. Piccione
A. Scoville
C. Seacord
N.F. Sinnott
R. Smith
C.B. Strang
C.O. Swanson
R. Thede
L.A. Trozpek
R.L. Van Alstine
B.J. Wimber
B.R. Youmans

* Past Chairman

The following persons were on the balloting committee that approved this document for submission to the IEEE Standard Board:

C.H. Barker
S.F. Becka
J.S. Beri
C.E. Bosson
A.T. Campbell
A. Champsi
M. Coles
J.F. Conroy
J.W. Davies
H. Diamond
N.C. Duffield
G. Erickson
T. Fuhrman
K.N. Green

R.M. Hensley
G. Hoffman
M. Hooser
M.G. Koning
P. Krebs
K. Lantz
T.C. Lear
A.M. Leeking
J.B. Lewis
D.D. Lynch
D.L. Macy
R.D. Marquess
M. McClure
F. Morgan
H.D. Morris

G.E.S. Morrison
G.C. Murray
G. Neugebauer
J.G. Neugroschl
R.B. Peters
W. Phillips
P. Simpson
N.F. Sinnott
C.O. Swanson
R. Thede
C.I. Thornberg
L.A. Trozpek
B.J. Wimber
B. Youmans

When the IEEE Standards Board approved this standard on August 17, 1988, it had the following membership:

Donald C. Fleckenstein, *Chair*

Marco Migliaro, *Vice Chair*

Andrew G. Salem, *Secretary*

Arthur A. Blaisdell

Fletcher J. Buckley

James M. Daly Frank

Stephen R. Dillon

Eugene P. Fogarty

Jay Forster *

Thomas L. Hannan

Kenneth D. Hendrix

Theodore W. Hissey, Jr

John W. Horch

Jack M. Kinn

D. Kirschner

Frank C. Kitzantides

Joseph L. Koepfinger *

Irving Kolodny

Edward Lohse

John E. May, Jr

Lawrence V. McCall

L. Bruce McClung

Donald T. Michael *

Richard E. Mosher

L. John Rankine

Gary S. Robinson

Frank L. Rose

Helen M. Wood

Karl H. Zaininger

Donald W. Zipse

* Member Emeritus

CLAUSE	PAGE
Part I — Specification Format	1
1. Scope and References	1
1.1 Scope	1
1.2 References	1
2. Applicable Documents	2
2.1 Specifications	2
2.2 Standards	2
2.3 Drawings	2
2.4 Bulletins	3
2.5 Other Publications	3
3. Requirements	3
3.1 Description	3
3.2 General Requirements	3
3.3 Performance	3
3.4 Mechanical Requirements	13
3.5 Electrical Requirements	17
3.6 Environmental Requirements	20
3.7 Reliability	25
4. Quality Assurance Provisions	26
4.1 Classification of Tests	26
4.2 Acceptance Tests	26
4.3 Qualification Tests	27
4.4 Reliability Tests	28
4.5 Test Conditions and Equipment	28
4.6 Test Methods	28
4.7 Data Submittal	31
5. Preparation for Delivery	31
6. Notes	32
6.1 Intended Use	32
6.2 Ordering Data	32
6.3 Model Equations	32
Part II — Test Procedure	35
7. Scope	35
8. Description	35
8.1 Angular Displacement Sensing	35
8.2 Angular Rate Sensing	35
8.3 Model Equation	35

CLAUSE	PAGE
9. Test Conditions and Test Equipment	36
9.1 Standard Test Conditions	36
9.2 Standard Operating and Test Equipment	38
10. Test Procedures	39
10.1 Examination of Product (Mechanical)	39
10.2 Examination of Product (Electrical)	39
10.3 Leak Test	41
10.4 Polarity	41
10.5 Operating Temperature Test Series	42
10.6 Pickoff Test Series	44
10.7 Torquer Test Series	46
10.8 Rotor Rotation Detector	50
10.9 Spin Motor Test Series	50
10.10 Axis Alignment	52
10.11 Limit Stop	54
10.12 Tuned Speed	55
10.13 Dynamic lime Constant	56
10.14 Drift Rate Test Series	57
10.15 Spring Rate Drift Rate Coefficients	68
10.16 Dynamic Response Test Series	69
10.17 Output Noise	72
10.18 Generated Fields	75
10.19 Turn-On and Warm-Up Times	76
10.20 Environmental Test Series	78
Annex A Dynamically Tuned Gyro Design Features (Informative)	80
Annex B Typical DTG Open-Loop Frequency Response (Informative)	81
Annex C A Guide to the Operation of a Dynamically Tuned Gyro (DTG) (Informative)	82

An American National Standard

IEEE Specification Format Guide and Test Procedure for Two-Degree-of- Freedom Dynamically Tuned Gyros

Part I—Specification Format

1. Scope and References

1.1 Scope

This specification defines the requirements for a two-degree-of-freedom dynamically tuned gyro (DTG) to be used as a sensor in a [strapdown, gimbaled] [inertial navigation system, attitude reference unit, _____] for use in [an aircraft, a missile, a spacecraft, _____] application. The characteristics of the external capture electronics are considered where necessary to define gyro performance.

1.2 References

- [1] ANSI/IEEE Std 100-1988, IEEE Standard Dictionary of Electrical and Electronic Terms.¹
- [2] ANSI/IEEE Std 528-1984, IEEE Standard Inertial Sensor Terminology.
- [3] MIL-STD-105D-1964, Sampling Procedure and Tables for Inspection by Attributes.²
- [4] MIL-STD-116J-1988, Methods of Preservation.
- [5] MIL-STD-461C-1987, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference.
- [6] MIL-STD-462-1987, Measurement of Electromagnetic Interference Characteristics.
- [7] MIL-STD-704D-1988, Aircraft Electric Power Characteristics.
- [8] MIL-STD-781D-1986, Reliability Testing for Engineering Development, Qualification, and Production.

¹ANSI/IEEE publications can be obtained from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the Service Center, The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08854-1331.

²MIL publications are available from the Director, US Navy Publications and Printing Service, Eastern Division, 700 Robbins Avenue, Philadelphia, PA 19111.

[9] MIL-STD-785B-1986, Reliability Program for Systems and Equipment Development and Production.

[10] MIL-STD-810D-1983, Environmental Tests Methods and Engineering Guidelines.

2. Applicable Documents

The following documents form a part of the specification to the extent specified herein. In the event of any conflict between the requirements of this document and the listed documents, the requirements of this document shall govern.

Give identification number, title, date of issue, and revision letter of each listed document.

2.1 Specifications

2.1.1 Government

MIL-STD-116J-1988 [4].*

*The numbers in brackets correspond to those of the references in 1.2 of this standard.

2.1.2 Industry/Technical

2.1.3 Company

2.2 Standards

2.2.1 Government

- 1) MIL-STD-105D-1964 [3].
- 2) MIL-STD-461C-1987 [5].
- 3) MIL-STD-462-1987 [6].
- 4) MIL-STD-704D-1988 [7].
- 5) MIL-STD-781D-1986 [8].
- 6) MIL-STD-785B-1986 [9].

2.2.2 Industry/Technical

(1) ANSI/IEEE Std 100-1988 [1].

(2) ANSI/IEEE Std 528-1984 [2].

2.2.3 Company

2.3 Drawings

2.3.1 Government

2.3.2 Industry/Technical

2.3.3 Company

2.4 Bulletins

2.4.1 Government

2.4.2 Industry/Technical

2.4.3 Company

2.5 Other Publications

Other applicable documents should be listed under the appropriate paragraph.

3. Requirements

3.1 Description

The major components of the herein specified DTG are: an enclosure and mounting means, a rotor driven by a _____ spin motor, _____ pickoffs, _____ torquers, and a _____ rotor suspension.

To fill in the blanks, refer to Appendix A.

3.2 General Requirements

3.2.1 Precedence

In the event of conflict among the purchase agreement, this specification, and other documents referred to herein, the order of precedence shall be as follows:

- 1) Purchase agreement.
- 2) This specification and its applicable drawings (see 3.4.2 and 3.5.1).
- 3) Other applicable documents (see Section 2.).

3.2.2 Definitions

The following standards and the model equation of 6.3 define terminology used in this specification: ANSI/IEEE Std 100-1988 [1], and ANSI/IEEE Std 528-1984 [2].

3.2.2.1 New Definitions

gyro operating null (DTG): The condition where minimum change in drift rate occurs due to changes in wheel speed.

pickoff offset (DTG): The difference in angular rotor position between operation at pickoff electrical null and at gyro operating null.

3.3 Performance

The wheel speed and pickoff adjustment significantly influence the performance characteristics of a DTG and consequently must be properly adjusted for operation at the gyro operating null. The performance requirements are

specified under these conditions. The performance tolerances include a summation of manufacturing and test errors, and environmental effects. Any exception due to environmental effects will be listed in 3.6.3.1.

When required by the application, the sensitivity of a gyro characteristic to variations in voltage, frequency, temperature, or other variables shall be included in the paragraph specifying that characteristic.

3.3.1 Run-Up Time

_____ $\pm$ _____ seconds to _____ percent of tuned speed.

3.3.2 Run-Down Time

_____ $\pm$ _____ seconds from _____ percent of tuned speed to _____ percent of tuned speed.

3.3.3 Operating Temperature

_____ $\pm$ _____ [K, °C].

3.3.4 Turn-On and Warm-Up Times

3.3.4.1 Turn-On Time

_____ [s, min] maximum.

The turn-on time conditions and performance limitations shall be specified.

3.3.4.2 Warm-Up Time

_____ [s, min] maximum.

3.3.5 Polarities

3.3.5.1 Input Axes

Positive input axes shall conform to [Drawing _____, Fig _____].

3.3.5.2 Pickoffs

A positive rotation of the gyro case about the X axis shall produce a signal from the X pickoff which is [in-phase, out-of-phase] with respect to the pickoff reference. A positive rotation of the gyro case about the Y axis shall produce a signal from the Y pickoff which is [in-phase, out-of-phase] with respect to the pick-off reference.

3.3.5.3 Torquers

With the spin motor on, a positive torquing signal applied to designated terminals of the X torquer shall produce an output from the Y pickoff which is [in-phase, out-of-phase] with respect to the pickoff reference. With the spin motor on, a positive torquing signal applied to designated terminals of the Y torquer shall produce an output from the X pickoff which is [in-phase, out-of-phase] with respect to the pickoff reference.

Torquer polarities may also be specified with the spin motor off, in which case the above polarity and axis relationships do not apply.

3.3.5.4 Motor

The rotor shall rotate in the direction indicated by [Drawing _____, Fig _____].

Polarities of rotation detectors, temperature sensors, etc, may also be specified.

3.3.6 Limit Stop

The rotor motion shall be mechanically limited. The limit shall be _____ $\pm$ _____ [mrad, °].

3.3.7 Tuned Speed

_____ $\pm$ _____ [Hz, _____].

The in-phase-spring-rate drift rate coefficient (see 3.3.12) is commonly specified in those applications where the gyro is operated at a predetermined rotor speed other than the nominal tuned speed.

3.3.8 Dynamic Time Constant

Shall be greater than _____ seconds.

3.3.9 Rotor Rotation Detectors

For pulse output type, specify peak output, repetition rate, pulse width, and rise time or fall time, or both. For near sinusoidal type, specify total output, fundamental signal, and fundamental frequency. Other types of rotor rotation detectors should be specified in accordance with their characteristics.

3.3.9.1 Peak Output

_____ $\pm$ _____ V (at rated speed).

3.3.9.2 Repetition Rate

_____ times rotor speed.

3.3.9.3 Pulse Width

_____ ms at _____ V (at rated speed).

3.3.9.4 [Rise, Fall] Time

_____ $\pm$ _____ μ s from _____ percent to _____ percent peak amplitude.

3.3.9.5 Total Output

_____ $\pm$ _____ V rms (at rated speed).

3.3.9.6 Fundamental Signal. (Sinusoidal)

_____ percent of total output.

3.3.9.7 Fundamental Frequency

_____ times rotor speed.

3.3.10 Pickoff

3.3.10.1 Scale Factor

_____ $\pm$ _____ V/[rad, °] output angle.

3.3.10.2 Composite Error

The maximum deviation in output from that defined by the scale factor shall not exceed _____ percent of output range.

Specific terms comprising composite error may be specified in addition to, or instead of, composite error.

3.3.10.3 Offset

0 $\pm$ _____ [", mrad] maximum.

3.3.10.4 Quadrature

_____ mV [rms, peak-to-peak] maximum.

3.3.10.5 Null

_____ mV [rms, peak-to-peak] maximum.

For ac pickoffs the electrical null is composed primarily of harmonics, noise, and quadrature (voltage at a fundamental frequency but 90° out of phase with the signal output for large signals). A common practice is to achieve a minimum in-phase voltage after which the quadrature and total voltage are determined.

3.3.10.6 Phase Shift

_____ $\pm$ _____ degrees.

3.3.10.7 One-N (1N) Modulation

The One-N (1N) modulation shall not exceed _____ mV [rms, peak-to-peak].

For some applications, the higher spin modulation harmonics may be specified. This is particularly important for high bandwidth loops.

3.3.11 Torquer Performance

3.3.11.1 Command Rate Scale Factor

_____ $\pm$ _____ [(rad/s)/mA, (rad/h)/mA, ($^{\circ}$ /s)/mA, ($^{\circ}$ /h)/mA].

If the gyro is to be used or tested with electronics, the output of which is a pulse train, it would be necessary to define in the test procedures a scale factor for the combined gyro and electronics with units such as arc seconds per pulse ($''/p$).

3.3.11.2 Command Rate Scale Factor Errors

3.3.11.2.1 Linearity

_____ [(rad/s)/mA, (rad/h)/mA, ($^{\circ}$ /s)/mA, ($^{\circ}$ /h)/mA] maximum.

This error can also be expressed in parts per million (ppm) of K_{TO} . K_{TO} is frequently obtained from a least-squares linear fit to the data. A higher order fit of scale factor variation with rate may be specified as an alternative to a linear model.

3.3.11.2.2 Asymmetry

The difference between the command rate scale factor measured with positive and negative input rates shall not exceed _____ [(rad/s)/mA, (rad/h)/mA, ($^{\circ}$ /s)/mA, ($^{\circ}$ /h)/mA].

This error can also be expressed in parts per million (ppm) of K_{TO} .

3.3.11.2.3 Repeatability

_____ [(rad/s)/mA, (rad/h)/mA, ($^{\circ}$ /s)/mA, ($^{\circ}$ /h)/mA] [maximum spread, 1 σ , _____].

This error can also be expressed in parts per million of K_{TO} . Motor shut-downs, cool-downs, time between runs, and other factors pertinent to the particular application shall be specified.

3.3.11.2.4 Stability

_____ [(rad/s)/mA, (rad/h)/mA, ($^{\circ}$ /s)/mA, ($^{\circ}$ /h)/mA] [maximum spread, 1 σ , _____] for _____ [hour, day, _____].

This error can also be expressed in parts per million of K_{TO} .

3.3.11.3 Command Rate Scale Factor Sensitivities

3.3.11.3.1 Temperature

The change in command rate scale factor resulting from a change in steady-state operating temperature shall be _____ $\pm$ _____ [((rad/s)/mA)/ $^{\circ}$ C, ((rad/h)/mA)/ $^{\circ}$ C, (($^{\circ}$ /s)/mA)/ $^{\circ}$ C, (($^{\circ}$ /h)/mA)/ $^{\circ}$ C].

This sensitivity can also be expressed in ppm/ $^{\circ}$ C.

3.3.11.4 Maximum Command Rate

Minimum _____ [rad/s, rad/h, °/s, °/h] for a minimum of _____ seconds.

3.3.11.5 Continuous Command Rate

Minimum: _____ [rad/s, rad/h, °/s, °/h].

The degree to which performance may be degraded during application of maximum command rate, and the recovery time, may both be specified if applicable.

3.3.11.6 Torquer Time Constant

_____ ± _____ seconds.

3.3.12 In-Phase-Spring-Rate Drift Rate Coefficient

_____ (°/h)"/" maximum.

This error is usually specified instead of tuned speed (see 3.3.7) when the gyro is operated at a predetermined rotor speed other than the tuned speed.

3.3.13 Quadrature-Spring-Rate Drift Rate Coefficient

_____ (°/h)"/" maximum.

3.3.14 Acceleration-Insensitive Drift Rate**3.3.14.1 Magnitude**

$D(y)_F, D(x)_F, 0 \pm$ _____ °/η.

3.3.14.2 Repeatability

_____ °/h [Maximum spread, 1 σ, _____], each axis.

Motor shut-downs, cool-downs, time between runs, and other factors pertinent to the particular application shall be specified.

3.3.14.3 Temperature Sensitivity

_____ (°/h)/°C maximum.

3.3.14.4 Stability

_____ °/h [maximum spread, 1 σ, _____], each axis.

3.3.15 Acceleration-Sensitive Drift Rate Coefficient**3.3.15.1 Magnitude**

1) $D(y)_Y, D(x)_X, 0 \pm$ _____ (°/h)/g

$$2) \quad D(y)_X, D(x)_Y, 0 \pm \text{_____} (^\circ/\text{h})/\text{g}$$

$$3) \quad D(y)_Z, D(x)_Z, 0 \pm \text{_____} (^\circ/\text{h})/\text{g}$$

3.3.15.2 Repeatability

_____ $(^\circ/\text{h})/\text{g}$ [Maximum spread, 1σ , _____].

Motor shut-downs, cool-downs, time between runs, and other factors pertinent to the particular application shall be specified.

3.3.15.3 Temperature Sensitivity

_____ $(^\circ/\text{h})/\text{g}/^\circ\text{C}$ maximum for any coefficient.

3.3.15.4 Stability

_____ $(^\circ/\text{h})/\text{g}$ [maximum spread, 1σ , _____], each axis.

3.3.16 Acceleration-Squared-Sensitive Drift Rate Coefficient

$$0 \pm \text{_____} (^\circ/\text{h})/(\text{g})^2.$$

The specification should state whether this requirement applies to each of the coefficients $D(y)_{XZ}$, $D(y)_{YZ}$, $D(x)_{XZ}$, and $D(x)_{YZ}$ individually, or represents a maximum value for acceleration along any axis. The coefficient(s) should be specified as a function of frequency if applicable.

3.3.17 Anisoinertia Drift Rate Coefficients

$$\text{_____} \pm \text{_____} [(\text{rad}/\text{h})/(\text{rad}/\text{s})^2, (^\circ/\text{h})/(\text{g}/\text{s})^2].$$

3.3.18 Rotor Speed Sensitivity

The change in in-phase-spring-rate drift rate coefficient due to a change in gyro rotor speed of $\pm$ _____ Hz shall be _____ $(^\circ/\text{h})/''/\text{Hz}$ maximum.

See 3.3.7, tuned speed, and 3.3.12, in-phase-spring-rate drift rate coefficient.

3.3.19 Cross-Coupling Drift Rate

This drift rate results from nonoscillatory or oscillatory rotations about the Z axis (see Fig 3).

3.3.19.1 Nonoscillatory

This component of cross coupling drift rate is not normally separable from the rotor spin axis misalignment. See 3.3.25.

3.3.19.2 Oscillatory

$0 \pm \text{_____}$ [rad/h, °/h].

Gyro axis misalignments, the hangoff angle due to null offset and the transfer function of the capture electronics must be considered when specifying this drift rate. This drift rate exists when a quadrature component of torquing current with respect to the input oscillation occurs.

3.3.20 Synchronous Vibration Sensitivity

- 1) *One-N (1N) Translational Sensitivity.* _____ [(°/h)/g, _____] maximum, for linear vibration along the Z axis.
- 2) *Two-N (2N) Translational Sensitivity.* _____ [(°/h)/g, _____] maximum, for linear vibration normal to the Z axis.
- 3) *Two-N (2N) Angular Sensitivity.* _____ [(°/h)/(rad/s²), _____] maximum, for angular vibration about an axis normal to the Z axis.

These sensitivities result from the rectification of the driving input with mass unbalances in the sensitive element, imperfections in the flexure elements, and inertia characteristics of the gimbal(s). Their magnitudes depend upon design features unique to each particular gyro configuration. In all cases the rectifications occur only for synchronous vibrations at either the spin frequency (1N) or twice the spin frequency (2N) along or about the indicated axis. The source of the synchronous vibrations can be either externally induced motions or internally induced motions, for example, shaft wobble induced by bearing anomalies. In certain applications involving gyros mounted in close proximity the rectification resulting from the external influence of one gyro on a companion gyro can be eliminated by operating each gyro at a slightly different spin frequency.

3.3.21 Torquer-Current Rectification Drift Rate

$0 \pm \text{_____}$ [rad/h, °/h].

The selected conditions under which the drift rate is to be specified should be defined.

3.3.22 Random Drift Rate

_____ °/h, 1 σ for each axis, with the gyro oriented [Z axis horizontal, Z axis vertical, _____].

Requirements for more than one orientation may be specified. Test duration and either sample time or frequency bandwidth should be specified, dependent upon data reduction techniques.

Random drift rate may be specified in terms such as rate white noise in °/h or (°/h)/Hz, correlated random drift rate in °/h rms, rate random walk in (°/h)/h or rate ramp in °/h².

3.3.23 Drift Rate Stability

_____ °/h [maximum spread, 1 σ , _____ 1, each axis for a period of _____ [minutes, hours, days, _____].

The fixed gyro-orientation and the steady-state environmental conditions such as temperature, vibration, etc, should be specified. Short-term and long-term drift rate stabilities may be specified.

3.3.24 Output Noise

3.3.24.1 Equivalent Input Angle Noise

The equivalent input angle noise in the electrical output signal for zero input shall not exceed _____ (μrad , arc seconds) rms as determined by the square root of the integral of the power spectrum between _____ Hz and _____ Hz.

3.3.24.2 Equivalent Rate Noise

The equivalent rate noise shall not exceed _____ [$\mu\text{rad/s}$, $''/\text{s}$, $^\circ/\text{h}$] rms as determined by the square root of the integral of the power spectrum between _____ Hz and _____ Hz.

If necessary, the power spectral density of input angle noise or rate noise may be specified over a specific frequency range in place of rms error. In any case, it must be recognized that the electronics associated with the gyro contribute to the total noise error.

For certain applications, inputs other than zero may be specified.

3.3.24.3 Noise Equivalent Angle (NEA)

The noise equivalent angle of the incremental angle outputs shall not exceed _____ arc seconds. It is the peak-to-peak difference between the following two functions over a _____ [min, h] duration, for input rates of $[0, \text{ }]''/\text{s}$, at a temperature of _____ $\pm$ _____ $^\circ\text{C}$, and in a benign environment (minimal vibration, thermal, magnetic inputs).

- 1) *Function 1.* The angular measurement over a _____ [min, h] duration with a sample interval of _____ $\pm$ _____ ms.
- 2) *Function 2.* The best linear fit (angle vs time) of function 1, in a least-squares manner.

3.3.25 Hysteresis Error

_____ $^\circ/\text{h}$ maximum over an input range of _____ [rad/s, rad/h, $^\circ/\text{s}$].

3.3.26 Dynamic Response

3.3.26.1 Open-Loop Response

The open loop response shall be within the limits defined by Fig _____.

Pickoff amplitude versus input amplitude as a function of frequency is generally not specified. For information, an example of the open loop response is shown in Appendix B.

3.3.26.2 Closed-Loop Response

Torquer current amplitude and phase versus input rate as a function of frequency shall be within the limits defined by Fig _____.

Closed-loop requirements are normally specified only for strapdown applications. Figure 1 is an example of a closed-loop response characteristic.

The dynamic response is largely determined by the capture electronics. Characteristics of the capture electronics must be specified.

3.3.27 Axis Alignment

Torquer axis X_T shall be aligned to case axis X within _____ [mrad, _____]. Torquer axis Y_T shall be aligned to case axis Y within _____ [mrad, _____]. Torquer axis X_T shall be perpendicular to torquer axis Y_T within _____ [mrad, _____]. The rotor spin axis shall be aligned to case axis Z within _____ [mrad, _____].

Misalignment angles are shown in Fig 2. Note that case axes must conform to 3.4.2 and 3.4.3. Axis stability and repeatability may also be specified.

3.3.28 Reference Constants

These constants are for reference only. They are not specified independently, because they may vary within the framework of the specification, or because they are difficult or impossible to measure independently in a completed gyro. Nominal values are listed.

3.3.28.1 Rotor Angular Momentum

_____ [$\text{g} \cdot \text{cm}^2/\text{s}$, dyn middot; $\text{cm} \cdot \text{s}$].

3.3.28.2 Rotor Speed

_____ [Hz, r/min].

3.3.28.3 Rotor X Axis, Transverse Moment of Inertia

_____ $\text{g} \cdot \text{cm}^2$.

3.3.28.4 Rotor Y Axis, Transverse Moment of Inertia

_____ $\text{g} \cdot \text{cm}^2$.

3.3.28.5 Rotor Z Axis, Polar Moment of Inertia

_____ $\text{g} \cdot \text{cm}^2$.

3.3.28.6 Gimbal(s) X Axis, Transverse Moment of Inertia

_____ $\text{g} \cdot \text{cm}^2$.

3.3.28.7 Gimbal(s) Y Axis, Transverse Moment of Inertia

_____ $\text{g} \cdot \text{cm}^2$.

3.3.28.8 Gimbal(s) Z Axis, Polar Moment of Inertia

_____ $\text{g} \cdot \text{cm}^2$.

In the case of multi-gimbal DTGs, the moment of inertia for each gimbal or the combined inertia may be specified.

3.3.28.9 Figure of Merit (FOM) _____.

$$FOM = \frac{C}{\sum_1^n (A_n + B_n + C_n)}$$

where

C = rotor polar moment of inertia
 A_n, B_n = transverse moment of inertia of the nth gimbal
 C_n = polar moment of inertia of the nth gimbal

3.4 Mechanical Requirements**3.4.1 Exterior Surfaces**

All exterior surfaces must withstand the environment specified herein and the handling expected in the normal course of operation, testing, and maintenance without deterioration that causes nonconformance to this specification.

Additional requirements controlling surface finish, workmanship, processing, etc, may be specified.

3.4.2 Outline and Mounting Dimensions

Outline and mounting dimensions, and accuracy requirements of mounting surface and reference index shall conform to [drawing number _____, Fig _____].

A typical outline drawing is shown in Fig 3.

3.4.3 Gyro Axes

The X and Y gyro case axes are mutually perpendicular and are located by means of the gyro mounting surface and the reference index on the gyro case [notch, pin, scribe line, _____]. The Z axis is perpendicular to the gyro mounting surface (see Fig 3). The nonrotating coordinate frame of the spinning rotor is nominally aligned to the gyro case axes (see Fig 2).

3.4.4 Weight

_____ ± _____ [g, _____].

Specify those components such as cables, connectors, and electronics which are to be included in the weight.

3.4.5 Seal

The gyro shall be sealed so that the leak rate is less than _____ [cm³/s, _____] when subjected to a pressure of _____ ± _____ [Pa, _____] and gyro temperature of _____ ± _____ °C for a minimum of _____ minutes.

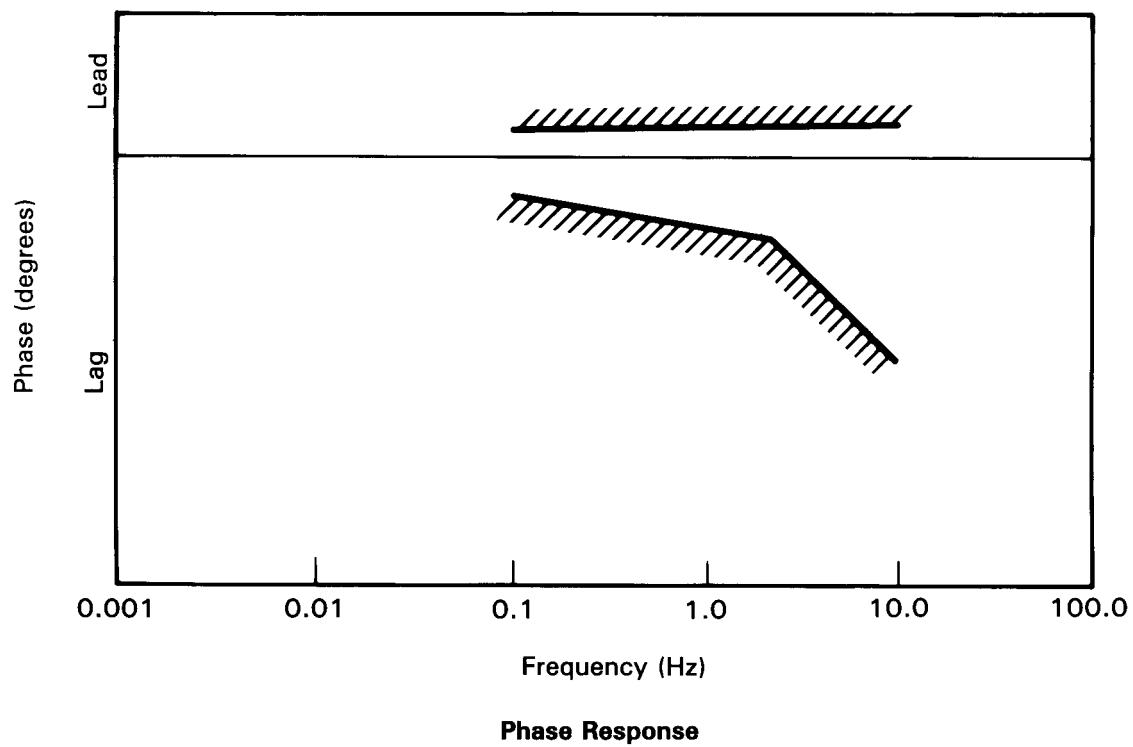
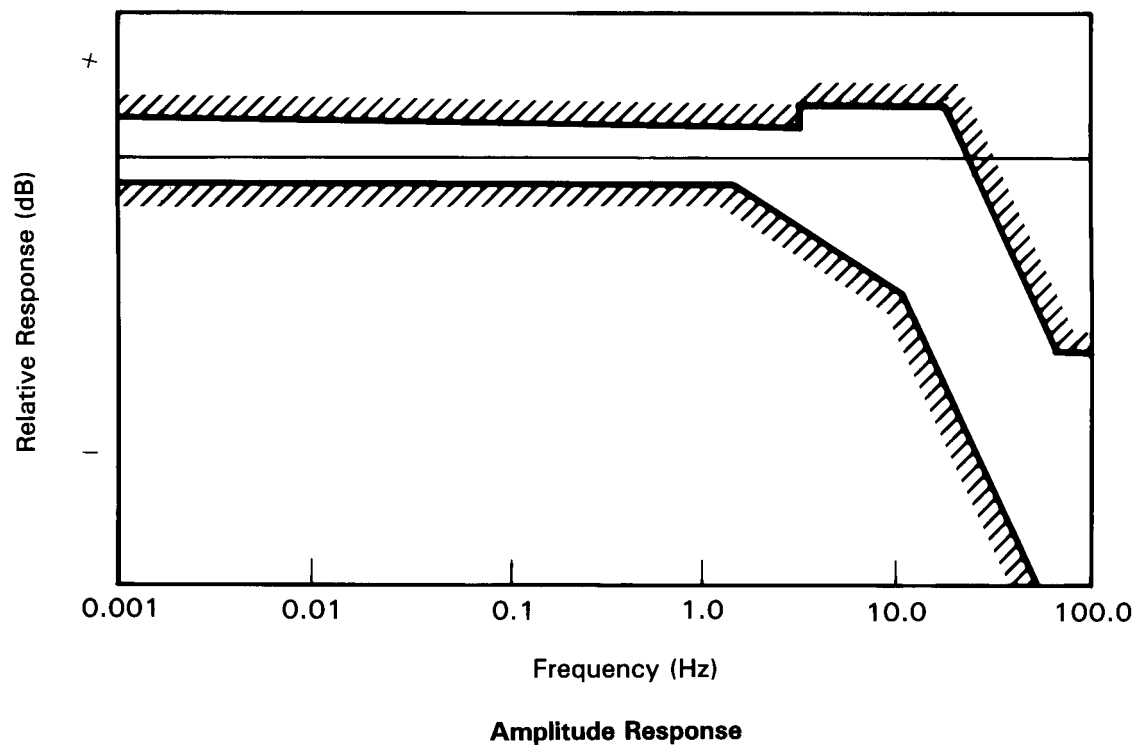


Figure 1—Closed-Loop Frequency Response

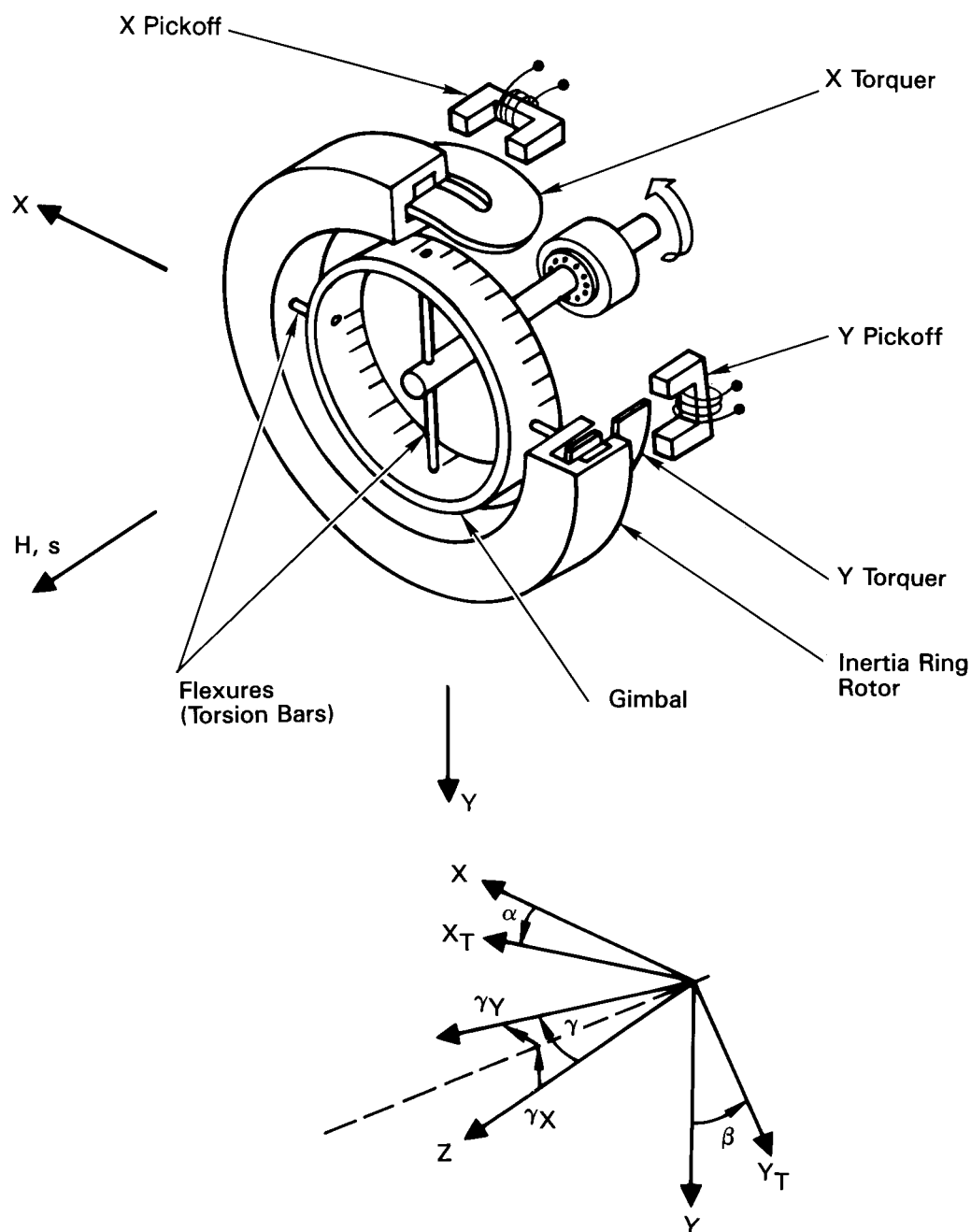


Figure 2—DTG Mechanical Schematic and Misalignment Angles

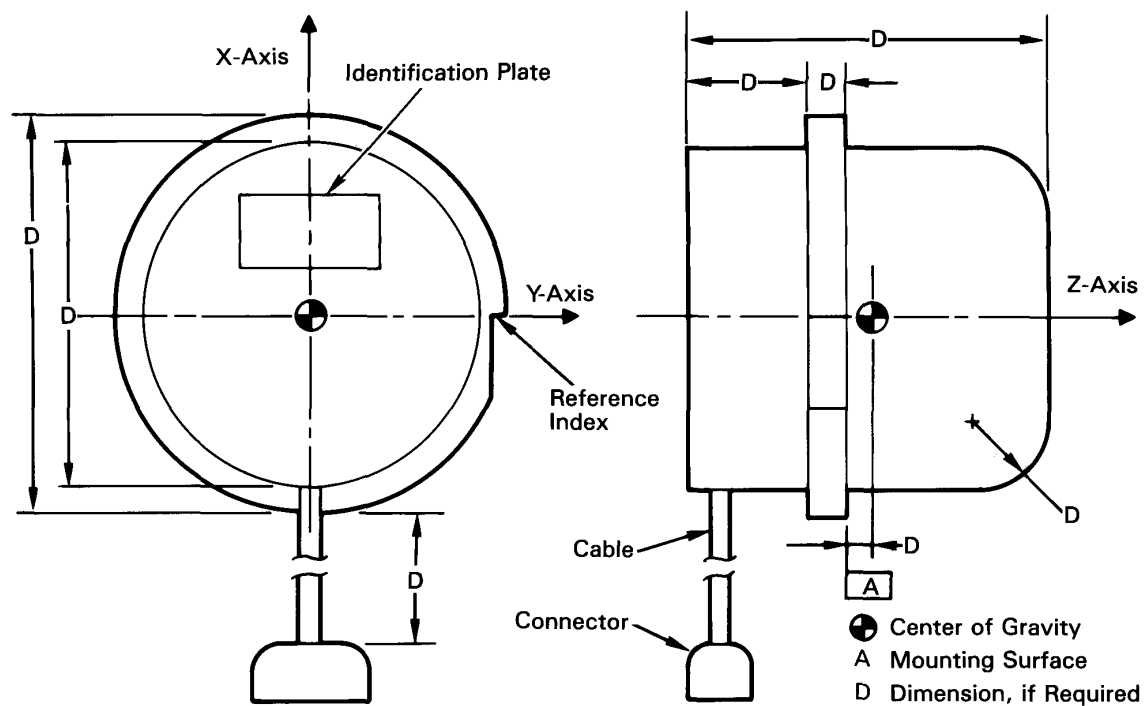


Figure 3—Typical DTG Outline Drawing

3.4.6 Internal Mechanical Configuration

Tuning provisions, shaft support, rotor suspension, vibration isolation, etc, shall be specified to the extent necessary.

3.4.7 Identification of Product

The gyro shall be identified on the surface and in the manner indicated in [drawing number _____, Fig _____]. Identification shall include:

- 1) Dynamically tuned gyro
- 2) Specification number
- 3) Unit serial number
- 4) Axis identification marking as shown in [drawing number _____, Fig _____]
- 5) Manufacturer's name or symbol

The purchase agreement may require additional identification such as date of manufacture.

3.5 Electrical Requirements

3.5.1 Schematic

The electrical circuits shall be connected as shown in [drawing number _____, Fig _____].

The schematic may include preamplifiers, temperature sensing circuits, heater circuits, trim components, test points, etc, as part of the DTG. Polarity, phasing, and axes identification of appropriate circuits shall be shown as well as their inter-connections with the electronics capture loops. A typical electrical schematic is shown in Fig 4.

3.5.2 Circuit Excitations and Impedances

The circuit excitations and impedances shall be as specified hereafter.

3.5.2.1 Spin Motor

- 1) Excitation, line to line: _____ $\pm$ _____ V [rms, _____] [dc, _____ phase, _____ $\pm$ _____ Hz].

Specify wave shape if other than sinusoidal, also grounding, harmonic content, ripple, power supply impedance, etc, if required. The frequency may be selected to reduce the in-phase-spring-rate drift rate for each individual gyro.

- 2) Starting current: _____ mA maximum.

A higher voltage, a different frequency, and the application time maybe specified for starting if required.

- 3) Starting power: _____ W maximum.
- 4) Running current: _____ mA maximum.
- 5) Running power: _____ W maximum.

As an alternate to running current, and running power, running voltamperes may be specified, or the specification may state: The impedance of the spin motor winding shall be _____ $\pm$ _____ Ω [+, -] j _____ $\pm$ _____ Ω when measured at _____ Hz and at [operating temperature, _____ $\pm$ _____ $^{\circ}\text{C}$].

- 6) Phase splitting capacitor: _____ $\pm$ _____ F.

3.5.2.2 Pickoffs

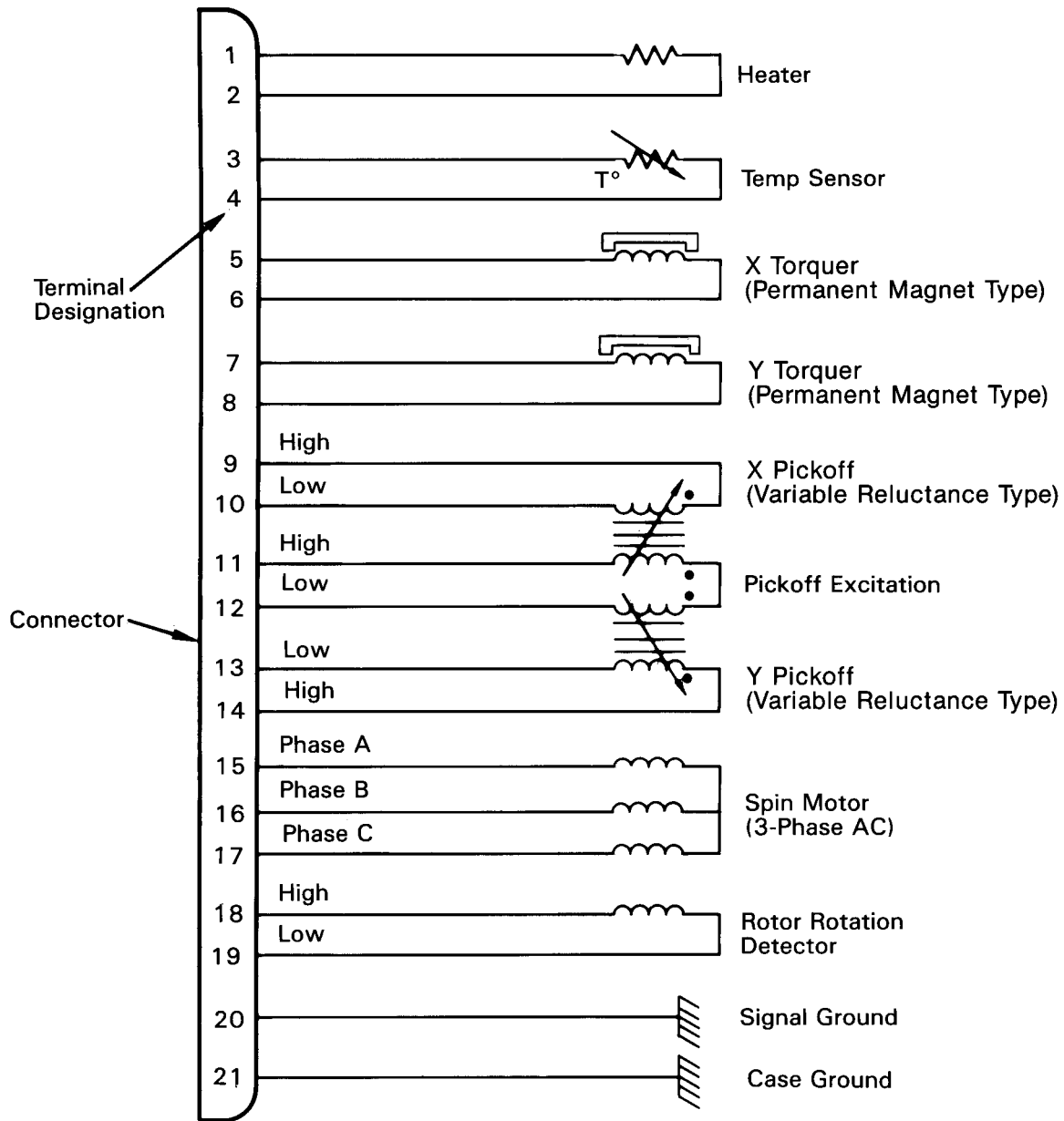
- 1) Excitation: _____ $\pm$ _____ [V, mA] [rms, _____] _____ $\pm$ _____ Hz.

Phase locking with spin motor excitation may be required.

- 2) Harmonics: _____ percent maximum of fundamental.

Specify wave shape if other than sinusoidal.

- 3) Primary impedances: Each primary impedance as measured with the secondary [open circuited, connected to the load impedance specified in (5) below] shall be _____ $\pm$ _____ Ω [+, -] j _____ $\pm$ _____ Ω when measured at _____ Hz and at [operating temperature, _____ $\pm$ _____ $^{\circ}\text{C}$].



NOTES:

- 1 — Phasing and polarities of pickoffs, torquers, motor and rotation detector must be specified.
- 2 — Alternate or additional circuit elements must be shown if required; such as pickoff amplifiers with supply voltages, optical or capacitance pickoffs, pickoff load resistors, solenoid torquers, torquer trim components, 2-phase or permanent-magnet motors, safety thermostats, heater terminal pins, etc.

Figure 4—Typical DTG Electrical Schematic

- 4) Secondary impedances: Each secondary impedance measured with the primary [open circuited, short circuited] shall be $\pm \text{ } \Omega$ [+,-] j $\pm \text{ } \Omega$, when measured at $\text{ } \text{Hz}$ and at [operating temperature, $\pm \text{ } ^\circ\text{C}$].
- 5) Load impedances: $\pm \text{ } \Omega$ [+,-] j $\pm \text{ } \Omega$.

- 6) Carrier phase shift, primary to secondary voltage: _____ $\pm$ _____ $^{\circ}$, when connected to the specified load.

Characteristics of other than variable reluctance pickoffs such as optical pickoffs, capacitance pickoffs, tuned resonance pickoffs, may be specified. Power supply requirements for pickoff preamplifiers as applicable, may also be specified.

3.5.2.3 Temperature Control

- 1) Warm-up heater excitation: _____ $\pm$ _____ V [dc, ac, _____ $\pm$ _____ Hz].
- 2) Warm-up heater power: _____ W maximum.
- 3) Control heater excitation: _____ $\pm$ _____ V [dc, ac, _____ $\pm$ _____ Hz].
- 4) Control heater power: _____ W maximum.

The output of the temperature sensor(s) shall be _____ $\pm$ _____ [Ω , V, μ A, _____] in the operating temperature range specified in 3.3.5. The temperature rise of the sensor due to self-heating shall not exceed _____ $^{\circ}$ C at _____ mA. The scale factor of the temperature sensor(s) shall be [+ , -] _____ $\pm$ _____ [$\Omega/^{\circ}$ C, V/ $^{\circ}$ C, μ A/ $^{\circ}$ C _____] at operating temperature.

Resistance Temperature Detectors (RTD), thermistors, thermocouples, or other means of temperature control may be specified.

3.5.2.4 Torquers

The resistance of each torquer shall be _____ $\pm$ _____ Ω and the inductance of each shall _____ $\pm$ _____ mH at [operating temperature, _____ $\pm$ _____ $^{\circ}$ C].

For variable reluctance torquers, specify excitation winding current or voltage, and impedances of both windings.

3.5.2.5 Rotor Rotation Detector

- 1) Impedance: _____ Ω , maximum, when measured at _____ Hz.
- 2) Load: _____ Ω , minimum.

3.5.3 Test Points

Specify the test points required for monitoring and testing of the DTG. These may include those for excitation voltages, control signals, or temperature sensor(s). Any special buffering or scaling requirements should be specified.

3.5.4 Grounding

Specify electrical grounding design requirements (for example, requirements for isolation between input, output, and power returns and the grounding requirements for shields, gyro case and critical components).

3.5.5 Closed-Loop Output Signals

When the gyro is operated in the closed-loop mode with associated electronics one of the following types of output signals is required:

3.5.5.1 Analog

Specify the characteristics of the analog output such as impedance characteristics, buffering, external drive capabilities, metering resistors, etc.

3.5.5.2 Digital

Specify the type and characteristics of the output signals required when the gyro is operating with a pulse torquing capture loop. The method of pulse torquing such as binary, ternary, etc, should be specified. The required waveshape should also be specified (see Fig 5 for an example of a waveshape specification).

3.5.6 Dielectric Strength

The leakage current shall not exceed _____ mA when _____ $\pm$ _____ V rms, at _____ Hz, are applied between isolated circuits, and between the case(s) and circuits isolated from the case(s), for _____ $\pm$ _____ s.

Different voltages may be specified for different circuits. In some instances, lower voltages may be specified for subsequent tests.

3.5.7 Insulation Resistance

The insulation resistance between isolated interface circuits and between the case(s) and circuits isolated from the case(s) shall not be less than _____ M Ω measured at _____ $\pm$ _____ V dc, applied for _____ $\pm$ _____ s.

Different voltages may be specified for different circuits.

3.5.8 Electromagnetic Interference

The electromagnetic emissions shall conform to _____.

Describe the requirements. In the United States, a common standard is MIL-STD-461C-1987 [5].

3.5.9 Magnetic Leakage

The magnetic leakage shall not exceed _____ [mT, G] at a distance of _____ $\pm$ _____ [cm, in] from the DTG in any direction.

3.6 Environmental Requirements

This section contains environmental requirements only. Test procedures that are to be used, including required combinations of environments, are covered in 4.6.

3.6.1 Storage

The gyro shall conform to all requirements of this specification after exposure to the following environments or specified combinations thereof, while packaged as specified in Section 5..

The procuring organization shall list the applicable environments from 3.6.4 and specify the limits for each based on the storage conditions expected.

3.6.2 Transport

The gyro shall conform to all requirements of this specification after exposure to the following environments or specified combinations thereof, while packaged as specified in Section 5.

The procuring organization shall list the applicable environments from 3.6.4 and specify the limits for each based on the transportation conditions expected.

3.6.3 Operation

In order to properly specify the environmental requirements for a gyro, three different sets of environments or environmental limits as defined in 3.6.3.1, 3.6.3.2, and 3.6.3.3 may need to be described. A guide for the selection of the environments most often included in each of the three sets can be obtained by referring to Table 3 of this document.

3.6.3.1 Operating Environment

The gyro shall conform to all requirements of this specification during exposure to the following environments or specified combinations thereof (except during exposure to _____ where the deviations of this specification are given in the following sections).

Where degraded performance is to be allowed, include the parenthetical phrase in 3.6.3.1 and list in the blank space those environments for which degraded performance is allowed. The procuring organization should list the applicable environments from 3.6.4 and specify the limits for each based on the conditions expected when the gyro is in use. For those environments where degraded performance is allowed, specify the performance deviation in the section that specifies the environment.

3.6.3.2 Survival Environment, Operating

The gyro shall conform to all requirements of this specification after the operating gyro has been exposed to the following environments or specified combinations thereof.

The procuring organization shall list the applicable environments from 3.6.4 and specify the limits for each based on the conditions expected when the gyro is operating but not in use.

3.6.3.3 Survival Environment, Nonoperating

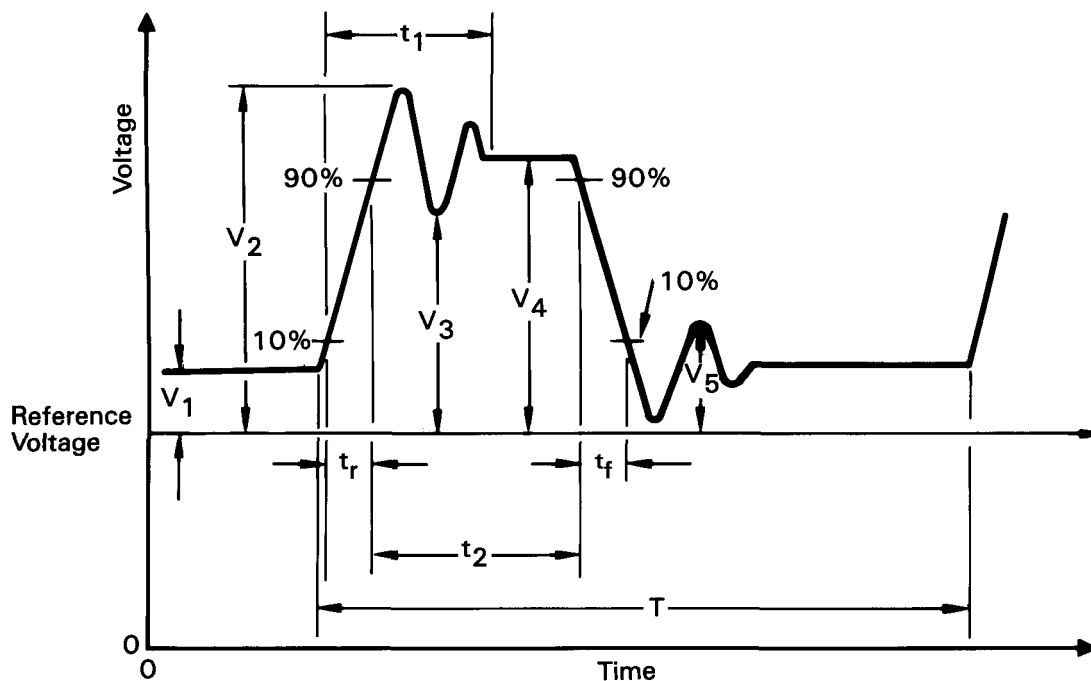
The gyro shall conform to all requirements of this specification after the nonoperating gyro has been exposed to the following environments or specified combinations thereof.

The procuring organization shall list the applicable environments from 3.6.4 and specify the limits for each based on the conditions expected when the gyro is not operating. Such conditions are expected to occur when the gyro is mounted in the system and the system is stored or transported in severe environments.

3.6.4 Environments

Environmental characteristics shall be as specified hereafter.

This list is intended as an aid to the selection of the applicable environments under 3.6.1, 3.6.2, and 3.6.3.



	Units	Maximum	Minimum	Remarks
V_1	volts	_____	_____	steady-state low voltage
V_2	volts	_____	N/A	overshoot voltage
V_3	volts	N/A	_____	undershoot voltage
V_4	volts	_____	_____	steady-state high voltage
V_5	volts	_____	N/A	maximum low voltage transient
t_r	seconds	_____	_____	rise time
t_f	seconds	_____	_____	fall time
t_1/t_2	—	_____	N/A	ratio of the TURN-ON transient time to required ON time
t_2	seconds	_____	_____	duration of high voltage ON time
t_2/T	—	_____	_____	$t_2/T(100) = \text{duty cycle}$
T	seconds	_____	_____	waveform period

N/A — not applicable

Figure 5—Pulse Wave Shape Requirements

3.6.4.1 Vibration

3.6.4.1.1 Linear. Sinusoidal:

_____ [cm, inches] DA (double amplitude) _____ to _____ Hz; _____ [m/s^2 , g] peak _____ to _____ Hz. Sweep rate: _____ minutes per octave (continuous). Exposure time: _____ per axis.