



AEROSPACE RECOMMENDED PRACTICE

ARP988™**REV. B**

Issued 1972-02
Revised 2016-05
Reaffirmed 2022-04

Superseding ARP988A

(R) Electrohydraulic Mechanical Feedback Servoactuators

RATIONALE

This ARP is updated to incorporate the following changes:

- a. Technical updates
- b. The references cited in the document have been updated
- c. Typographical and grammatical errors have been corrected

ARP988B has been reaffirmed to comply with the SAE Five-Year Review policy.

FOREWORD

Mechanical feedback servoactuators have been used for missile and rocket booster applications to ensure the actuator automatically centers in the event all wire bundles (channels) commanding the actuator are severed (e.g., fire related to the use of propellants). This type of design helps to ensure a booster with multiple engines could thereby survive this type of failure.

Mechanical feedback (MFB) fly-by-wire (FBW) servoactuators typically compare the torque produced by the torque motor of an electrohydraulic servovalve, proportional to the electrical current command, with a torque derived mechanically from the output position of the servoactuator. Consequently, the loop closure does not suppress the torque motor non-linearities as it does in the more typical electrical feedback FBW servoactuator and, for example, the torque motor non-linearity, saturation effects and magnetic hysteresis reflect directly into servoactuator linearity, saturation and hysteresis performance limitations, respectively. These features of mechanical-feedback FBW servoactuators place some limits on their performance capability. In addition, their performance requirements must be expressed in slightly different terms.

SAE Executive Standards Committee Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2022 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
<http://www.sae.org>

SAE WEB ADDRESS:

Full document details: [SAE ARP988B](#)

For more information on this standard, visit
<https://www.sae.org/standards/content/ARP988B/>

Documents

Document Sharing Hub

TABLE OF CONTENTS

1.	SCOPE.....	3
1.1	Field of Application.....	3
2.	REFERENCES.....	3
2.1	Applicable Documents	3
2.1.1	SAE Publications.....	3
2.1.2	EASA Publications	3
2.1.3	FAA Publications.....	4
2.1.4	AIA Publications	4
2.1.5	U.S. Government Publications.....	4
2.2	Definitions	4
2.2.1	General.....	4
2.2.2	Electrical Characteristics.....	5
2.2.3	Static Performance Characteristics.....	6
2.2.4	Dynamic Performance Characteristics.....	9
2.3	Symbols and Abbreviations	10
3.	SPECIFICATION CONSIDERATIONS	11
3.1	Scope	11
3.2	Reference Specifications	11
3.3	Requirements.....	11
3.3.1	Mechanical Design Requirements	11
3.3.2	Electrical Design Requirements.....	13
3.3.3	Hydraulic Design Requirements	14
3.3.4	Performance Requirements	15
3.3.5	Environmental Requirements.....	19
4.	NOTES.....	21
4.1	Revision Indicator.....	21
FIGURE 1	POSITION CURVE	7
FIGURE 2	LINEARITY/SYMMETRY	8
FIGURE 3	RECOMMENDED TORQUE MOTOR COIL CONNECTIONS.....	13

1. SCOPE

This recommended practice is intended as a guide for the specification of electrohydraulic mechanical feedback servoactuators used for position control. It provides performance definitions and capabilities that are specific to mechanical-feedback servoactuators and different from those applicable to electrical-feedback servoactuators.

1.1 Field of Application

The recommendations contained herein are confined to the input and output characteristics of electrohydraulic mechanical feedback servoactuators. It does not cover hydro-mechanical feedback servoactuators which do not require electrohydraulic servovalves for operation. The information presented should be useful for standardizing the terminology and for specification of physical and performance parameters.

The recommendations do not restrict nor attempt to define the internal design characteristics of servoactuators. As such, the material is equally applicable to servoactuators having different internal functioning, different ratings, different physical size, etc. In certain instances, standards for actuator design are recommended to increase interchangeability as, for example, pigtail color-coding and actuator polarity.

The requirement recommendations contained herein should be adequate to describe electrohydraulic mechanical feedback servoactuators used for position control. Additional requirements may be necessary to define special requirements for specific control systems. Certain dynamic compensation methods will be discussed.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP1281	Actuators: Aircraft Flight Controls, Power Operated, Hydraulic, General Specification For
AS4059	Aerospace Fluid Power – Contamination Classification for Hydraulic Fluids
ARP4386	Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies
AS4941	Aerospace - General Requirements for Commercial Aircraft Hydraulic Components
AS5440	Hydraulic Systems, Military Aircraft, Design and Installation, Requirements For
AS8775	Hydraulic System Components, Aircraft and Missiles, General Specification For

2.1.2 EASA Publications

Available from European Aviation Safety Agency, Ottoplatz, 1, D-50679 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

CS-25 Certification Specifications for Large Aeroplanes

CS-29 Certification Specifications for Large Rotorcraft

2.1.3 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

14 CFR Part 25 Code of Federal Regulations, 14 CFR 1.1, part 25 Airworthiness Standards, Transport Category Airplanes

14 CFR Part 29 Airworthiness Standards: Transport Category Rotorcraft

2.1.4 AIA Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

NASM33540 Safety Wiring, Safety Cabling, Cotter Pinning, General Practices For

2.1.5 U.S. Government Publications

Copies of these documents are available online at <http://quicksearch.dla.mil>.

MIL-PRF-87257 Performance Specification: Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile

2.2 Definitions

Refer to ARP4386 for any terminologies and definitions not noted below.

2.2.1 General

SERVOACTUATOR, ELECTROHYDRAULIC, MECHANICAL FEEDBACK

An electrical-input, hydraulic powered position control servoactuator which is capable of continuous control and includes a mechanical feedback device for loop closure. It includes the following elements:

a. Servovalve, Electrohydraulic

An electrical-input servovalve which controls the position, rate of change of position, and force or torque output of the actuator.

b. Actuator, Hydraulic

A piston(s) or vane(s) type mechanism which utilizes hydraulic power to position a load. The output shaft of the hydraulic actuator is capable of control displacement which may be either rectilinear or rotary.

c. Feedback, Mechanical

A mechanical device which transmits the actuator output shaft position to the servovalve. Normally this position feedback is converted to a torque which is applied to the torque motor armature.

2.2.2 Electrical Characteristics

TORQUE MOTOR

The electromechanical transducer commonly used in input stages of the MFB actuators.

INPUT CURRENT

The current to the MFB servoactuator, expressed in mA, which commands actuator position.

RATED CURRENT

The specified input current (expressed in mA) of either polarity to produce rated stroke. The particular coil connection (differential, series, or parallel) must be specified in conjunction with the rated current. Rated current does not include null bias current.

QUIESCENT CURRENT

A dc current that is present in each torque motor coil when using a differential coil connection, the polarity of the current in the coils being in opposition such that no electrical control power exists.

ELECTRICAL QUIESCENT POWER

The power dissipation required for differential operation when the current through each coil is equal and opposite in polarity.

ELECTRICAL CONTROL POWER

The power dissipation required for control of the servoactuator. Control power is a maximum with full input signal, and is zero with zero input signal. It is independent of the coil connection (series, parallel, or differential) for any conventional two coil operation. For differential operation, the control power is the power consumed in excess of the electrical quiescent power. This power increase is a result of the differential current change.

TOTAL ELECTRICAL POWER

The sum of the instantaneous control power and the quiescent power, expressed in mW.

COIL IMPEDANCE

The complex ratio of coil voltage to coil current. It is important to note that the coil impedance may vary with signal frequency, signal amplitude and other operating conditions due to back emf generated by the moving armature of the torque motor.

COIL RESISTANCE

The DC resistance of each torque motor coil, expressed in ohms.

POLARITY

The directional relationship between actuator motion and input current.

DITHER

A low amplitude, relatively high frequency electrical signal, sometimes superimposed on the servoactuator input to reduce threshold. Dither is expressed by the dither frequency (Hz) and the peak-to-peak dither current amplitude (mA).

2.2.3 Static Performance Characteristics

CONTROL POSITION

The magnitude and direction of actuator output shaft displacement from the mechanical null position. Rectilinear actuator position is expressed in inches (or cm) extend (+) and inches (or cm) retract (-). Rotary actuator position is expressed in deg (or rad) cw (+) and deg (or rad) ccw (-) as viewed from the output shaft side of servoactuator.

MECHANICAL NULL

The specified zero reference point for actuator position.

NULL BIAS

The input current required to bring the servoactuator to mechanical null excluding the effects of hysteresis, expressed as percent of rated current.

NULL SHIFT

A change in null bias, expressed as percent of rated current. Null shift may occur with changes in supply pressure, temperature, external load, and other operating conditions.

RATED STROKE

The specified displacement of the actuator output shaft from mechanical null corresponding to the rated current with no external load applied. Normally, maximum displacement is limited by fixed mechanical stops. The maximum displacement is not necessarily the same as rated stroke. Rated stroke for rectilinear actuators is expressed in inches (or cm) extend (+) and inches (or cm) retract (-). Rated stroke for rotary actuators is expressed in deg (or rad) cw (+) and deg (or rad) ccw (-) as viewed from the output shaft side of servoactuator. In most applications the positive and negative rated strokes are symmetrical.

POSITION CURVE

The graphical representation of actuator control position versus input current. This is usually a continuous plot of a complete cycle between plus and minus rated current values with no external load applied. See Figure 1.

NORMAL POSITION CURVE

The locus of the midpoints of the complete cycle position curve, which is the zero hysteresis position curve. Usually servoactuator hysteresis is sufficiently low such that one side of the position curve can be used for the normal position curve. See Figure 1.

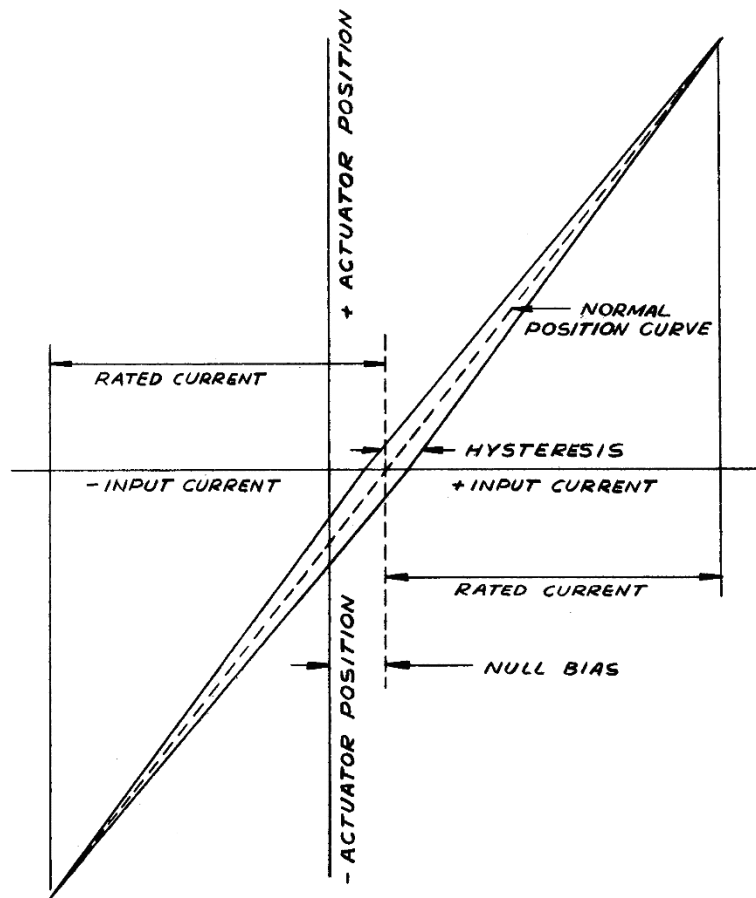


Figure 1 - Position curve

POSITION GAIN

The slope of the actuator control position versus input current curve in any specific operating region expressed in in/mA (cm/mA) or deg/mA (rad/mA). When this term is used without qualification, it is assumed to mean normal position gain.

RATED POSITION GAIN

The gain determined by dividing rated total actuator displacement between plus and minus rated currents by the total change in current between plus and minus rated currents.

NORMAL POSITION GAIN

The slope of a straight line drawn from the zero position point of the normal position curve, throughout the range of rated current of one polarity, and drawn to minimize deviations of the normal flow curve from the straight line. Position gain may vary with the polarity of the input and with changes in operating conditions (see Figure 1).

SYMMETRY

The degree of equality between the normal position gain of one polarity and that of the reversed polarity. Symmetry is measured as the difference in normal flow gain of each polarity, expressed as a percent of the greater (see Figure 2).