The purpose of this program was to document and pass on experience to current and future generations of flight control engineers, hopefully, to prevent costly rediscovery of past mistakes and to stimulate trade studies between possible competing mechanizational approaches.

The documentation is divided into two volumes. Volume I (NASA CR-2500) contains the technical discussion while this volume is a compendium of stability augmentation system and autopilot block diagrams and descriptive material for 48 different types of aircraft. These provide a broad representation of the many mechanizational approaches which have been employed in the past.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. BLOCK DIAGRAMS</td>
<td>2</td>
</tr>
<tr>
<td>III. REFERENCES</td>
<td>139</td>
</tr>
</tbody>
</table>
SECTION I

INTRODUCTION

This volume contains a compendium of SAS and autopilot block diagrams for some 48 attack, bomber, cargo, drone, fighter, research, and transport type aircraft. It also contains references to specific documents from which information was gleaned for this study.

This compendium incorporates and expands upon an earlier effort (Ref. 67) initiated by the A-18 Aerospace Control and Guidance Systems Committee of the Society of Automotive Engineers. It is by no means a complete exposition of systems past and present. There are many systems for which no information was available, and there are others for which the information available was incomplete or conflicting, and therefore not included here.

An initial attempt was made to put all block diagrams into a consistent format which identified functional blocks and associated transfer characteristics, functional switching, etc. However, it rapidly became apparent that such a task was beyond the scope of this program. Therefore in most instances the diagrams presented here have been reproduced directly from the original documents listed in the references. In all probability they reflect but one version of systems which may have undergone several modifications. Consequently, additions or revisions are solicited from those who make use of these volumes.
### SECTION II

**BLOCK DIAGRAMS**

<table>
<thead>
<tr>
<th>AIRCRAFT</th>
<th>Pages</th>
<th>Ref. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3J-1</td>
<td>4-8</td>
<td>5</td>
</tr>
<tr>
<td>A-4</td>
<td>9-11</td>
<td>1</td>
</tr>
<tr>
<td>A-7A</td>
<td>12-14</td>
<td></td>
</tr>
<tr>
<td>B-52</td>
<td>15-19</td>
<td>9, 10</td>
</tr>
<tr>
<td>B-58</td>
<td>20-29</td>
<td>11, 32</td>
</tr>
<tr>
<td>B-66</td>
<td>30</td>
<td>67</td>
</tr>
<tr>
<td>XB-70</td>
<td>31-33</td>
<td>12</td>
</tr>
<tr>
<td>C-5A</td>
<td>34-45</td>
<td>16, 17, 19</td>
</tr>
<tr>
<td>KC-135</td>
<td>46</td>
<td>67</td>
</tr>
<tr>
<td>XC-142A</td>
<td>47-49</td>
<td>18, 20</td>
</tr>
<tr>
<td>E-1B</td>
<td>50-51</td>
<td>100</td>
</tr>
<tr>
<td>S-2D/S-2E</td>
<td>52-53</td>
<td>100</td>
</tr>
<tr>
<td>Regulus II</td>
<td>54</td>
<td>22</td>
</tr>
<tr>
<td>Q-2C</td>
<td>55-56</td>
<td>24, 31</td>
</tr>
<tr>
<td>BQM-34</td>
<td>57-58</td>
<td>25, 26, 33</td>
</tr>
<tr>
<td>MQM-74A</td>
<td>59-60</td>
<td>27</td>
</tr>
<tr>
<td>F3H</td>
<td>61-63</td>
<td>67</td>
</tr>
<tr>
<td>F-4</td>
<td>64</td>
<td>34</td>
</tr>
<tr>
<td>F-8D</td>
<td>65</td>
<td>3</td>
</tr>
<tr>
<td>F-14</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>F-86</td>
<td>67</td>
<td>37</td>
</tr>
<tr>
<td>F-89</td>
<td>68-69</td>
<td>38, 67</td>
</tr>
<tr>
<td>F-100D/F</td>
<td>70-72</td>
<td>41, 42, 67</td>
</tr>
<tr>
<td>F-101A</td>
<td>73</td>
<td>43, 67</td>
</tr>
<tr>
<td>F-101B</td>
<td>74-77</td>
<td>43, 44, 67</td>
</tr>
<tr>
<td>F-102</td>
<td>78</td>
<td>45, 46</td>
</tr>
<tr>
<td>F-105A</td>
<td>79-81</td>
<td>67</td>
</tr>
<tr>
<td>F-106</td>
<td>82-83</td>
<td>67</td>
</tr>
<tr>
<td>F-111</td>
<td>84-87</td>
<td>53-55</td>
</tr>
<tr>
<td>T-38</td>
<td>88</td>
<td>59</td>
</tr>
<tr>
<td>AVRO CF-100</td>
<td>89</td>
<td>67</td>
</tr>
<tr>
<td>AIRCRAFT</td>
<td>Pages</td>
<td>Ref. No.</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>Fiat G-91</td>
<td>90</td>
<td>67</td>
</tr>
<tr>
<td>Viggen (AJ-37)</td>
<td>91-95</td>
<td>58</td>
</tr>
<tr>
<td>VJ101-C</td>
<td>96</td>
<td>61</td>
</tr>
<tr>
<td>M2-F2</td>
<td>97</td>
<td>62</td>
</tr>
<tr>
<td>X-15</td>
<td>98-100</td>
<td>64, 65</td>
</tr>
<tr>
<td>B-707</td>
<td>101-103</td>
<td>67</td>
</tr>
<tr>
<td>DC-8</td>
<td>104-106</td>
<td>81</td>
</tr>
<tr>
<td>L-188</td>
<td>107-110</td>
<td>67</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R/D SYSTEMS</th>
<th>Pages</th>
<th>Ref. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GESAC</td>
<td>111-113</td>
<td>88, 89</td>
</tr>
<tr>
<td>Honeywell Adaptable</td>
<td>114-118</td>
<td>35</td>
</tr>
<tr>
<td>SFCS</td>
<td>119-124</td>
<td>90</td>
</tr>
<tr>
<td>NASA F9F-2</td>
<td>125-128</td>
<td>69-73</td>
</tr>
<tr>
<td>TWEAD I</td>
<td>129-130</td>
<td>74, 75</td>
</tr>
<tr>
<td>TWEAD II</td>
<td>131-134</td>
<td>78</td>
</tr>
<tr>
<td>AVRO-707C</td>
<td>135-137</td>
<td>79</td>
</tr>
<tr>
<td>Lear Rate Integrating</td>
<td>138</td>
<td>67</td>
</tr>
</tbody>
</table>
A3J-1 LONGITUDINAL CONTROL SYSTEM
LATERAL CONTROL SYSTEM

**BLOCK DIAGRAMS**

**A3J-1 LATERAL CONTROL SYSTEM**
A3J-1 AUTOMATIC FLIGHT CONTROL SYSTEM
TO FLAP CONTROL SYSTEM

RATIO CHANGER

TEIL ACTUATOR

FEEL BUNGEES

WASHOUT NETWORK

YAW DAMPER

AMPIFIER

SERVO VALVE

SERIES (YAW DAMPER ACTUATOR)

ELECTRICAL FEEDBACK

MECHANICAL FEEDBACK

BLOCK DIAGRAM

WASHOUT NETWORK

YAW DAMPER

SERVO VALVE

SERIES (YAW DAMPER ACTUATOR)

ELECTRICAL FEEDBACK

MECHANICAL FEEDBACK

HYDRAULIC SCHEMATIC

A3J-1 DIRECTIONAL CONTROL SYSTEM
A-4 Elevator Channel
A-4 Roll Channel
RUDDER BANDPASS FILTER → RUDDER SERVO AMPLIFIER → DUAL INPUT VALVE → RUDDER ACTUATOR

δPED, δr

MECHANICAL FOLLOW-UP

LOST MOTION LINK

PEDAL POSITION TRANSMITTER

RUDDER PEDALS OR TRIM

PILOT

Fs (IAS)

YAW RATE GYRO

AF

A-4 Yaw Channel
A-7A Pitch Axis
A-7A Roll Axis
B-52 Modified Yaw SAS Block Diagram

B-52 Modified Pitch SAS Block Diagram
B-52 Original Yaw Damper
B-52 Original AFCS
B-52 Longitudinal Control Wheel Steering
B-52 Lateral Control Wheel Steering
B-58 Stability Augmentation
B-58 Attitude Stabilization Mode

Pitch
B-58 Attitude Stabilization Mode
Lateral
C.S.S. SWITCH

Control Stick Steering Mode

STABILITY AUGMENTATION MODE

SWITCHING SUBSYSTEM

ATTITUDE STABILIZATION AND OPTIONAL MODES

Control Stick Steering Switch Depressed

Control Stick Steering Switch Released

B-58 Control Stick Steering Mode
B-58 Mach Mode
B-58 Mach-Altitude Mode
B-58 Constant Heading
B-58 Heading Nav Mode
B-58 Localizer Mode
B-58 Automatic Glide Path Mode
B-66 Autopilot
XB-70 Pitch Axis Augmentation

- Differential Servo Deflection Degrees EQUIVALENT ELEVON
- Master Cylinder Deflection Degrees EQUIVALENT ELEVON
- Guard Deflection
- Feel Force Gain, F(f)
- Compressible Dynamic Pressure
- Pitch Trim Knob Rotation
- Pilot Input Force
- Pitch Trim Actuator Position
- Pitch Column Position

\( \delta_{e_1} \) - Pitch Normal Acceleration at ROBWEIGHT Location
\( \delta_{e_2} \) - Pitch Normal Acceleration at Sensor Location
\( \gamma \) - Body Axis Pitch Rate
\( \alpha \) - Mach Number
\( \dot{\gamma} \) - Pitch Rate of Change
\( \dot{\alpha} \) - Forward Rate of Change

\( C_{D_0} \) - CAS Altitude Error
\( C_{D_1} \) - Hydraulic Differential Flow
XB-70 Roll Axis Augmentation
XB-70 Yaw Axis Augmentation

- Yaw Trim Actuator Position
- $F_p$ = Pilot Input Force
- $X_p$ = Roll Position (positive for right pedal forward)
- $K_{p/e}$ = Altitude Gain = $\frac{-\beta e}{\beta e}$
- $\dot{\gamma}$ = Body Axis Yaw Rate
- $\beta$ = Altitude Error (above or below)
- $\delta_{r}$ = Differential Servo in Degrees Equivalent Rudder
- $\dot{\delta}_{r}$ = Rudder Rate in Degrees Equivalent Rudder
- $\delta_{r}$ = Rudder Deflection
- $K_g$ = Gearing (1 at Gear Up, 1 at Gear Down)
Kq1 = 0.5

Kq2 = 2.0

SWITCH POSITION: 1 PITCH AUTOPILOT OFF
2 PITCH AUTOPILOT ENGAGED

C-5A Pitch Stability Augmentation System
C-5A Roll Stability Augmentation System (SAS)
C-5A Yaw Stability Augmentation System (SAS)
C-5A Pitch Autopilot: Inner Loops
C-5A Pitch Autopilot: Radar Approach, Glide Slope and Flare Modes
C-5A Pitch Autopilot: Vernav, Terrain Following and Mach/IAS Modes
C-5A Pitch Autopilot: Altitude Capture and Altitude Hold Modes
C-5A Roll Autopilot: Inner Loops Including Control Wheel Steering
C-5A Roll Autopilot: VOR and TACAN Modes

<table>
<thead>
<tr>
<th>SUB-MODE ENTRY</th>
<th>VOR, TACAN ( \leq 62 \text{ NM} )</th>
<th>TACAN &gt; 62 NM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPTURE</td>
<td>5.0 DEG</td>
<td>5.4 NM</td>
</tr>
<tr>
<td>PRE-TRACK</td>
<td>2.1 DEG</td>
<td>2.3 NM</td>
</tr>
<tr>
<td>TRACK</td>
<td>1.2 DEG</td>
<td>1.3 NM</td>
</tr>
</tbody>
</table>
C-5A Roll Autopilot: Courseline and Air-Drop Modes
C-5A Roll Autopilot: Localizer Mode, Including Autoland
C-5A Autothrottle Analytical Diagram
KC-135 Pitch Diagram

KC-135 Lateral-Directional Axis Diagram
XC-142A Pitch Control System Block Diagram
XC-142A Roll and Yaw Control System Block Diagram
XC-142A Collective-Throttle System Block Diagram
E-1B Roll Axis

S-2D/S-2E Roll Axis

53
Regulus II Lot I Autopilot
Q-2C Longitudinal Control System
$K_b = \frac{f(h)}{s+2}$

$K_\theta s \frac{(s+40)(s+100)}{(s+40)(s+100)}$

Derived Rate

Launch Condition Bias

Scheduled $\phi = f(h)$

$\theta (V.G.)$

Fitter AltCont.

Pitot-Static System

BQM-34 Pitch Axis
Der. Head. Hold

Norm

Rel.

\[ \frac{1}{s} \]

Limit

Actuator

\[ \delta_A \]

A/F

\[ \phi (V.G.) \]

IAS

\[ K_\phi \]

Derived Rate

\[ \frac{s}{(s+40)(s+100)} \]

\[ \frac{1}{s+2} \]

\[ K_\phi' \]

\[ \frac{10}{s} \]

\[ \phi_c \]

RQM-34 Roll Axis
\[ K_\theta = \text{pitch control gain} = \frac{G_\theta}{G_{\theta h}} \left( \frac{\text{deg}}{\text{deg}} \right) \]
\[ K_h = \text{altitude control gain} = \frac{G_h}{G_{\theta h}} \left( \frac{\text{deg}}{\text{ft}} \right) \]

Note: \( G_h \) is function of \( h_0 \)

\[ (\text{i.e. } G_h = \frac{\Delta V}{\Delta P} \bigg|_{h=h_0}) \]
MQO-A Atlieron Control System

\[
K_o = \ \text{Roll control gain} = \frac{G_o}{G_x}
\]
F3H PITCH CHANNEL

TURN MANEUVER COMPENSATION
MINIATURE CONTROL STICK (PITCH)

RATE GYRO

$\pm 50 \text{ deg/sec}$

$K_6$

$\pm 82 \text{ deg}$

VERTICAL GYRO

$G_{\text{TH}}$

$\dot{G}_{\text{TH}}$

$\dot{G}_{\text{TH}}$

$\frac{4.5}{1+4.5}$

MANEUVER (PITCH)

RELIEF ENGAGE

MANEUVER (PITCH)

STABILATOR ACTUATOR

$K_{\text{st}}$

$1+0.16$

SERVO FOLLOW-UP

RELIANCE ENGAGE

MANUAL TRIM

RELIEF ENGAGE

MANEUVER CONTROLLER

MINIATURE CONTROL STICK

AND RAYS (PITCH)

$\pm 70 \text{ deg}$

ALTITUDE CONTROLLER

$K_a$

$\pm 150 \text{ feet}$

MANEUVER ENGAGE

RELIEF ENGAGE

STAND BY
F3H YAW CHANNEL

\[ K_\gamma \]

\[ f(\dot{\gamma}) \]

\[ \frac{s}{1 - s} \]

\[ \frac{s}{\left( \frac{1}{100} \right)^2 + \left( \frac{0.2}{s} \right)^2} = 1 \]

\[ = 0.5 \text{ INCH} \]

\[ K_{SR} = 0.075 \]

\[ = 5^\circ/\text{SEC} \]

\[ \text{AIRFRAME} \]
YAW AXIS DAMPER

ROLL AXIS DAMPER

F-8D
\[ \delta_e = K_\alpha (\alpha - \alpha_T) + K_\dot{\theta} \dot{\theta} \quad \text{when} \quad K_\alpha (\alpha - \alpha_T) + K_\dot{\theta} \dot{\theta} > 0 \]
\[ \delta_e = 0 \quad \quad \text{when} \quad K_\alpha (\alpha - \alpha_T) + K_\dot{\theta} \dot{\theta} < 0 \]

F-86 Pitch-up Preventer
F-89 Sideslip Stability Augmenter
(FC) indicates block functions which are part of the flight controller - WG1828-1

Shaded blocks indicate automatic gain control functions of the airspeed compensator - PG7007B-3

(q) indicates gain is varied as a function of differential pressure

(tas) indicates gain is varied as a function of true air speed

‡ symbol indicates signal summing

F-89 Autopilot
PITCH CHANNEL
F-100 D/F Autopilot
F-100 D/F Autopilot
F-101A Autopilot

73
STABILATOR BRIDGE CIRCUIT

NOTES:

- Closed to B when Mach Hold is engaged and closed to A when Altitude Hold is engaged.
- Closed to D when Fire Control mode is engaged.
- Open for Attitude Hold.
- Open for Control Stick Steering and Fire Control.
- Closed for Pitch Attitude Hold.
- Open for Mach Hold.
- Closed for Altitude Hold.
- Closed for Beam Guidance.
- Closed for Control Stick Steering.
- TAScheduling
- Mach Scheduling
- Airspeed Scheduling
- Altitude Scheduling

F-101B Autopilot
VERTICAL GYRO

AIRCRAFT

ROLL RATE

PRE-EngAGE TRIM

Lag

SERVO

AILERON SERVO AMPLIFIER

MODIFIED HIGH PASS

FEEDBACK

AILERON CONTROL SYSTEM

FEEDBACK

MODIFIED HIGH PASS

SERVO

AILERON SERVO AMPLIFIER

PRE-EngAGE TRIM

LAG

FIRE CONTROL

TRIM

BANK LIMITER

VERTICAL GYRO

J-4 COMPASS SYSTEM

INTEGRATED COUPLER

COMPASS SYNC

DEMODULATOR

BEAM GUIDANCE

Notes:

Δ OPEN WHEN AUTOPILOT IS ENGAGED.

Δ OPEN FOR CONTROL STICK STEERING MODE.

Δ SWITCH POSITION SHOWN FOR BEAM GUIDANCE MODE.

Δ CLOSED AFTER AUTOPILOT IS ENGAGED.

Δ CLOSED FOR FIRE CONTROL MODE.

Δ OPEN FOR FIRE CONTROL MODE.

Δ GAIN SCHEDULED AS A FUNCTION OF AIRSPEED.

Δ INDICATES SUMMING POINT.

AILERON BRIDGE CIRCUIT

F-101B Autopilot

75
NOTE:

This loop is not in circuit when damper or autopilot is engaged.

\[ \text{INDICATES GAIN SCHEDULED AS FUNCTION OF AIRSPEED.} \]

\[ \text{INDICATES GAIN SCHEDULED AS FUNCTION OF MACH NUMBER.} \]

Rudder bridge circuit

F-101B Autopilot

76
PARALLEL SERVO

E-H Valve

Engaged

Disengaged

Servo Ram

Force Switch

System Engage

Hi Pass

P-1013 Stick Pusher
F-102 YAW DAMPER

F-102 PITCH DAMPER
F-105A PITCH CHANNEL
F-105A ROLL CHANNEL
F-105A YAW CHANNEL

Rudder Actuator

\[ \frac{1}{1 + 0.075} \]

Linkage

\[ K_L \]

Airframe

\[ \delta_R \]

Series Actuator Loop

\[ \pm 7.5^\circ \text{ LIMIT} \]

\[ K_{sa} \]

\[ \left( \frac{S^2}{20} + \frac{2(4)}{80} S + 1 \right) \]

Pre-Amp.

\[ K_{PA} \]

Canceler

\[ \frac{K_c S}{1 + 1.15 S} \]

Rate Gyro

\[ \dot{\psi} \]

Gain Changer

\[ K_{ADC} f(\dot{\psi}) \]

Lateral Accelerometer

\[ K_{HY} \]

\[ \dot{N}_Y \]

Side-Slip Amplifier

\[ K_{SSA} \]

Roll Rate Gyro

\[ \dot{\psi} \]
MANUAL MODE, PITCH DAMPER MODE AND AFCS MODE

ELECTRICAL FEEDBACK

SERVO AMPL

108+1

DAMPER

AFCS

SUM AMPL

DAMPER

Synchronizer

AFCS

DAMPER

AFCS

Synchronizer

AFCS

Synchronizer

AFCS

Synchronizer

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER

AFCS

DAMPER
MANUAL MODE, YAW DAMPER AND TURN COORDINATOR MODE, AND AILAS MODE

YAW RATE GYRO

K_p s
1+s

AILAS

TRIM CANAL POT

ELECTRICAL FEEDBACK
AILAS

DAMPER
OR MAN

DAMPER

AFCS (AILAS MODE)

AILAS

RUDDER COMMAND

SERVO AMP.

1 RIS-1

DAMPER

DAMPER

AILAS

AILERON

AILERON POS POT

AILERON POS POT

AILERON POS POT

AILERON POS POT

AILERON

AILERON

(PILOT'S INPUTS)

RUDDER

RUDDER

TRIM AND FEEL

RUDDER TRIM AND FEEL

ACTUATING CYLINDER (KAM)

MECHANICAL FEEDBACK

SUMMING JUNCTIONS

\(\times\) IRREVERSIBLE

\(\times\) REVERSIBLE

COMPONENTS
OF AIR DATA
COMPUTER

ALL SWITCHES SHOWN IN
DAMPER MODE.

F-106
F-111 Roll Channel Functional Diagram
F-111 Yaw Channel Functional Diagram
F-111 Adaptive Principle
T-38 Stability Augmentation System
There is no Pitch Axis in this autopilot.

FIAT G-91 Lateral Diagram
Viggen Pitch Axis Stability Augmentation and Control Stick Steering Mode
Viggen Roll SAS-CSS Loop
Viggen Yaw Axis Stability Augmentation System
Viggen Pitch Outer Loops
Viggen Lateral Outer Loops
GENERAL BLOCK DIAGRAM
FOR ROLL AND PITCH AXES

STICK POSITION

MECHANICAL GEARING

GAIN & MODEL

SHAPING NETWORK

RATE FEEDBACK

ATTITUDE FEEDBACK

SHAPING NETWORK

AMPLIFIER & ACTUATOR

ENGINES & FUEL CONTROL

AIRPLANE DYNAMICS

RUDDER PEDAL POSITION

SHAPING NETWORKS

AMPLIFIER AND SERVO

RATE GYRO

TILT ACTUATOR

1/3

AIRPLANE DYNAMICS

YAW AXIS
BLOCK DIAGRAM

VJ101-C

96
M2-F2 Lateral-Directional Flight Control System
X-15 Pitch Axis Configuration Block Diagram
X-15 Yaw Axis Configuration
B-707 Autopilot
Rudder Channel

B-707 Autopilot
BASIC ROLL STABILIZATION

\[ \frac{K 40s}{(40s+1)(8s+1)(02s+1)} \]

\[ \phi_c \]

\[ \phi_{\text{in}} \]

Position Servo

E/M Servo

Tach.

Synch.

Aux. May.

\[ 0 \]

12

ILS a.c.

ROLL PATH AND NAV MODES

Doppler & X-Track

Heading Select

D.G.

Heading Synch.

Head Hold

\[ \frac{K}{s} \]

Turn Knob

Limit

Out of Det.

Detent

\[ \phi_c \]

DC-8 Roll Axis
YAW STABILIZATION

DC-8 Yaw Axis
L-188 Autopilot
L-188 Autopilot
L-188 Autopilot
L-188 Autopilot

LONGITUDINAL

PITCH RATE
GYRO & A/P COUPLER

RATE FEEDBACK

POSITION FEEDBACK

HYDRAULIC AMPLIFIER & MODULATING PISTON

SERVO AMPLIFIER

LINKAGE

MAIN BOOST SPOOL

HYDRAULIC RAM

EE/Xp

ELEVATOR SERVO

VERTICAL GYRO
mv/θ=200 mv/deg. PROP ERECT to 80deg Erection Rate, 1/20 deg/sec/deg.

OUTPUT LIMITER

SYNCHRONIZER

Switch Open when A/P Engaged

FIXED EXC.

INTEGRATOR .07/s

Airspeed Error Compensation

Switch Closed Altitude Control

Pitch Controller

Up Attitude

FLAP POSITION TRANSMITTER & ATTENUATOR

AIRFRAME
GESAC Pitch Channel (F-4A)
GESAC Roll Channel (F-4A)
GESAC Yaw Channel (F-4A)
Adaptable FCS Pitch Stability Augmentation System (F-4)
Adaptable FCS Lateral-Directional Stability Augmentation System (F-4)
NOTE:

\( l_x = 12 \text{ FT} \)

\[ \frac{Z_{\delta e}}{Z_\alpha} = 0.2 \]
Adaptable FCS Pitch Autopilot Functions (F-4)
Adaptable FCS Lateral/Directional Autopilot Functions
F-4 SPCS Directional Axis
Switching Logic

\[ SW = C_1 + C_2 + C_3 + \text{SMRD} \hat{\theta}_1 + \text{SMRD} \hat{\theta}_2 \]

\[ V_1 = 1.66V \]
\[ V_2 = 2.42V \]
\[ V_0 = 4.56V \]

\[ \text{BIAS} = 30^\circ \alpha \]

Note: 0 to 100% Modulation Occurs for Range of 0 to \( V_0 \).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Nominal</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>( K_1 )</td>
<td>0.5</td>
<td>0.25 ... 1.0</td>
</tr>
<tr>
<td>( K_2 )</td>
<td>15,000</td>
<td>TBA</td>
</tr>
<tr>
<td>( K_3 )</td>
<td>6.0</td>
<td>3.0 ... 12.0</td>
</tr>
<tr>
<td>( K_4 )</td>
<td>TBA</td>
<td></td>
</tr>
<tr>
<td>( K_5 )</td>
<td>TBA</td>
<td></td>
</tr>
<tr>
<td>( K_6 )</td>
<td>TBA</td>
<td></td>
</tr>
<tr>
<td>( K_7 )</td>
<td>0.843</td>
<td>TBA</td>
</tr>
</tbody>
</table>

\[ \hat{\theta}_1 \]

0.12 V/Deg/Sec

\[ \hat{\theta}_2 \]

0.12 V/Deg/Sec

\[ \alpha L_1 \] 0.6V/Deg
\[ \alpha R_1 \] 0.6V/Deg

\[ \alpha L_2 \] 0.6V/Deg
\[ \alpha R_2 \] 0.6V/Deg

Comparator C_1

\[ K_2 \]

BIAS \( [S + K_3] [S + 50] [S + 50] \)

Comparator C_2

\[ \frac{V_0}{V_1} \]

Pulse Width Modulator

Comparator C_3

\[ \frac{K_6}{[S + K_4] [S + K_5]} \]

Logic and Switching

To CVU-1

To CVU-2

To CVU-3

To CVU-4

SMRD \( \hat{\theta}_1 \)

SMRD \( \hat{\theta}_2 \)

F-4 SFCS Stall Warning
F-14 Survivable Stabilator Actuator Package
F-4 SFCS Adaptive Gain Changer
Grumman F9F-2 Attitude Command FBW

(a) Pitch channel.

- Pitch gyro
- Rate gyro
- Vertical gyro (pitch)
- Stick controller
- Pitch trim
- Servo amplifier
- Servo motor
- Follow-up canceler system
- Tachometer
- Amplifier and motor
- Cancelerelsen
- Elevator control system
- Airplane
(b) Roll and yaw channels.

Grumman F9F-2 Attitude Command BFW

126
(a) Pitch channel.

Grumman F9F-2 Rate Command FBW
Grumman F9F-2 Normal-Acceleration Control System
SYSTEM BLOCK OF PITCH C.A.S.

ONE CHANNEL

FLT 3.9

TWEAD I Pitch Axis
TWEAD I Lateral-Directional
TWEAD II Longitudinal Functional CAS Block Diagram
F-4C TWEAD II CAS Longitudinal Block Diagram
TWEAD II Lateral-Directional Functional CAS Block Diagram
AVRO Pitch Rate Demand Control System (Duplex)
AVRO Roll Rate Demand Control System (Simplex with Comparison Monitor)
AVRO Rudder Control System Including Yaw Damper
(Simplex with Comparison Monitor)
LONGITUDINAL DIAGRAM

F-100 Lear Rate Integrating Autopilot

138
REFERENCES


* U.S. GOVERNMENT PRINTING OFFICE: 1975--635-048 / 50