NASA CONTRACTOR REPORT

NASA CR-2501

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FLIGHT CONTROL SYSTEMS PROPERTIES AND PROBLEMS

Volume II - Block Diagram Compendium

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Prepared by
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16. Abstract

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.

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TABLE OF CONTENTS

		Page
I.	INTRODUCTION	1
II.	BLOCK DIAGRAMS.	2
III.	REFERENCES	139

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.

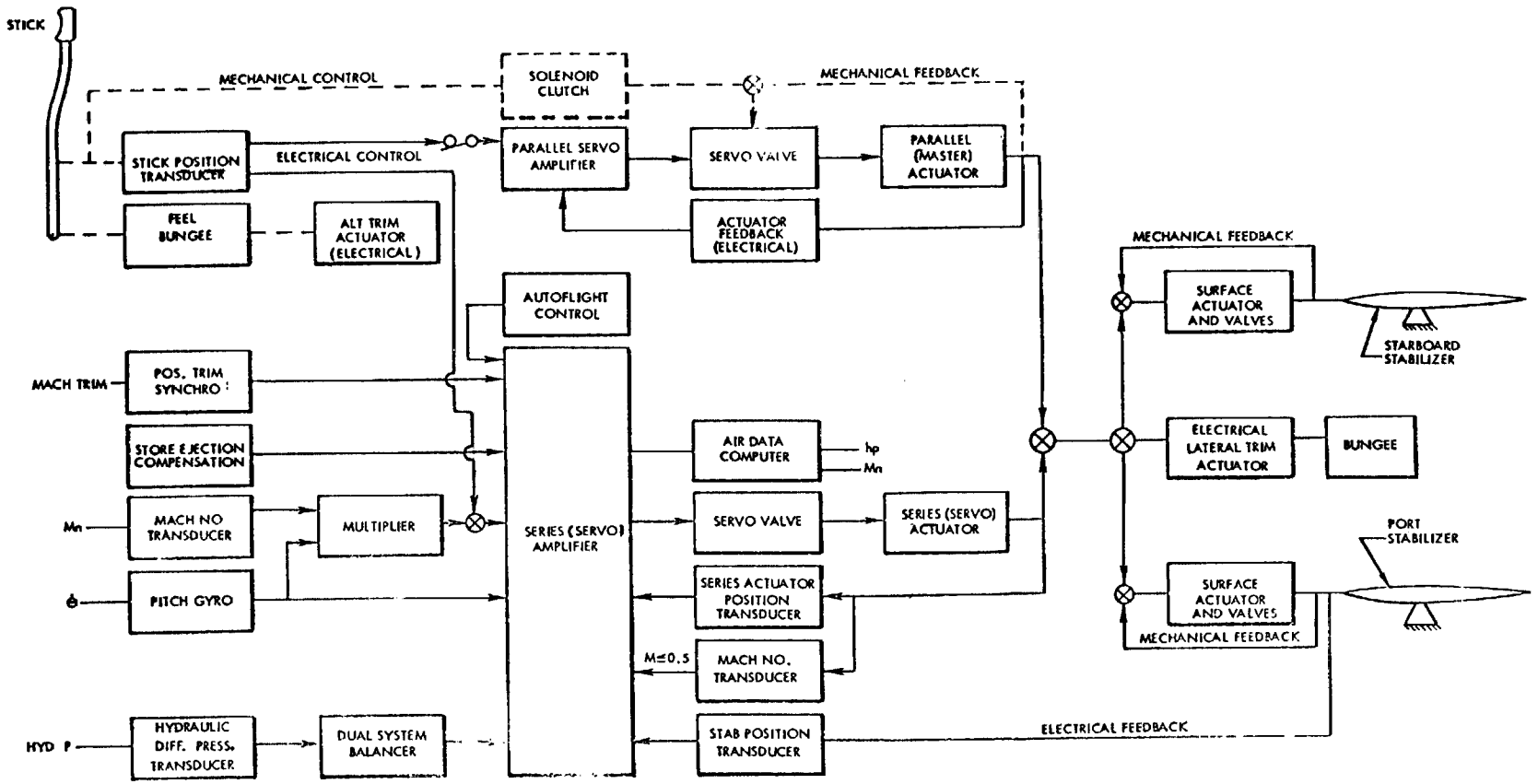
An initial attempt was made to put all block diagrams into a consistent format which identified functional blocks and associated transfer characteristics, functional switching, etc. However, it rapidly became apparent that such a task was beyond the scope of this program. Therefore in most instances 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

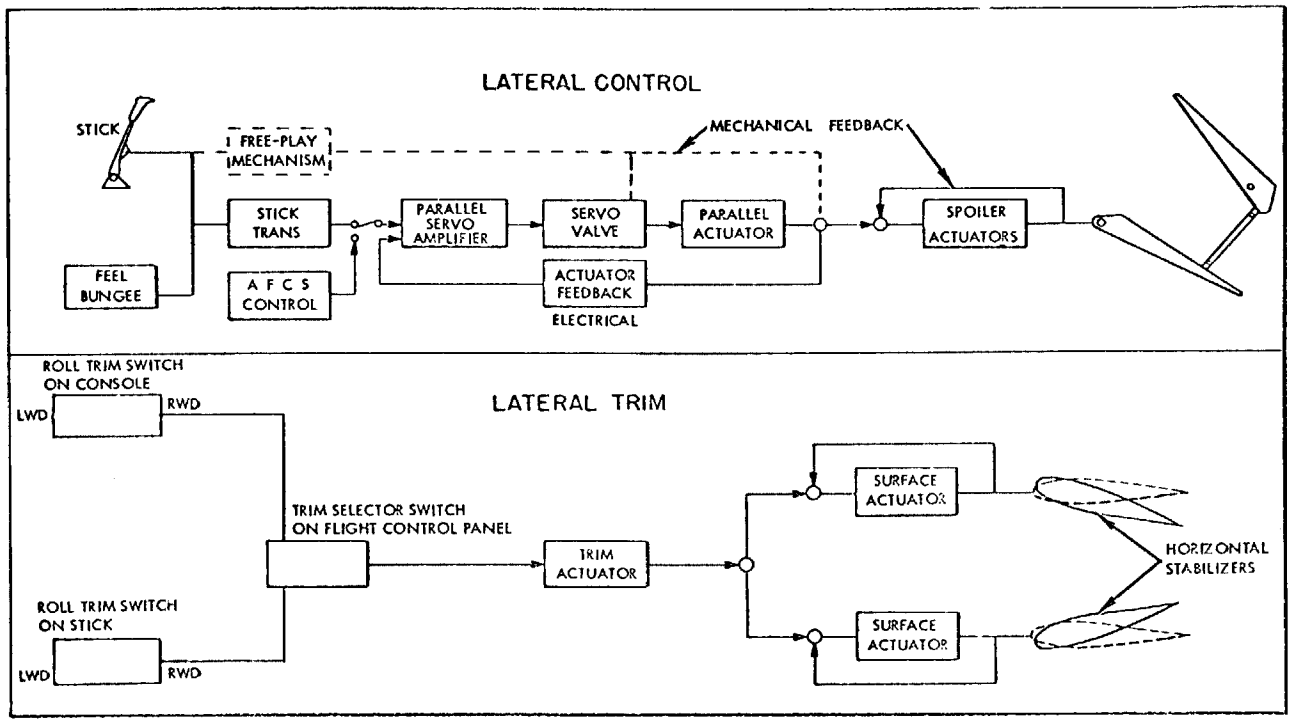
AIRCRAFT	Pages	Ref. No.
A3J-1	4- 8	5
A-4	9-11	1
A-7A	12-14	
B-52	15-19	9, 10
B-58	20-29	11, 32
B-66	30	67
XB-70	31-33	12
C-5A	34-45	16, 17, 19
KC-135	46	67
XC-142A	47-49	18, 20
E-1B	50-51	100
S-2D/S-2E	52-53	100
Regulus II	54	22
Q-2C	55-56	24, 31
BQM-34	57-58	25, 26, 33
MQM-74A	59-60	27
F3H	61-63	67
F-4	64	34
F-8D	65	3
F-14	66	
F-86	67	37
F-89	68-69	38, 67
F-100D/F	70-72	41, 42, 67
F-101A	73	43, 67
F-101B	74-77	43, 44, 67
F-102	78	45, 46
F-105A	79-81	67
F-106	82-83	67
F-111	84-87	53-55
T-38	88	59
AVRO CF-100	89	67

	Pages	Ref. No.
AIRCRAFT		
Fiat G-91	90	67
Viggen (AJ-37)	91-95	58
VJ101-C	96	61
M2-F2	97	62
X-15	98-100	64, 65
B-707	101-103	67
DC-8	104-106	81
L-188	107-110	67
R/D SYSTEMS		
GESAC	111-113	88, 89
Honeywell Adaptable	114-118	35
SFCS	119-124	90
NASA F9F-2	125-128	69-73
TWEAD I	129-130	74, 75
TWEAD II	131-134	78
AVRO-707C	135-137	79
Lear Rate Integrating	138	67



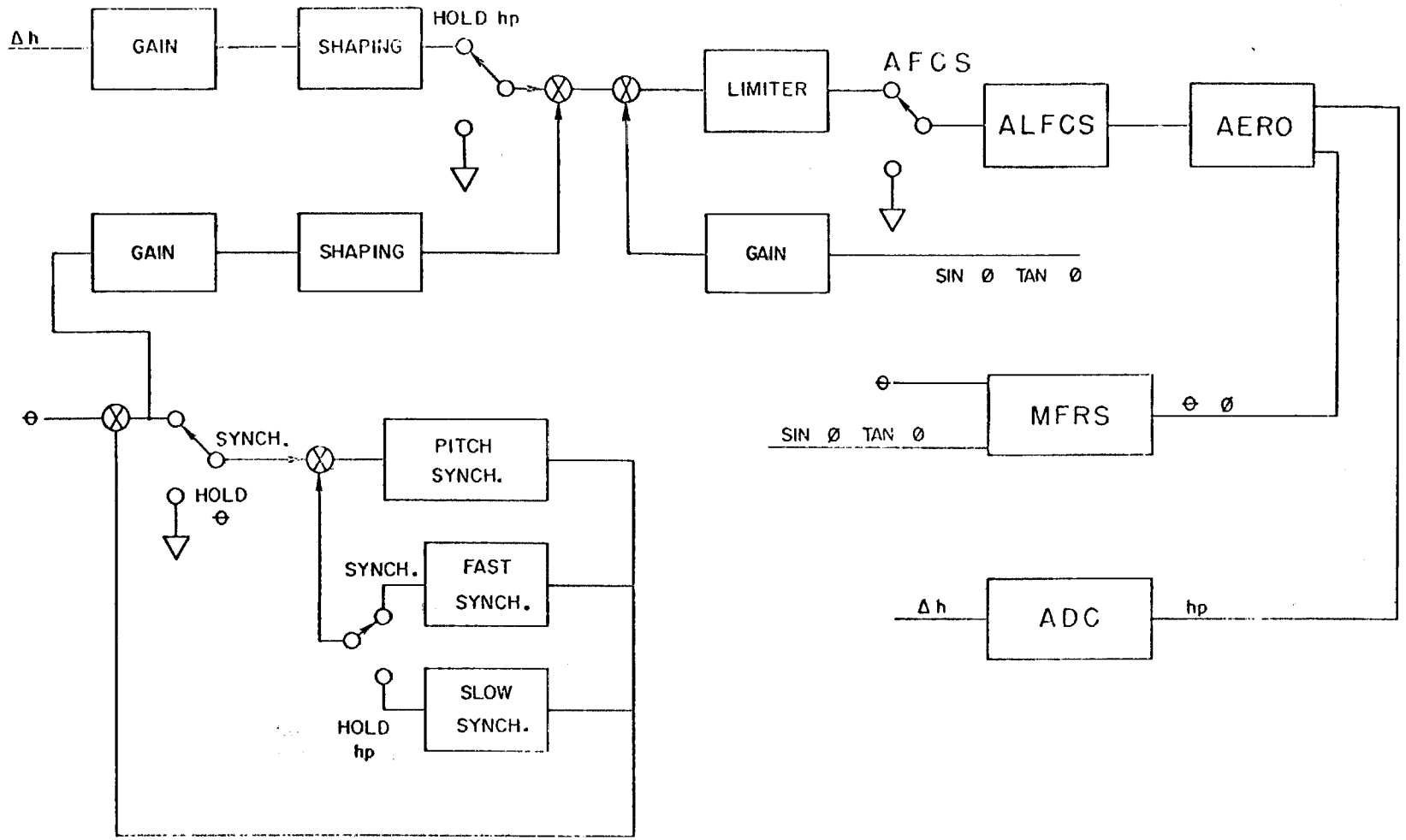
BLOCK DIAGRAM

A3J-1 LONGITUDINAL CONTROL SYSTEM



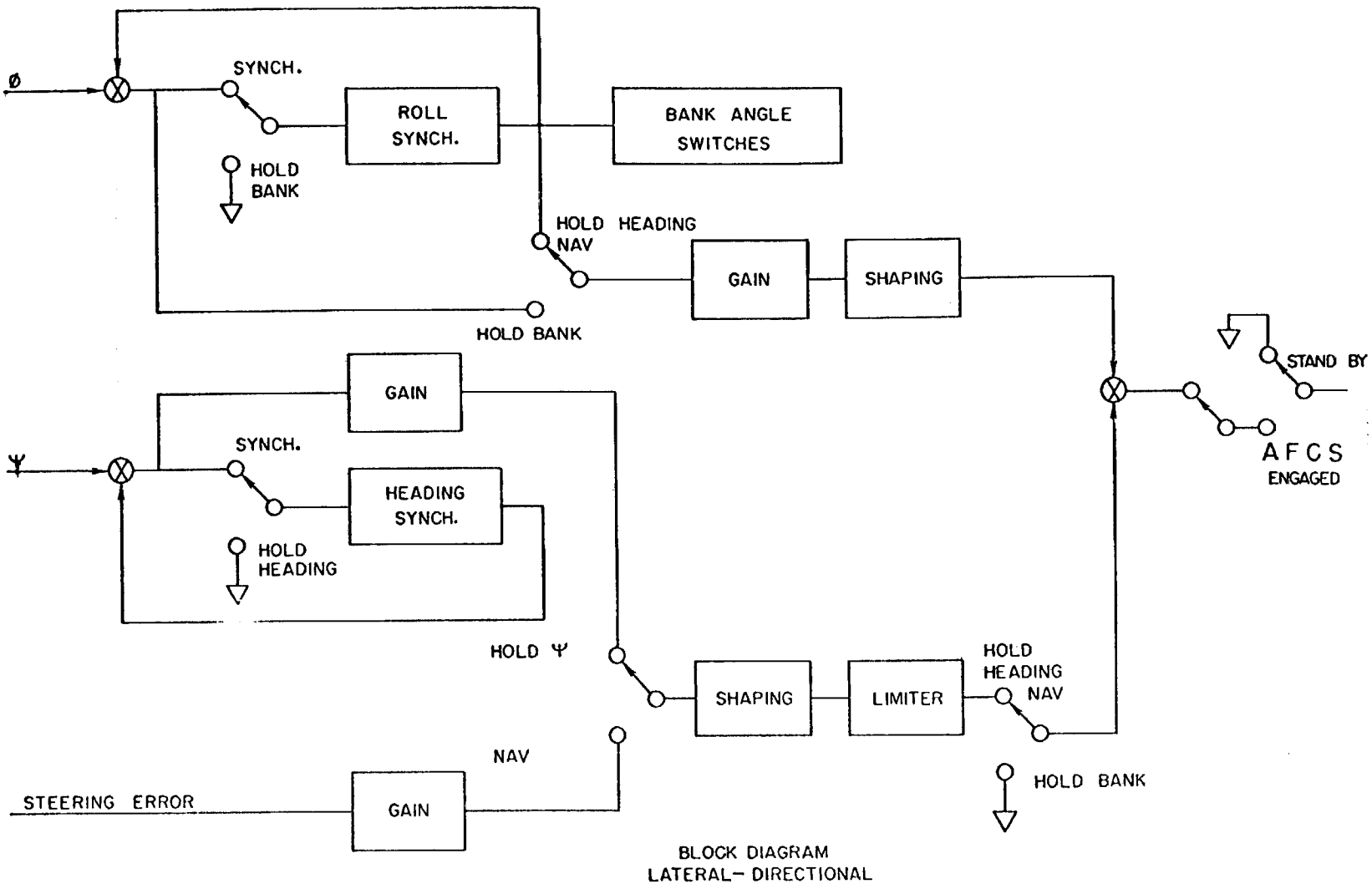
BLOCK DIAGRAMS

A3J-1 LATERAL CONTROL SYSTEM



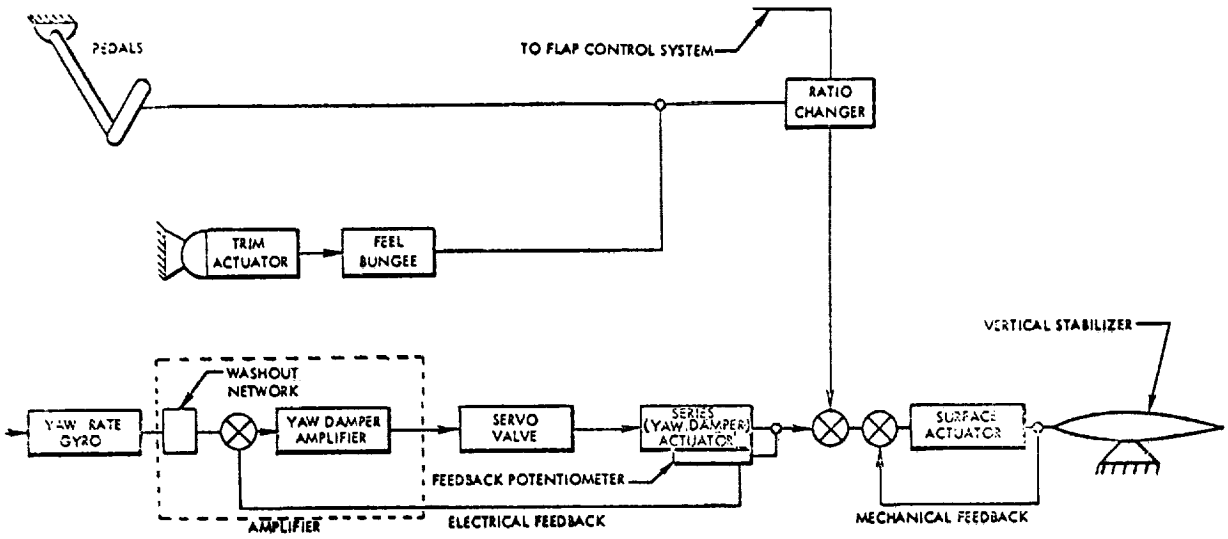
BLOCK DIAGRAM
LONGITUDINAL

A3J-1 AUTOMATIC FLIGHT CONTROL SYSTEM

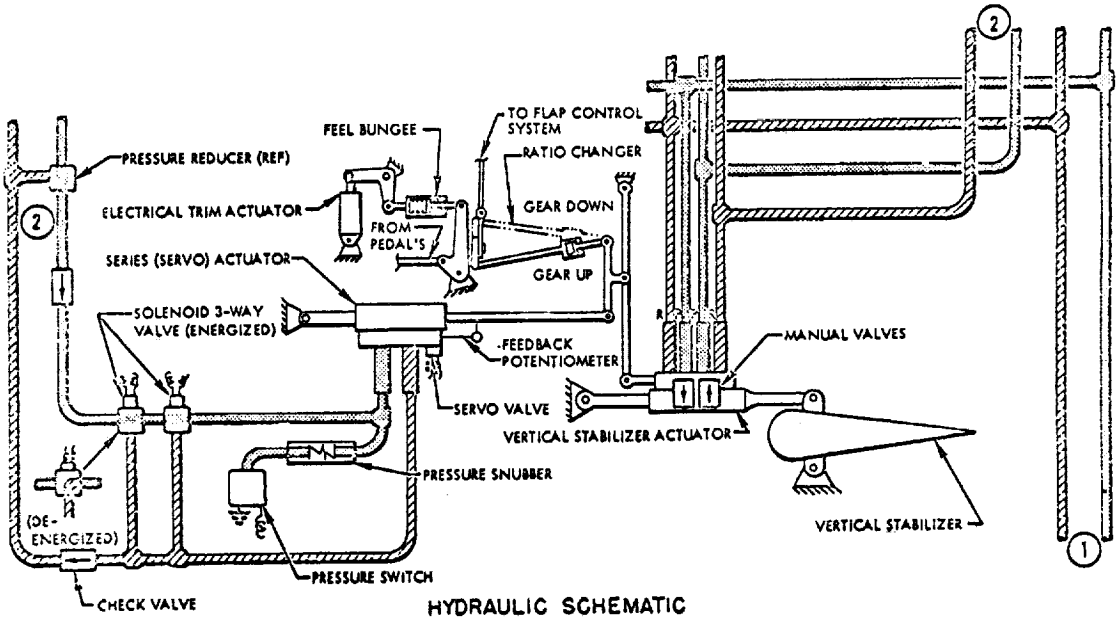


BLOCK DIAGRAM
LATERAL- DIRECTIONAL

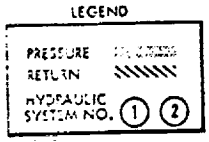
A3J-1 AUTOMATIC FLIGHT CONTROL SYSTEM



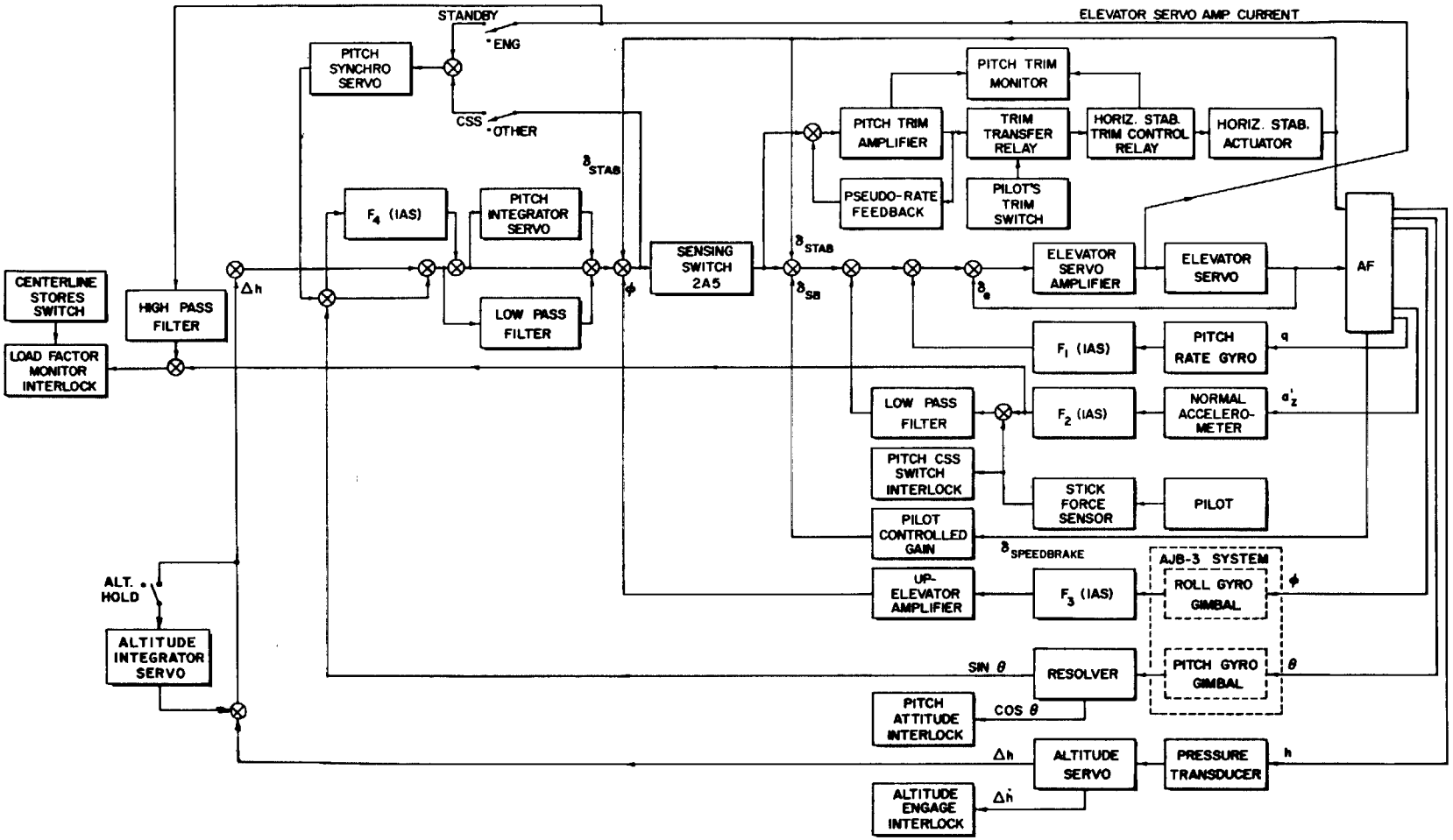
BLOCK DIAGRAM



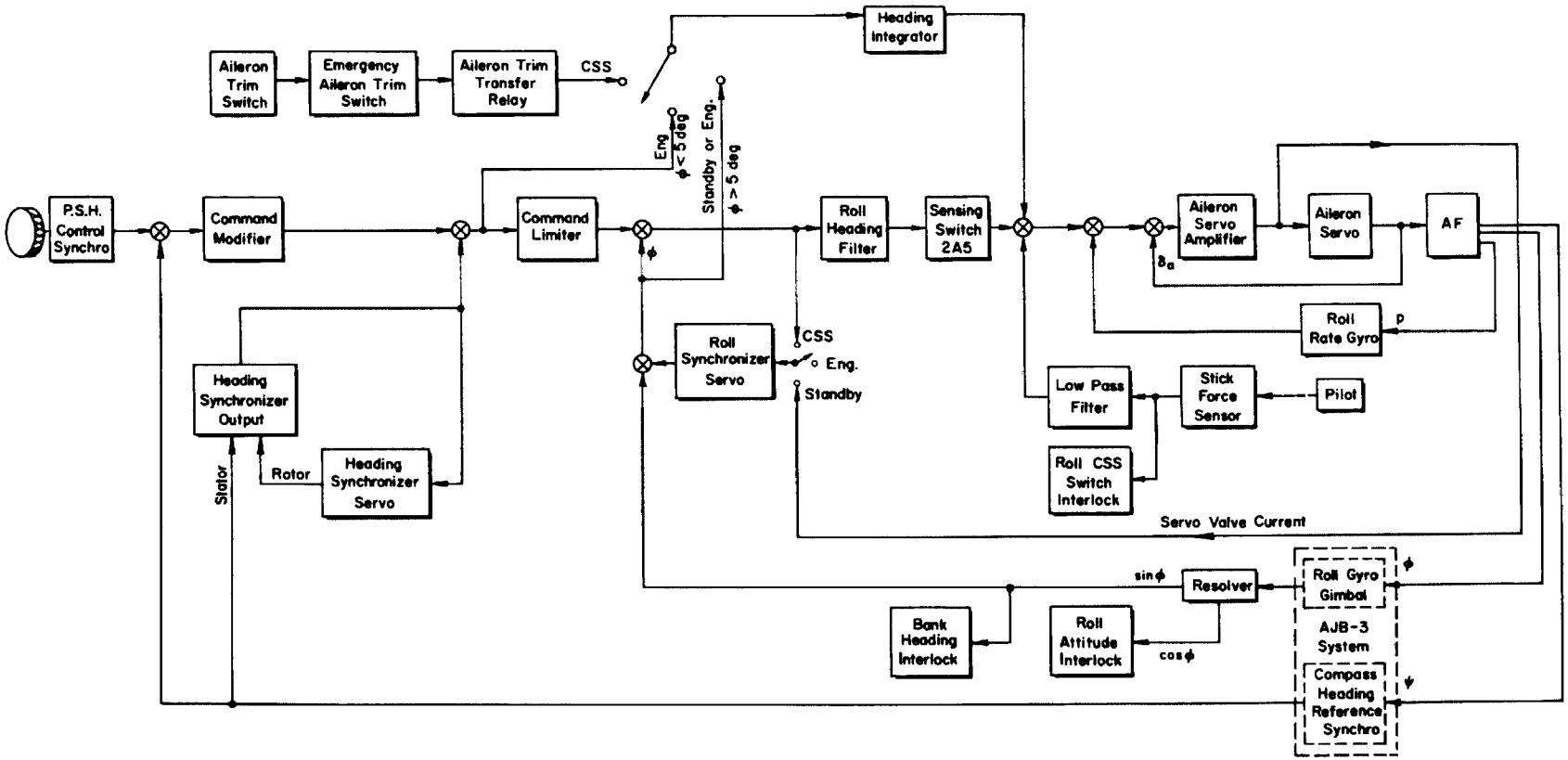
HYDRAULIC SCHEMATIC



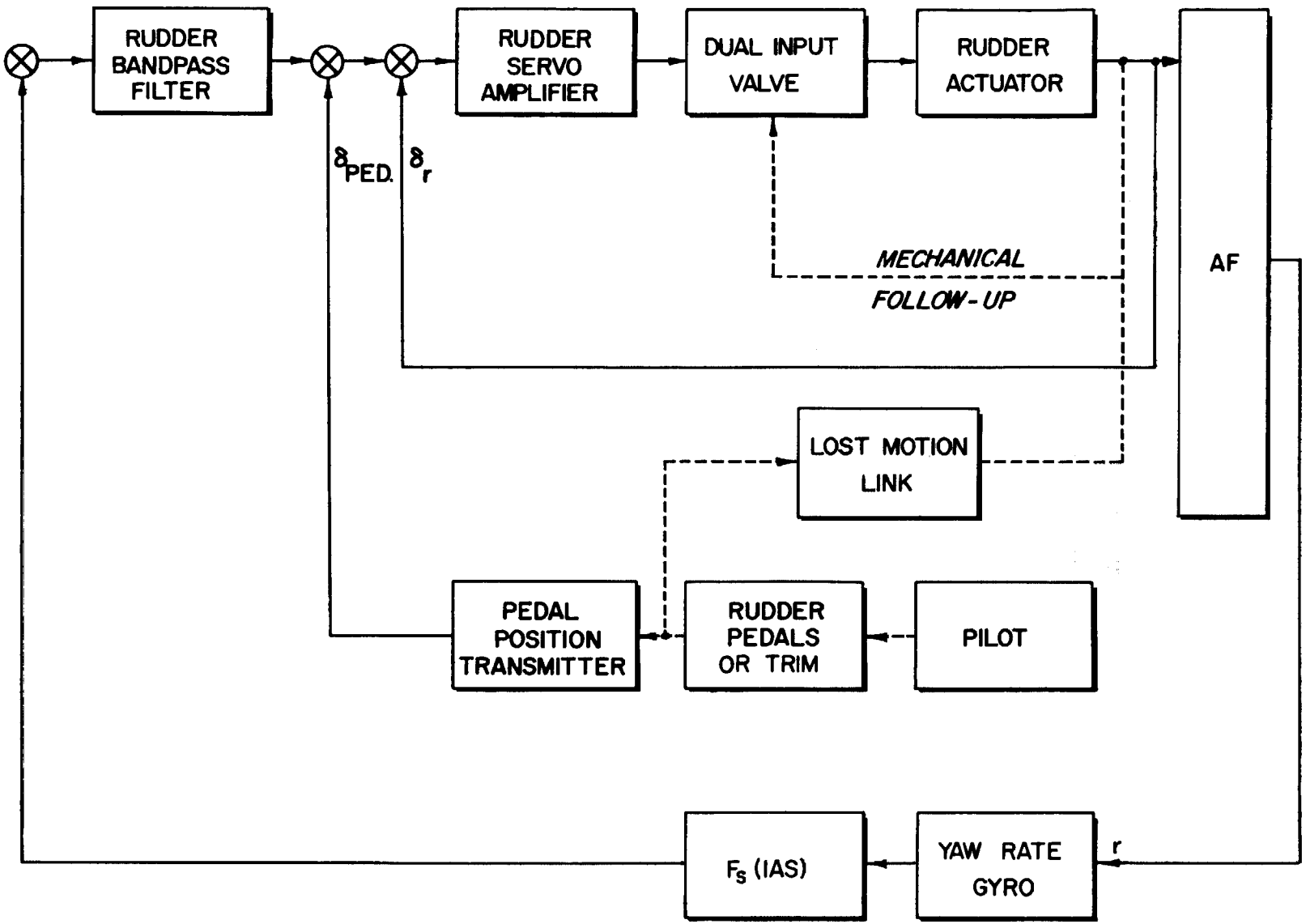
A3J-1 DIRECTIONAL CONTROL SYSTEM



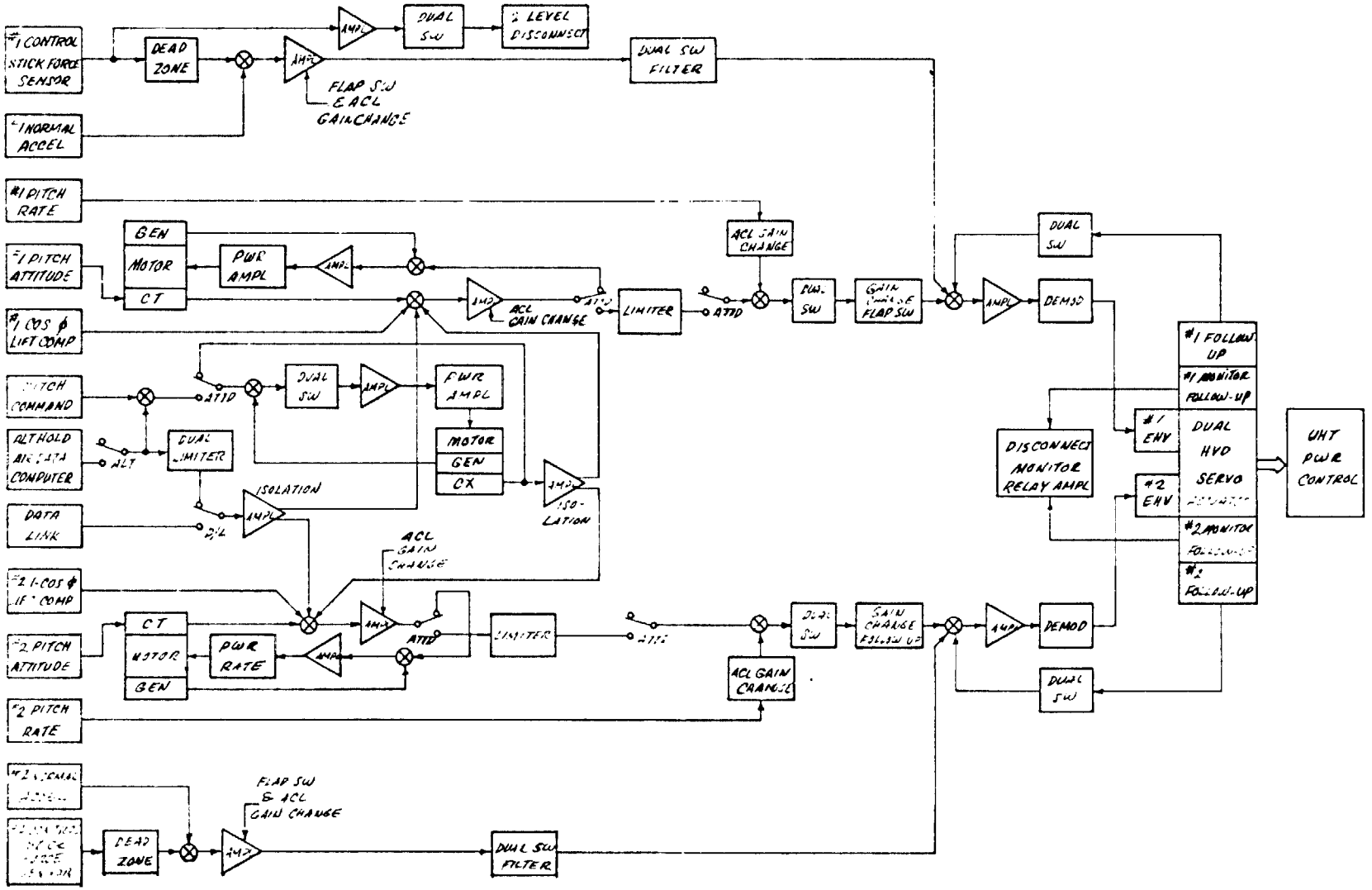
A-4 Elevator Channel



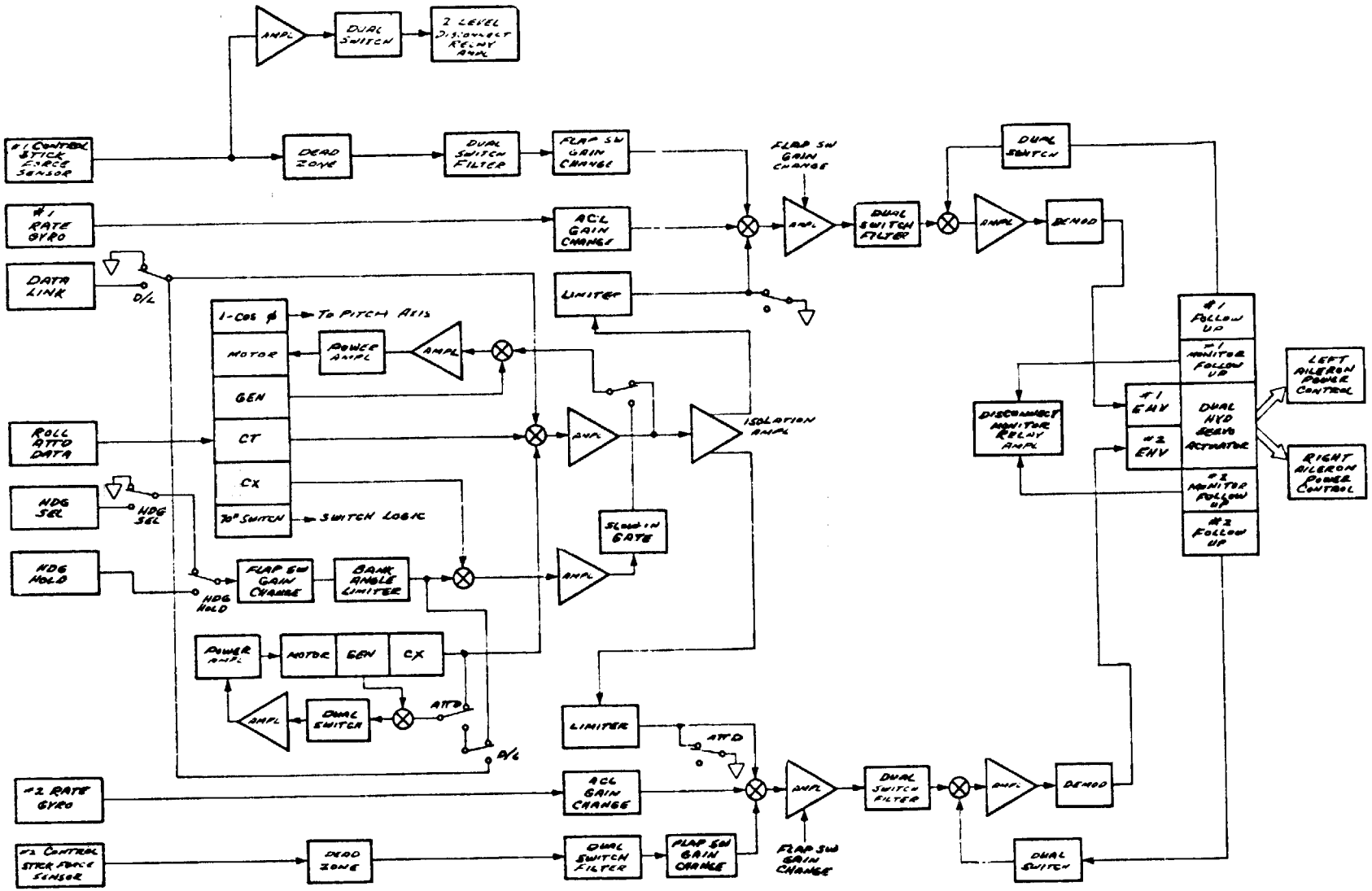
A-4 Roll Channel



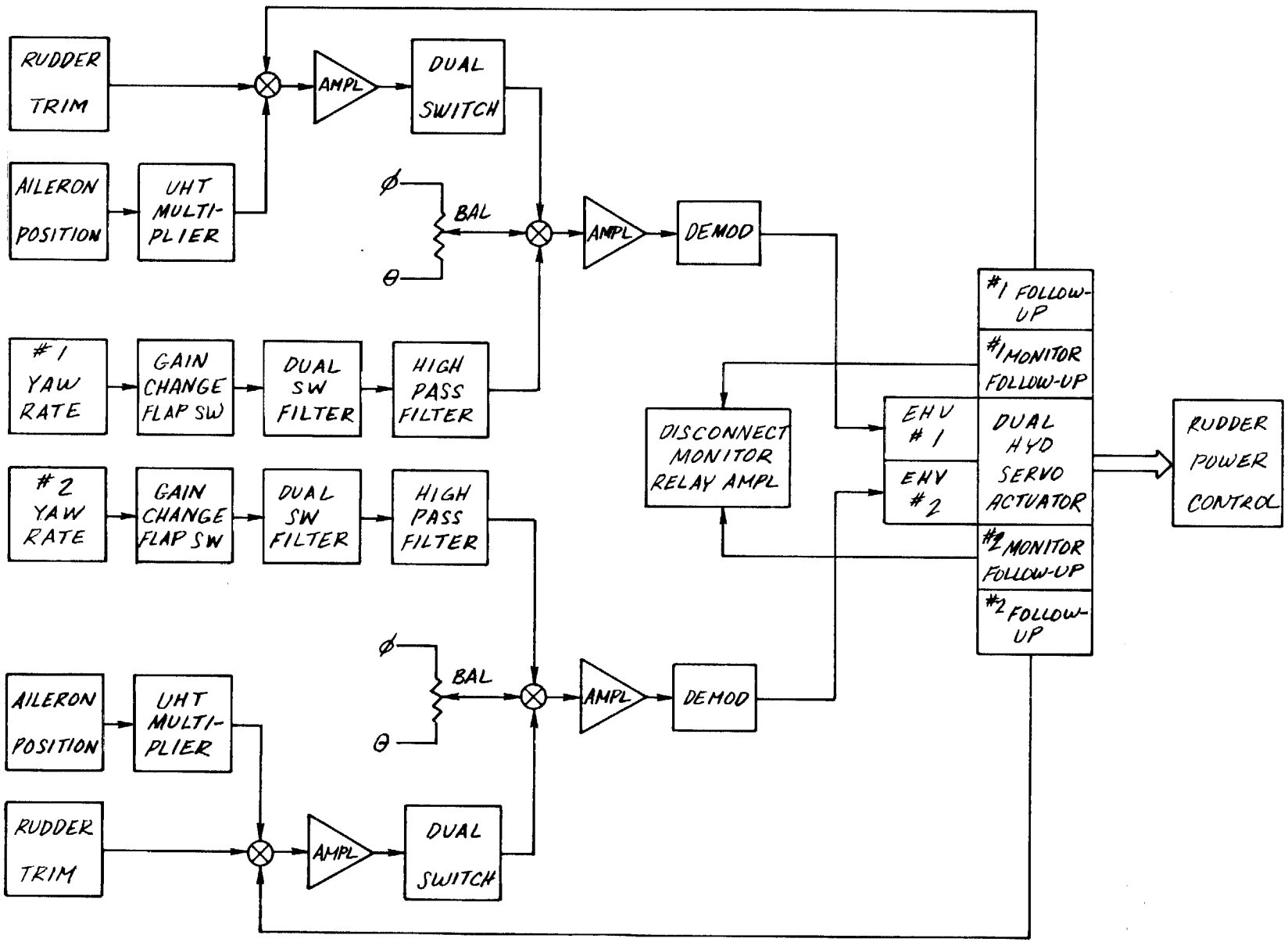
A-4 Yaw Channel



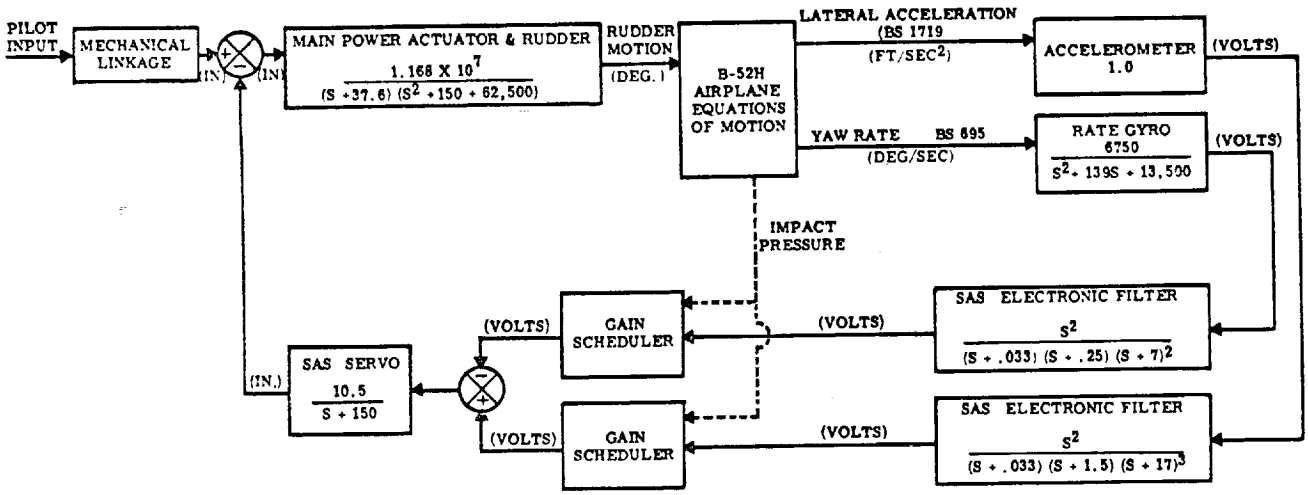
A-7A Pitch Axis



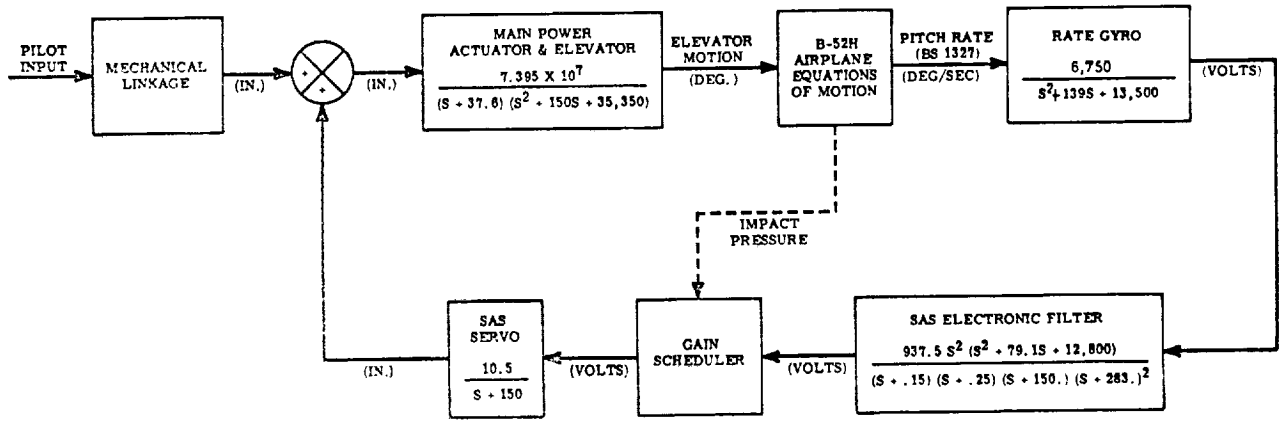
A-7A Roll Axis


RUDDER TRIM
AMPL
DUAL SWITCH
AILERON POSITION
UHT MULTI-PLIER
BAL
AMPL
DEMOD
#1 YAW RATE
GAIN CHANGE FLAP SW
DUAL SW FILTER
HIGH PASS FILTER
#2 YAW RATE
GAIN CHANGE FLAP SW
DUAL SW FILTER
HIGH PASS FILTER
DISCONNECT MONITOR RELAY AMPL
#1 FOLLOW-UP
#1 MONITOR FOLLOW-UP
EHV #1
EHV #2
DUAL HYD SERVO ACTUATOR
#2 MONITOR FOLLOW-UP
#2 FOLLOW-UP
RUDDER POWER CONTROL
AILERON POSITION
UHT MULTI-PLIER
BAL
AMPL
DEMOD
RUDDER TRIM
AMPL
DUAL SWITCH

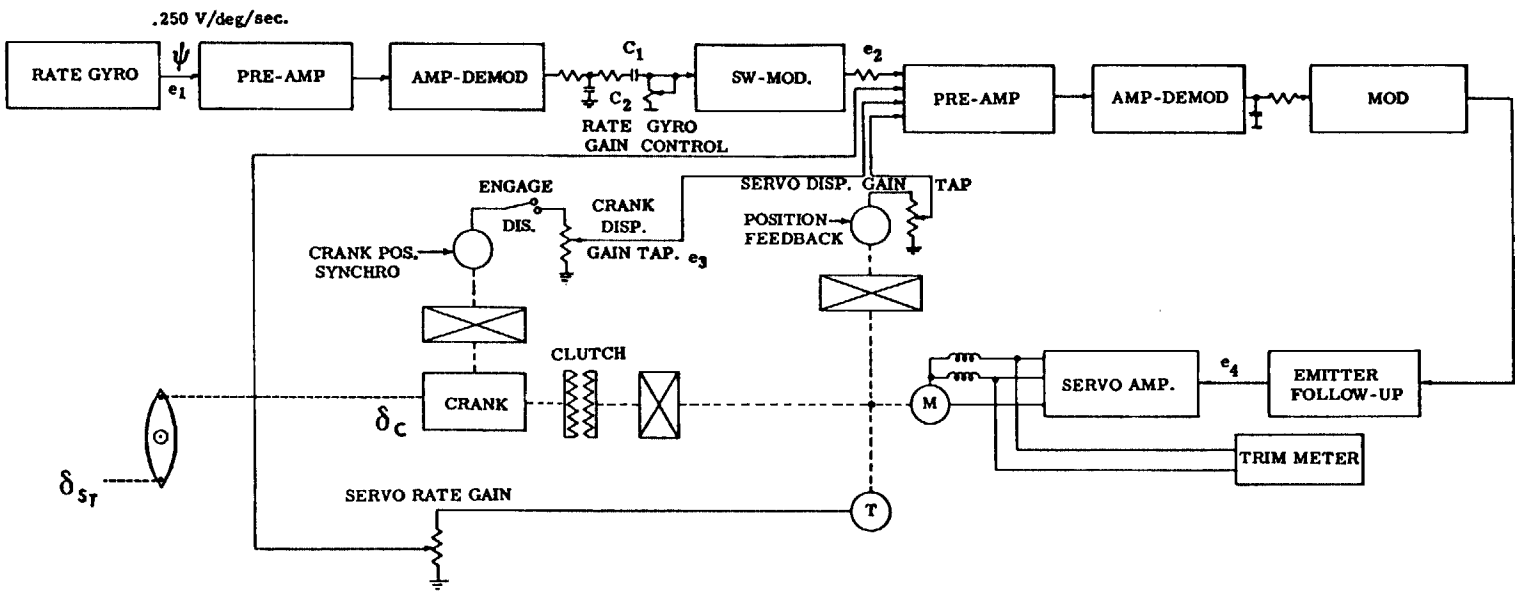
A-7A Yaw Axis



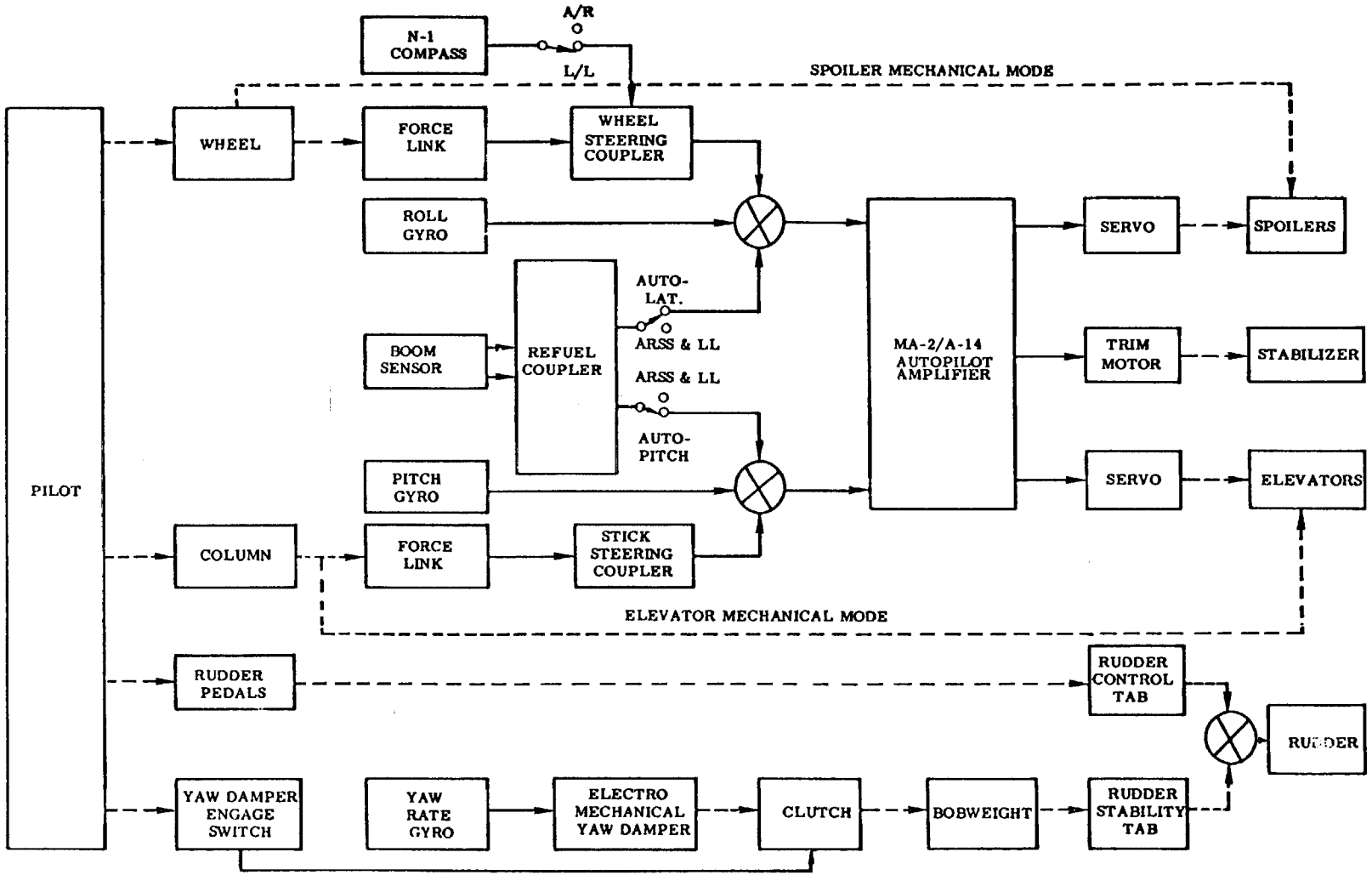
B-52 Modified Yaw SAS Block Diagram



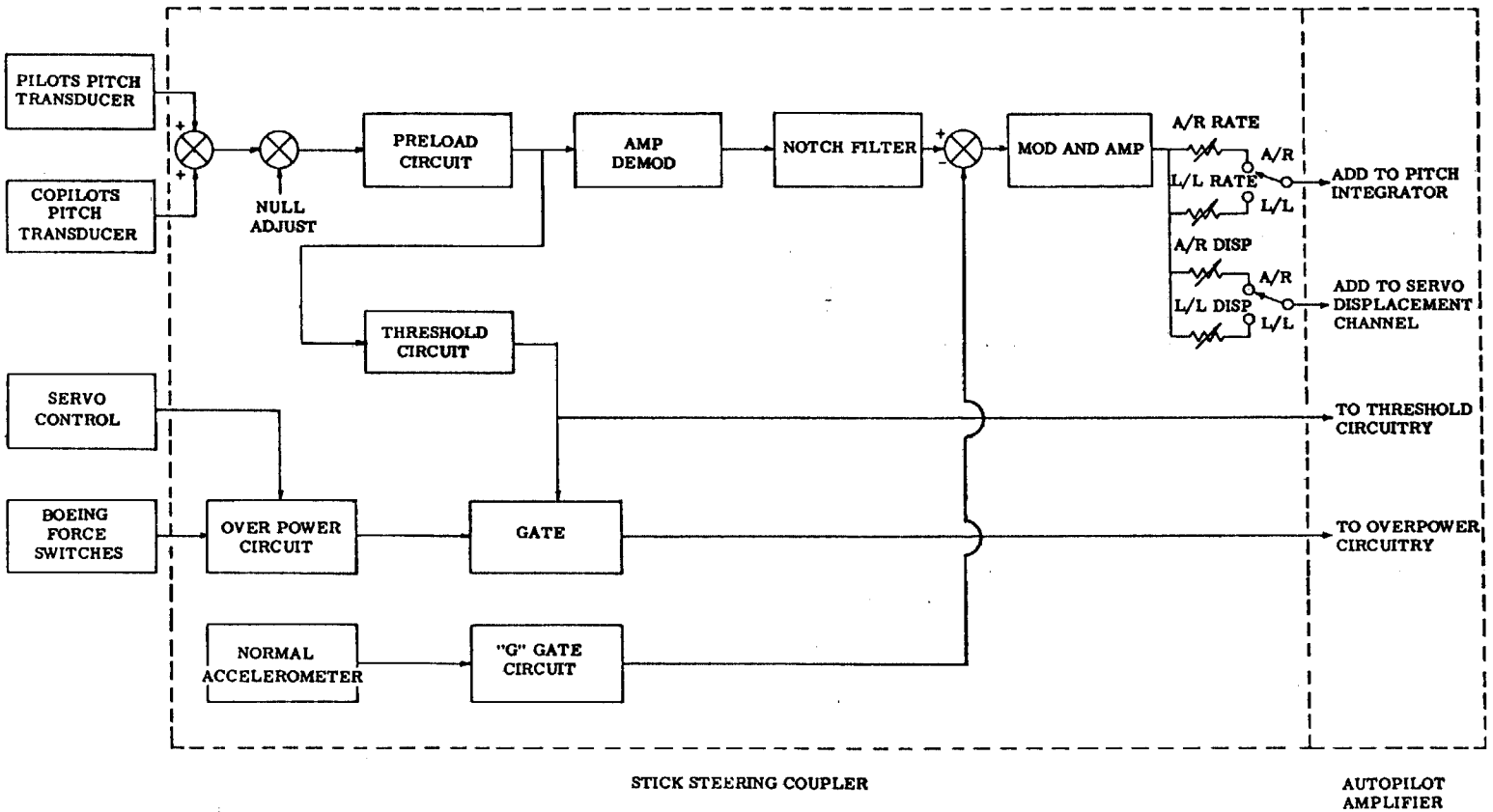
B-52 Modified Pitch SAS Block Diagram



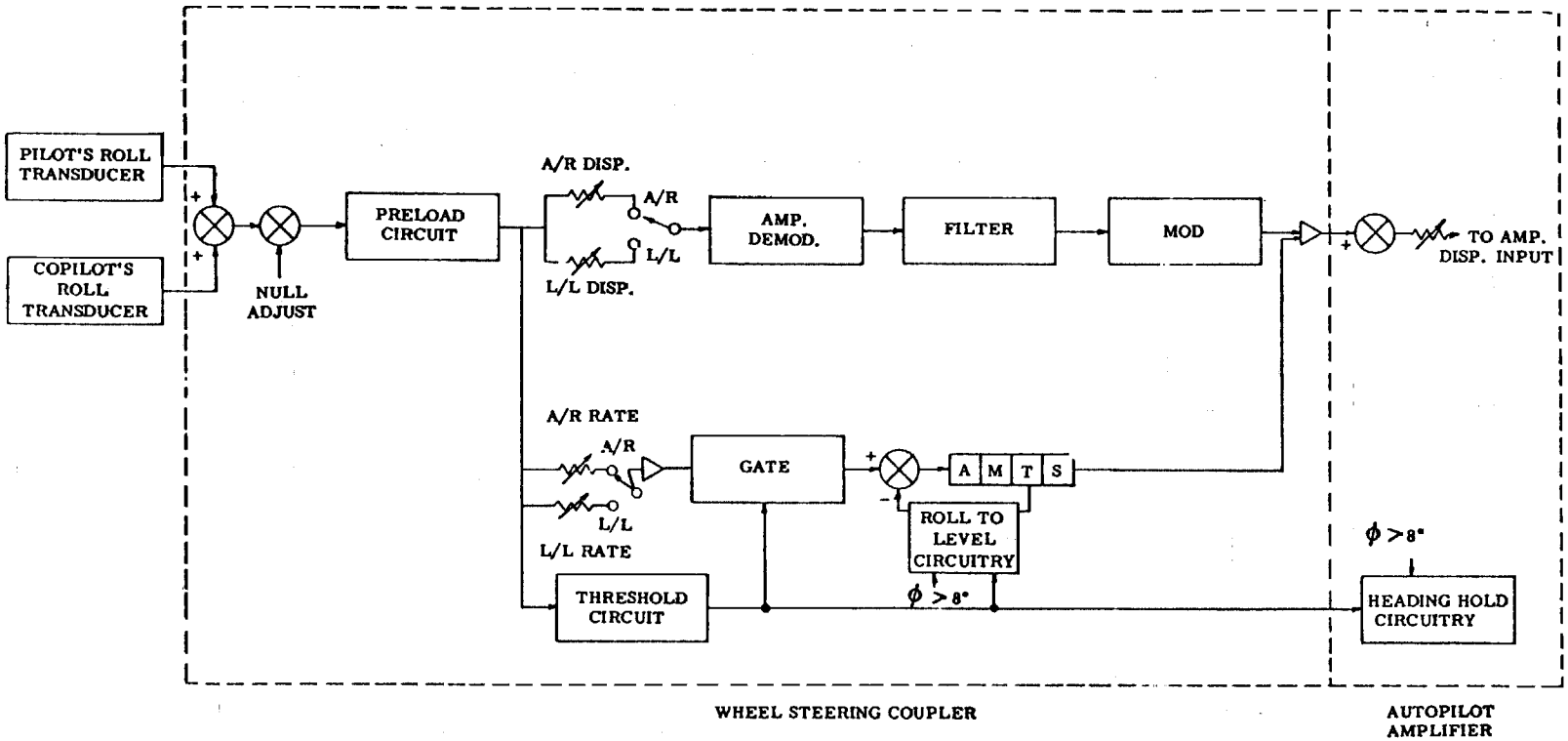
B-52 Original Yaw Damper



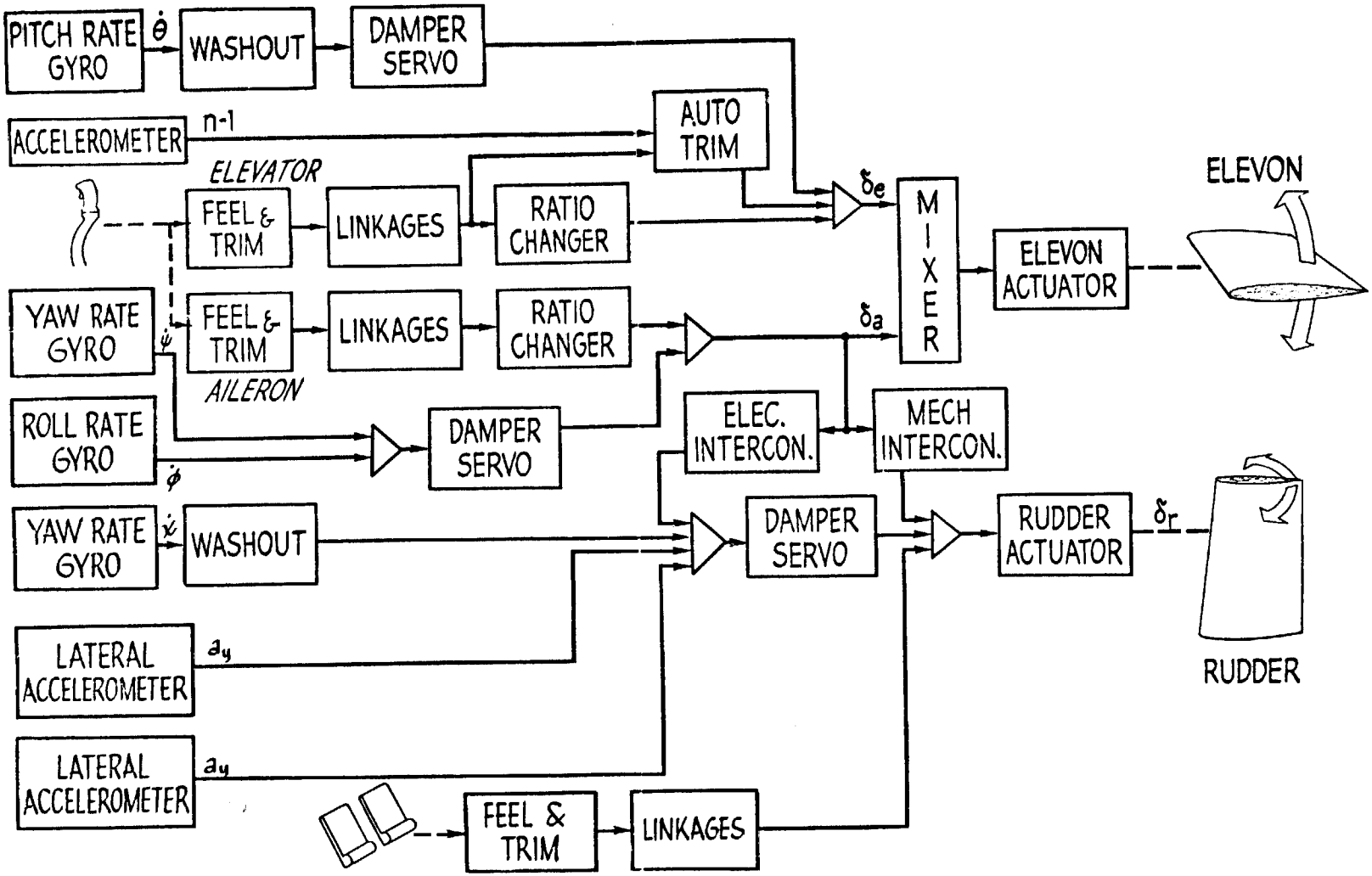
B-52 Original AFCS



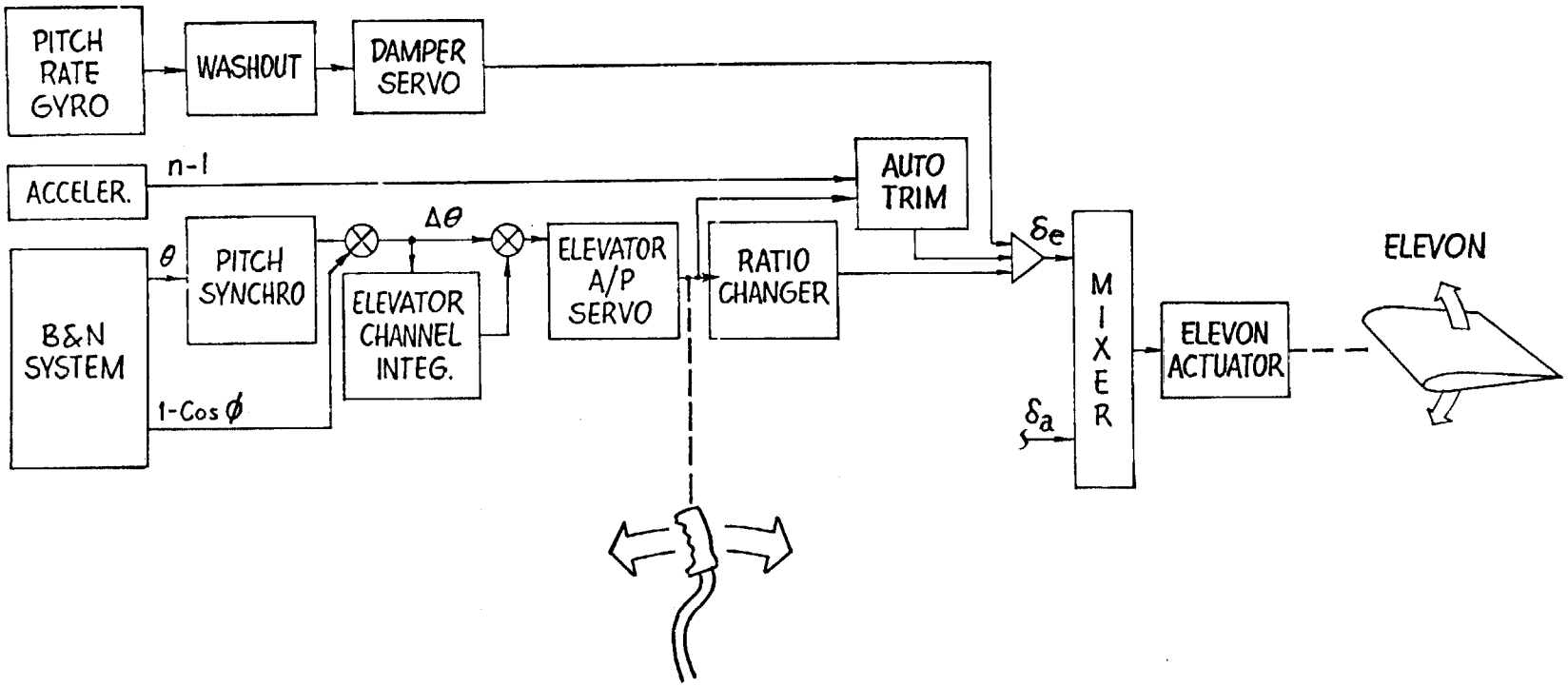
B-52 Longitudinal Control Wheel Steering



B-52 Lateral Control Wheel Steering

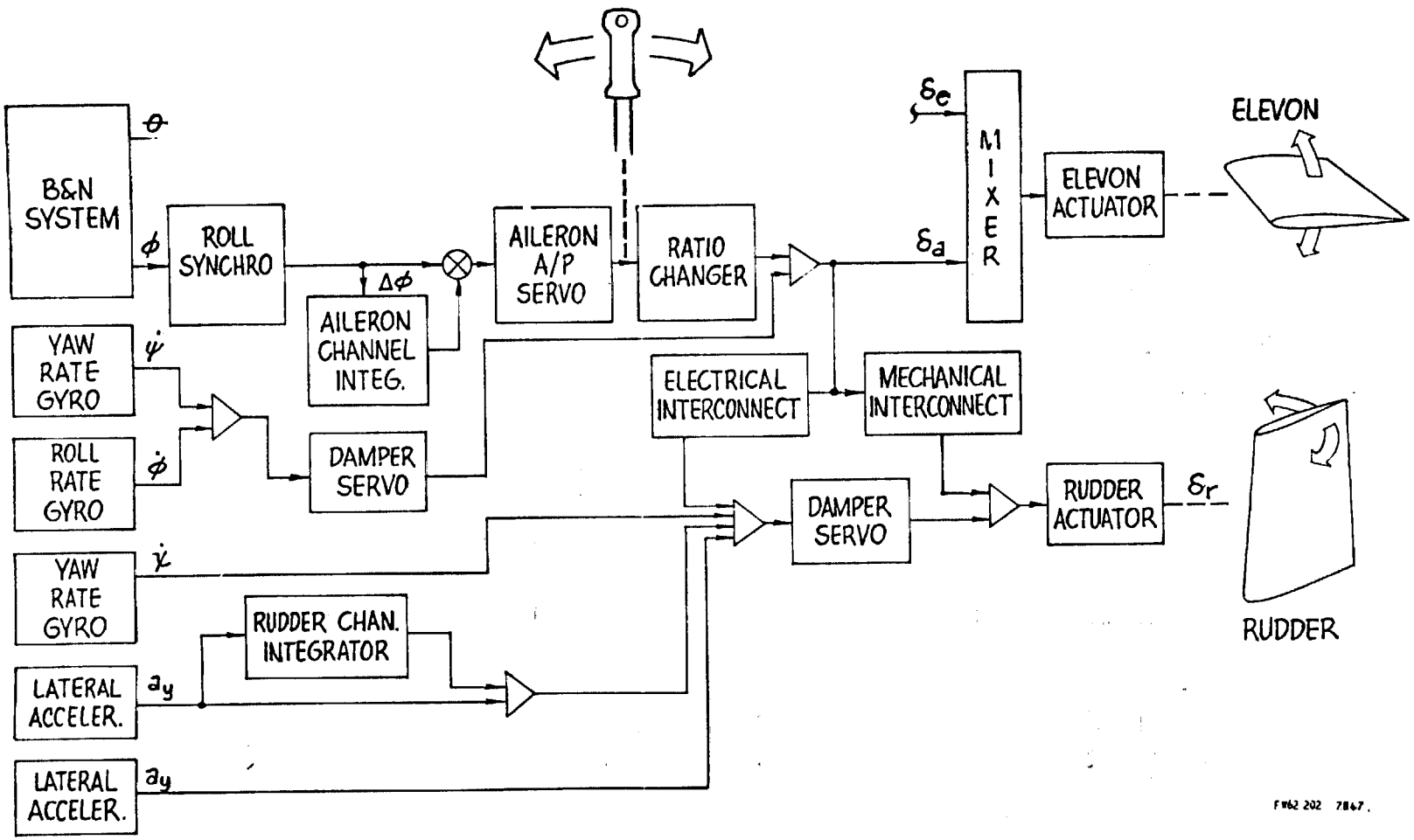


B-58 Stability Augmentation



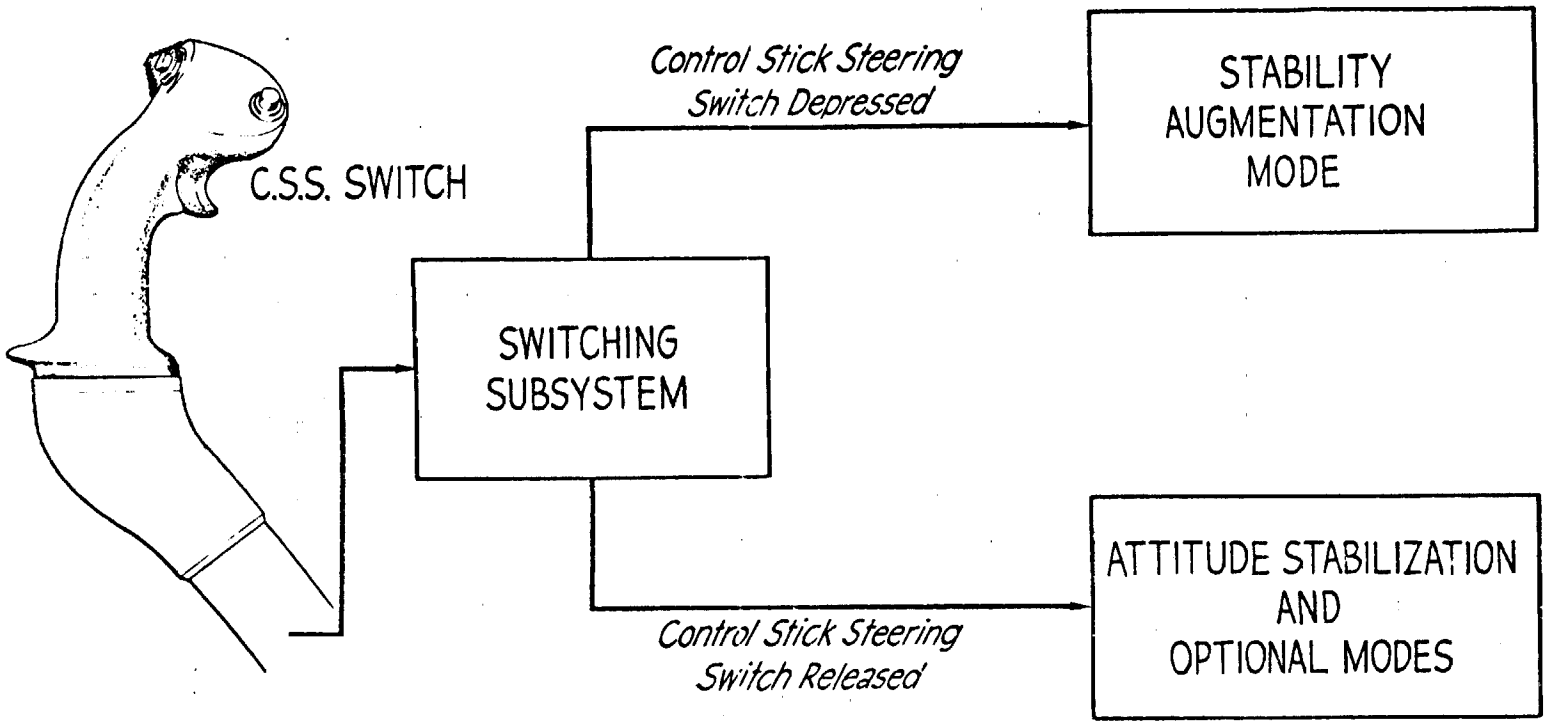
B-58 Attitude Stabilization Mode

Pitch

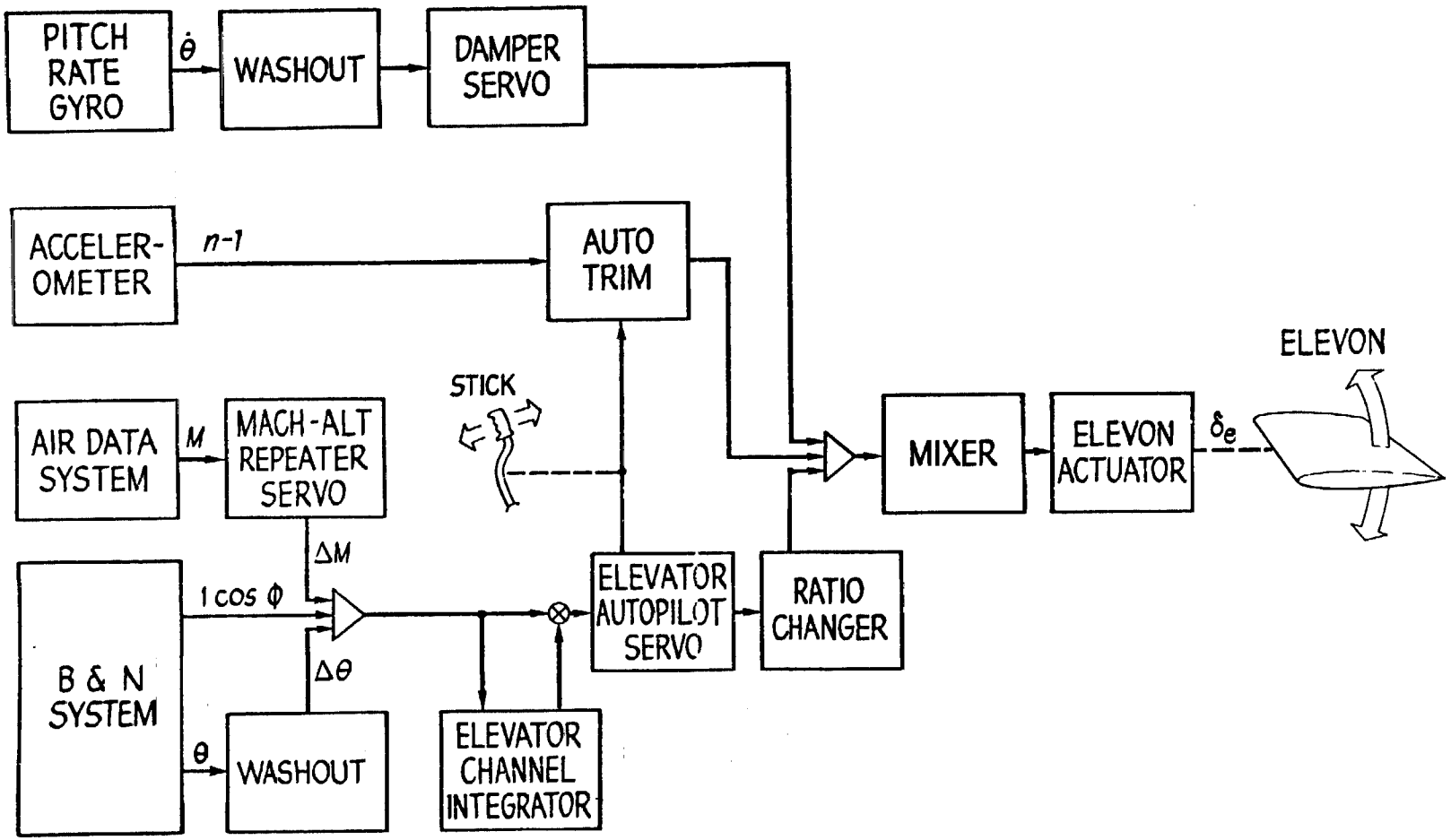


B-58 Attitude Stabilization Mode

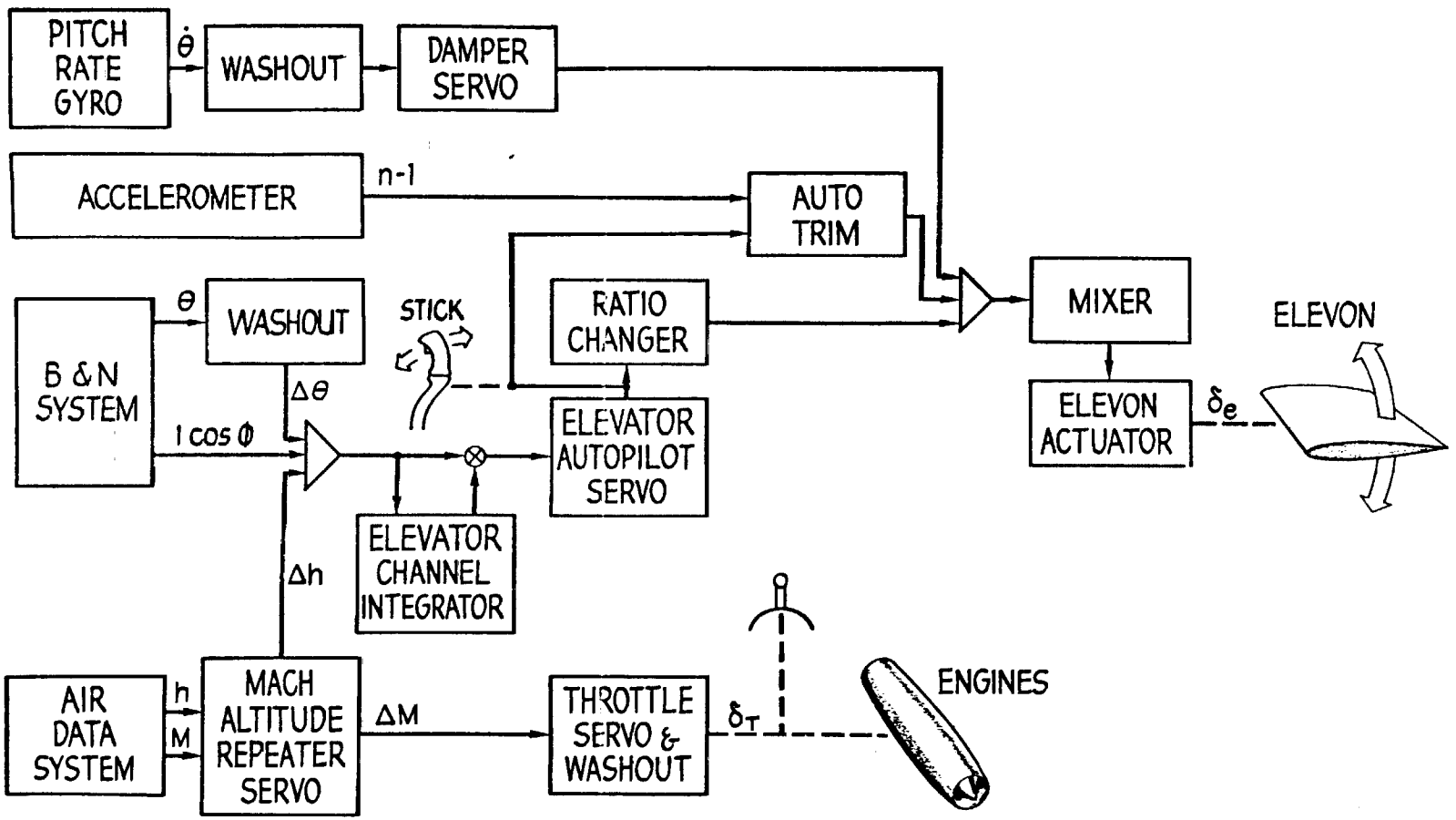
Lateral



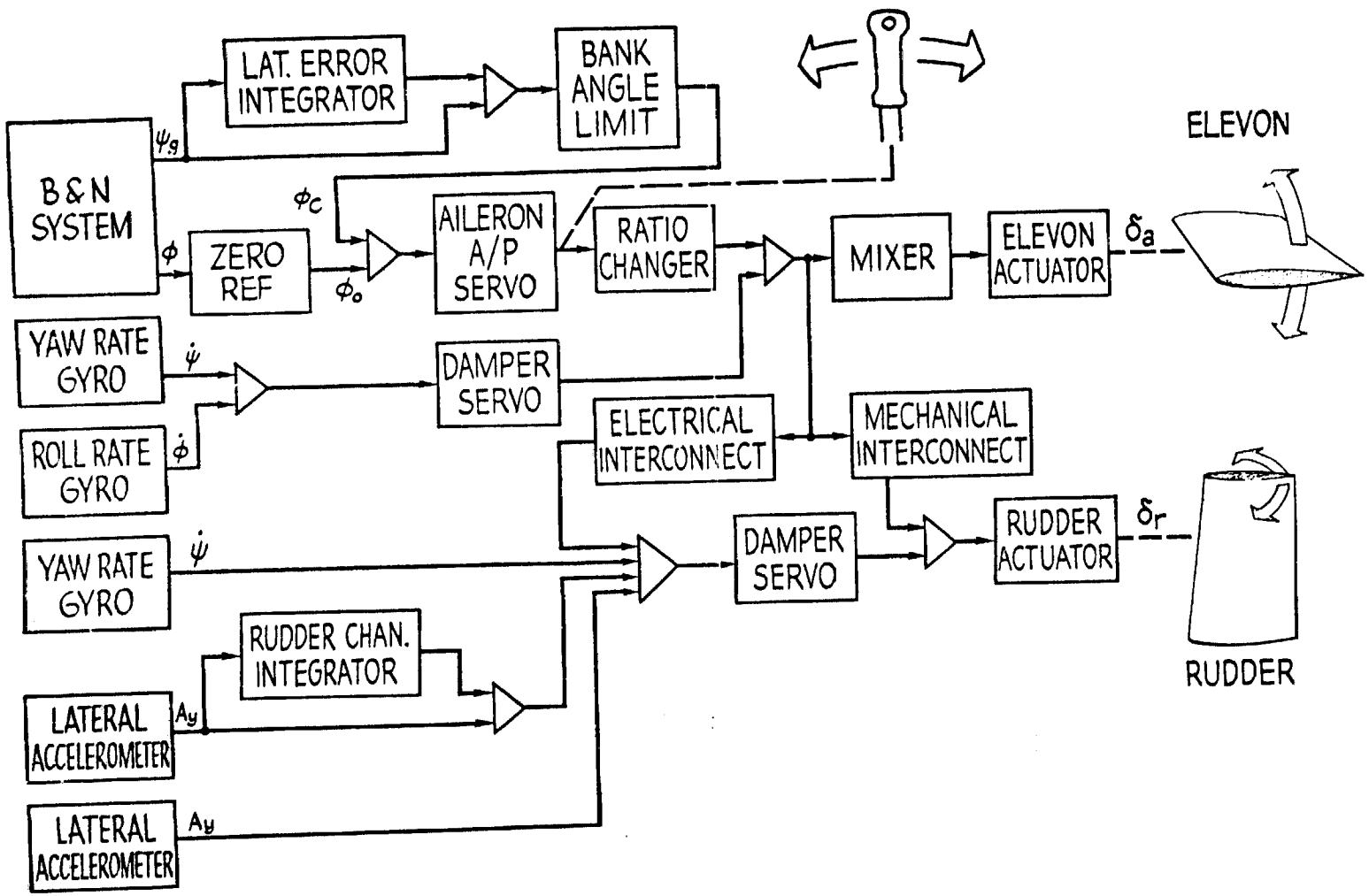
B-58 Control Stick Steering Mode



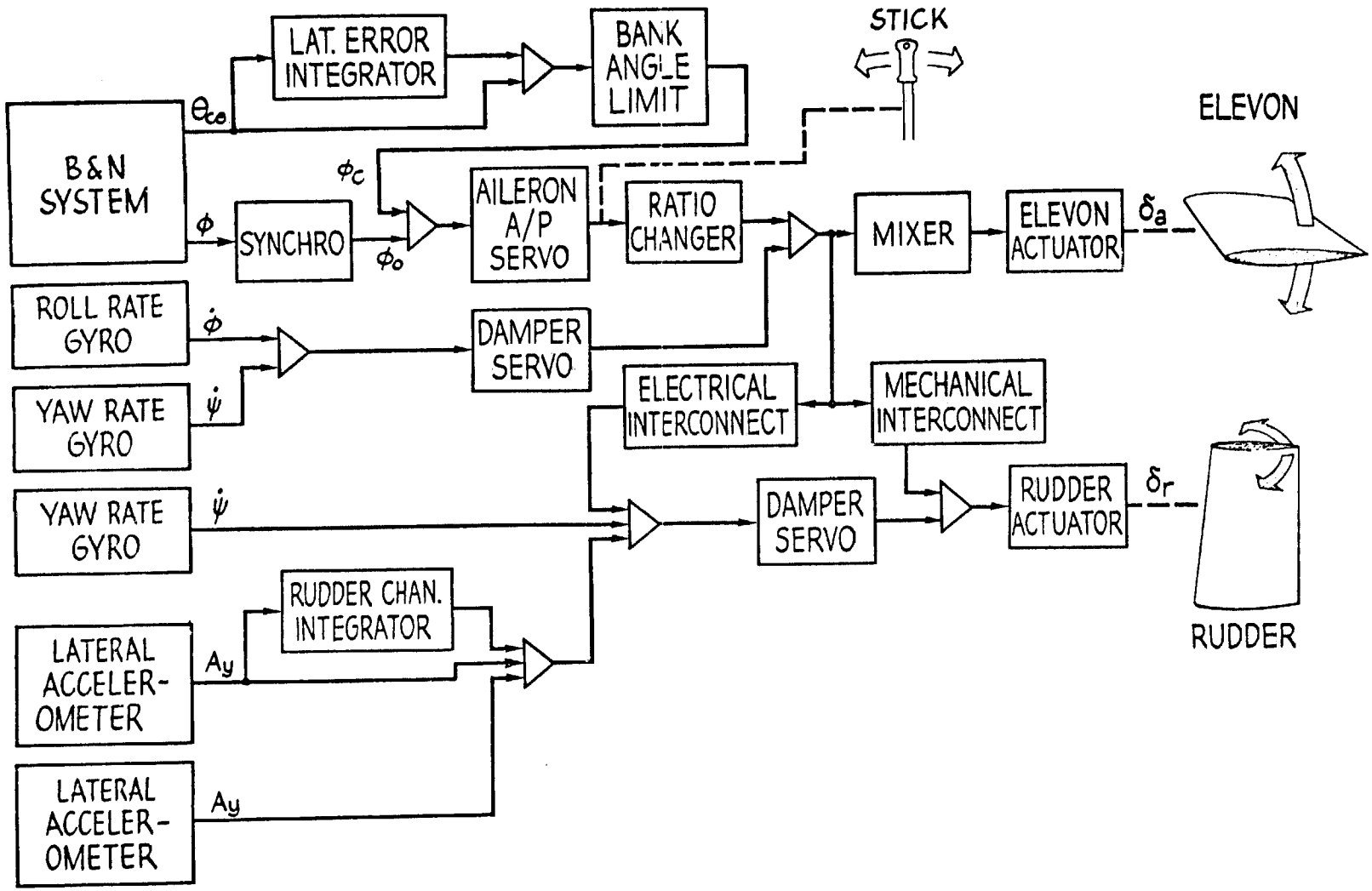
B-58 Mach Mode



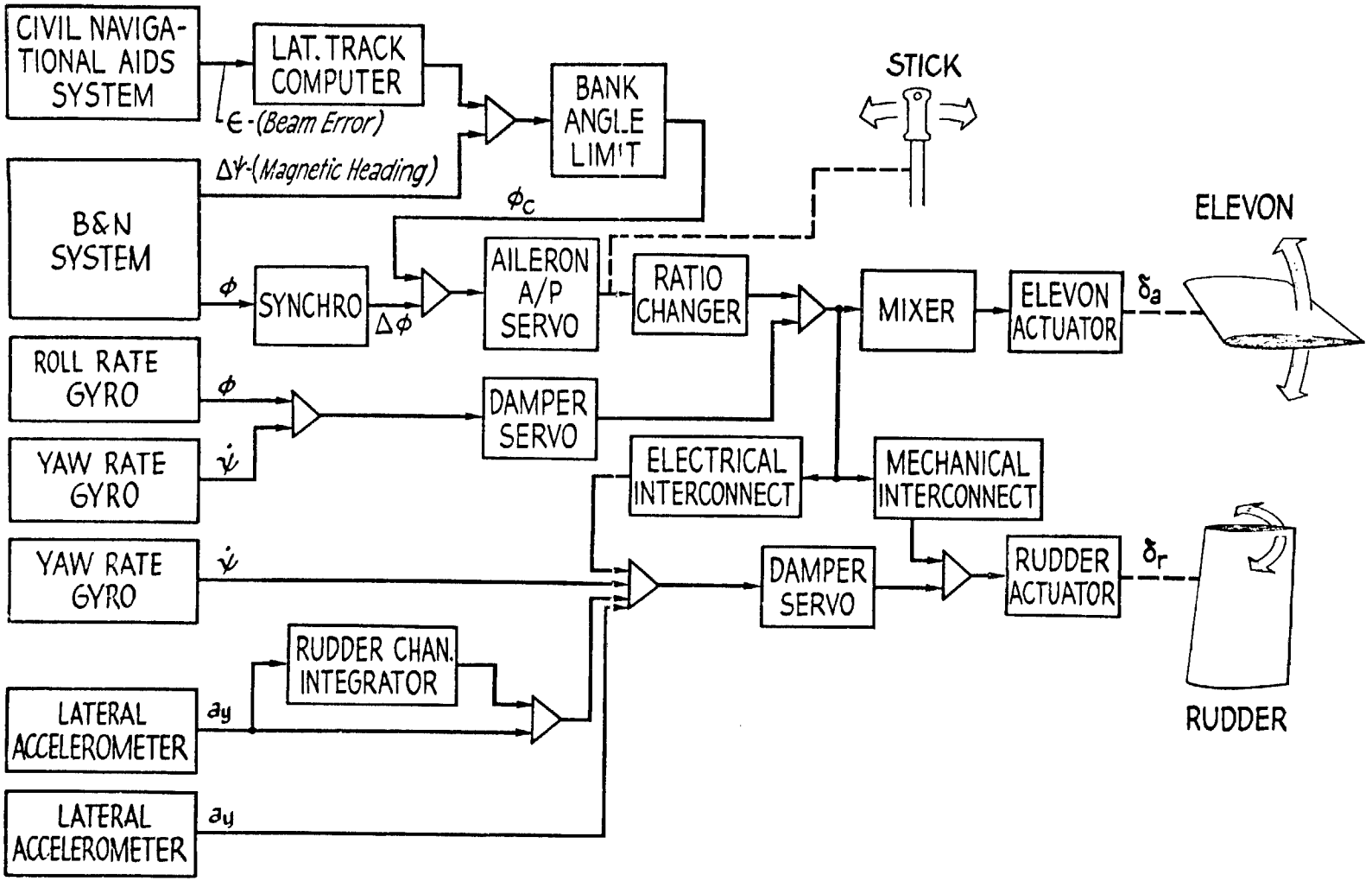
B-58 Mach-Altitude Mode



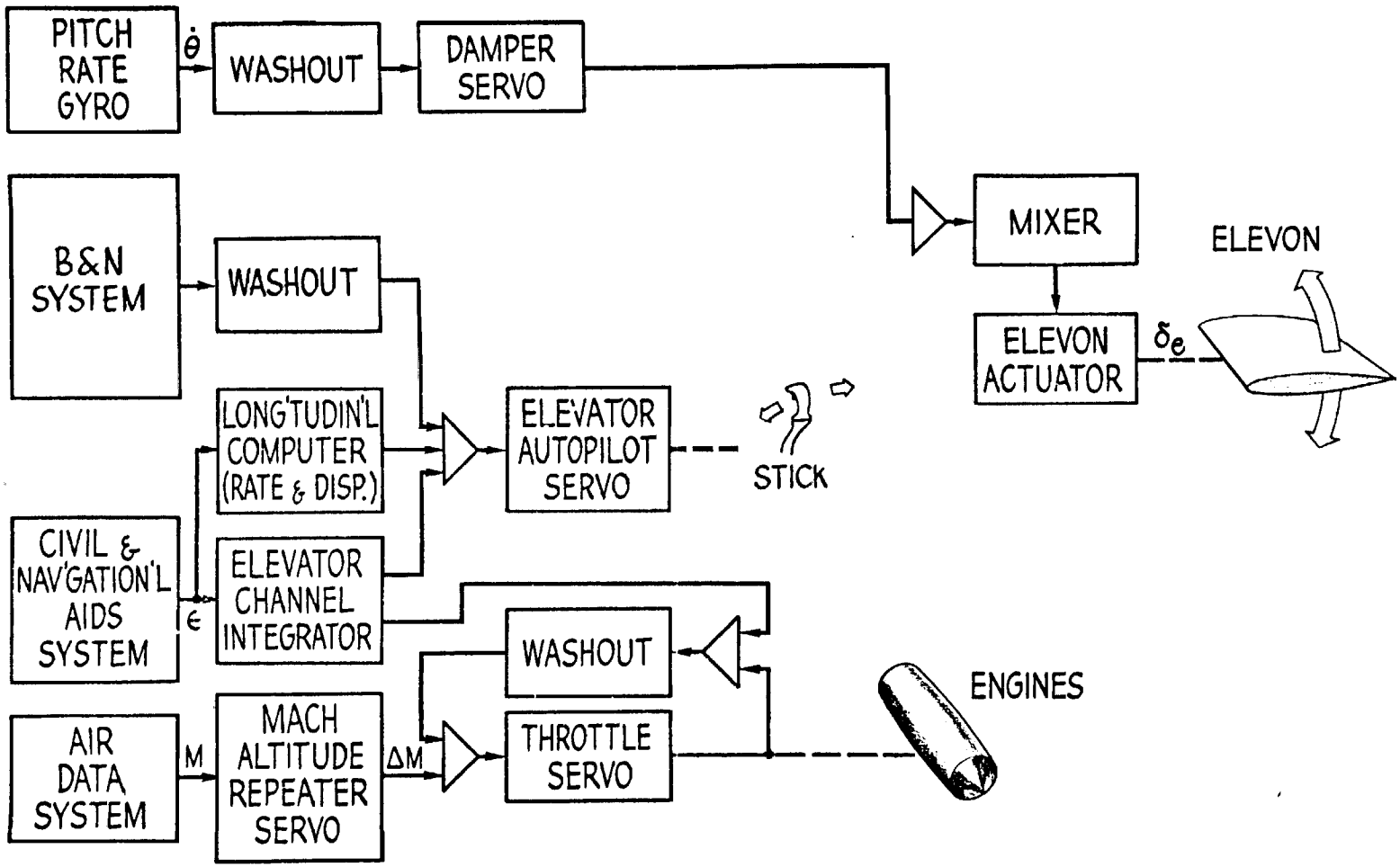
B-58 Constant Heading



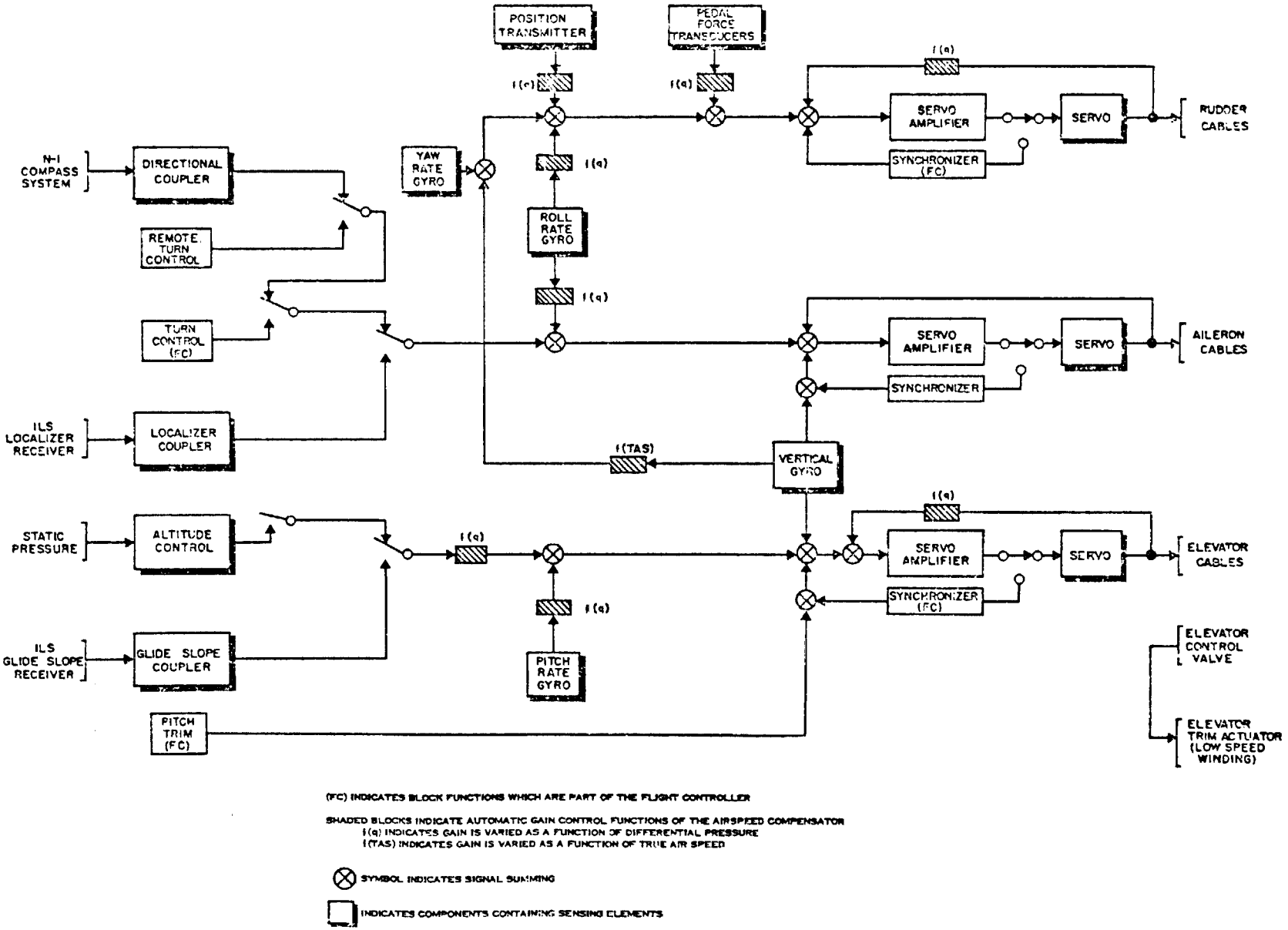
B-58 Heading Nav Mode



B-58 Localizer Mode



B-58 Automatic Glide Path Mode



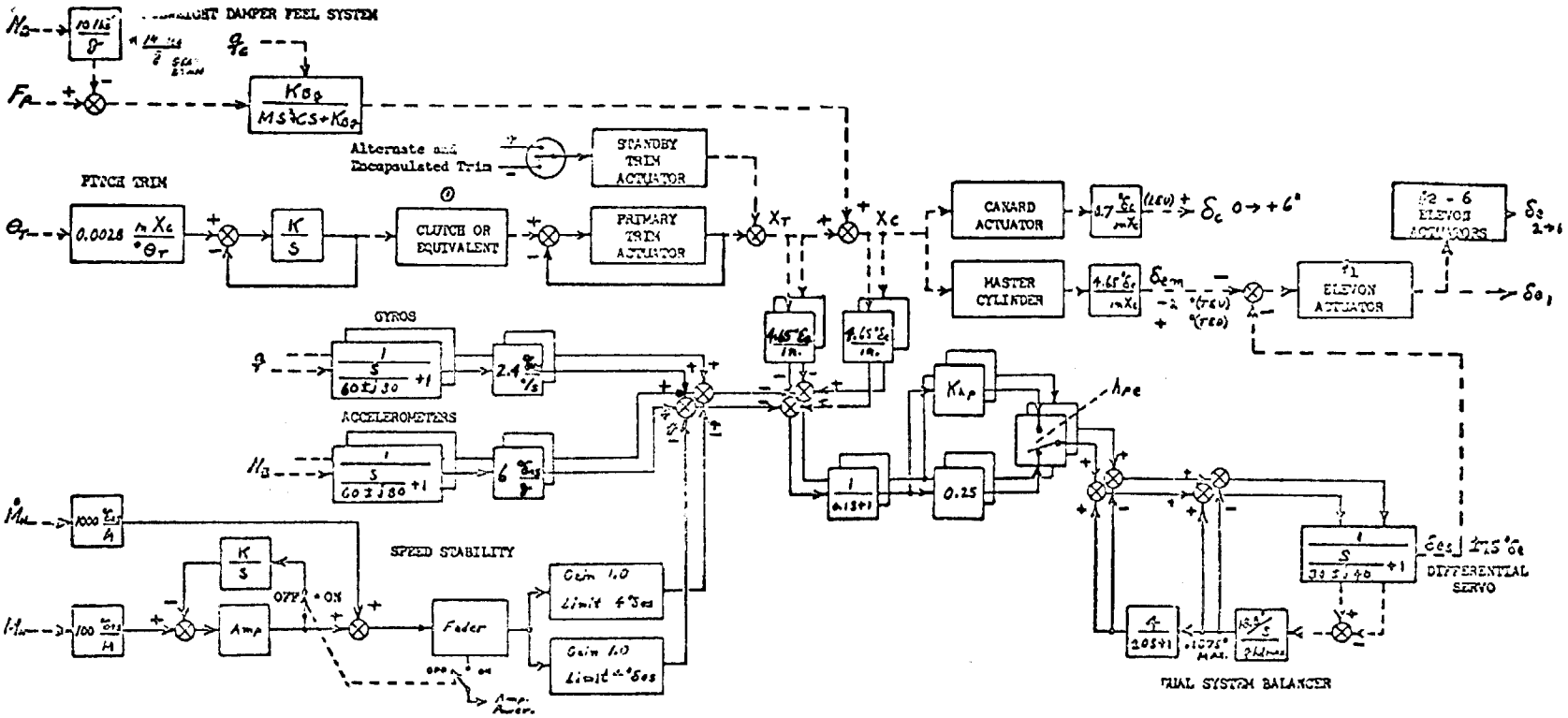
(FC) INDICATES BLOCK FUNCTIONS WHICH ARE PART OF THE FLIGHT CONTROLLER

SHADED BLOCKS INDICATE AUTOMATIC GAIN CONTROL FUNCTIONS OF THE AIRSPEED COMPENSATOR
f(q) INDICATES GAIN IS VARIED AS A FUNCTION OF DIFFERENTIAL PRESSURE
f(TAS) INDICATES GAIN IS VARIED AS A FUNCTION OF TRUE AIR SPEED

⊗ SYMBOL INDICATES SIGNAL SUMMING

□ INDICATES COMPONENTS CONTAINING SENSING ELEMENTS

B-66 Autopilot



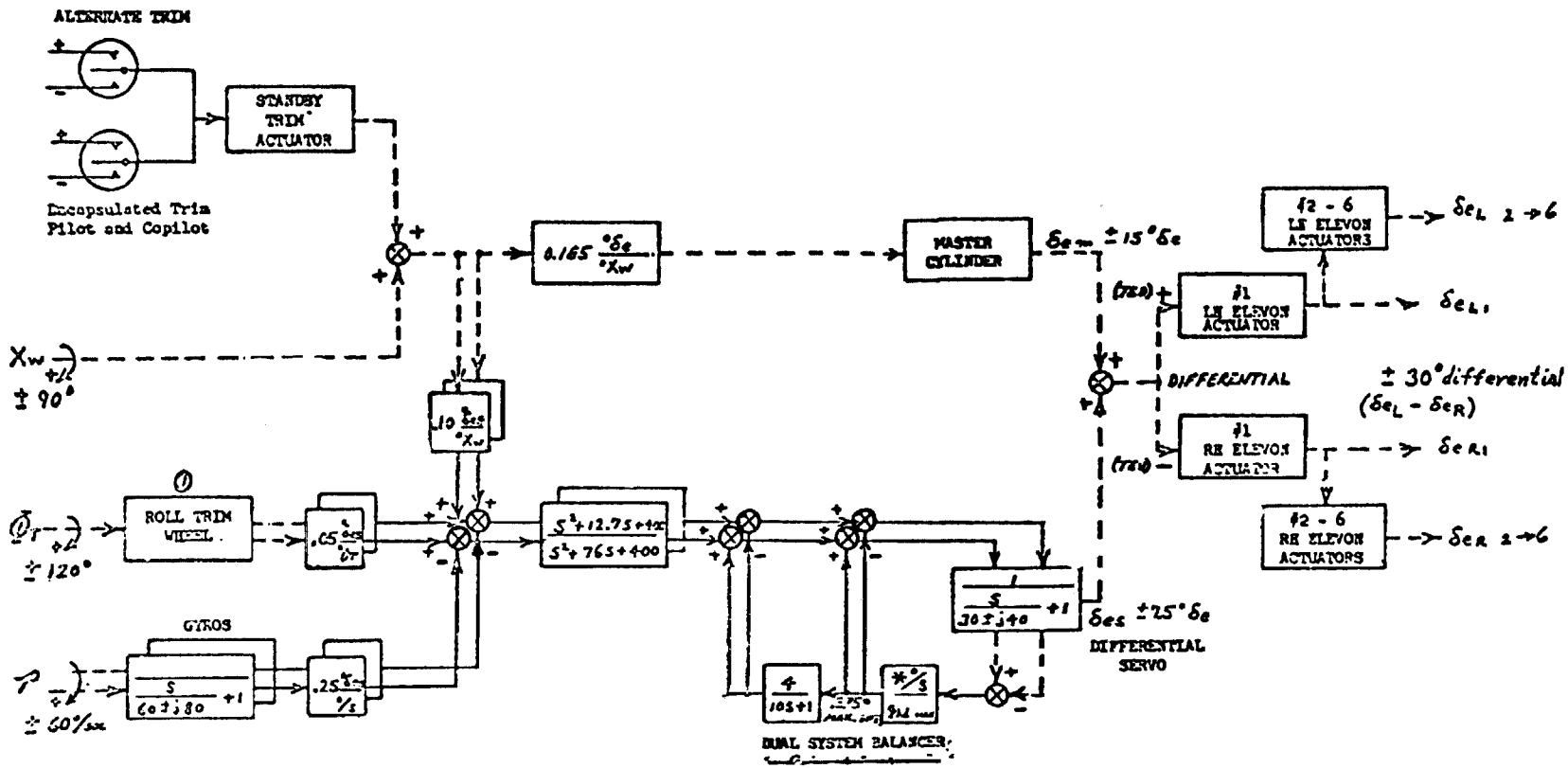
LEGEND

δ_{cs} - Differential Servo Deflection Degrees Equivalent Elevon
δ_{cm} - Master Cylinder Deflection Degrees Equivalent Elevon
δ_e - Elevon Deflection
δ_c - Canard Deflection
M_{δ_p} - Feel Damper Gain, $f(\phi_c)$
Q_c - Compressible Dynamic Pressure
θ_T - Pitch Trim Knob Rotation
F_p - Pilot Input Force
X_T - Pitch Trim Actuator Position
X_c - Pitch Column Position

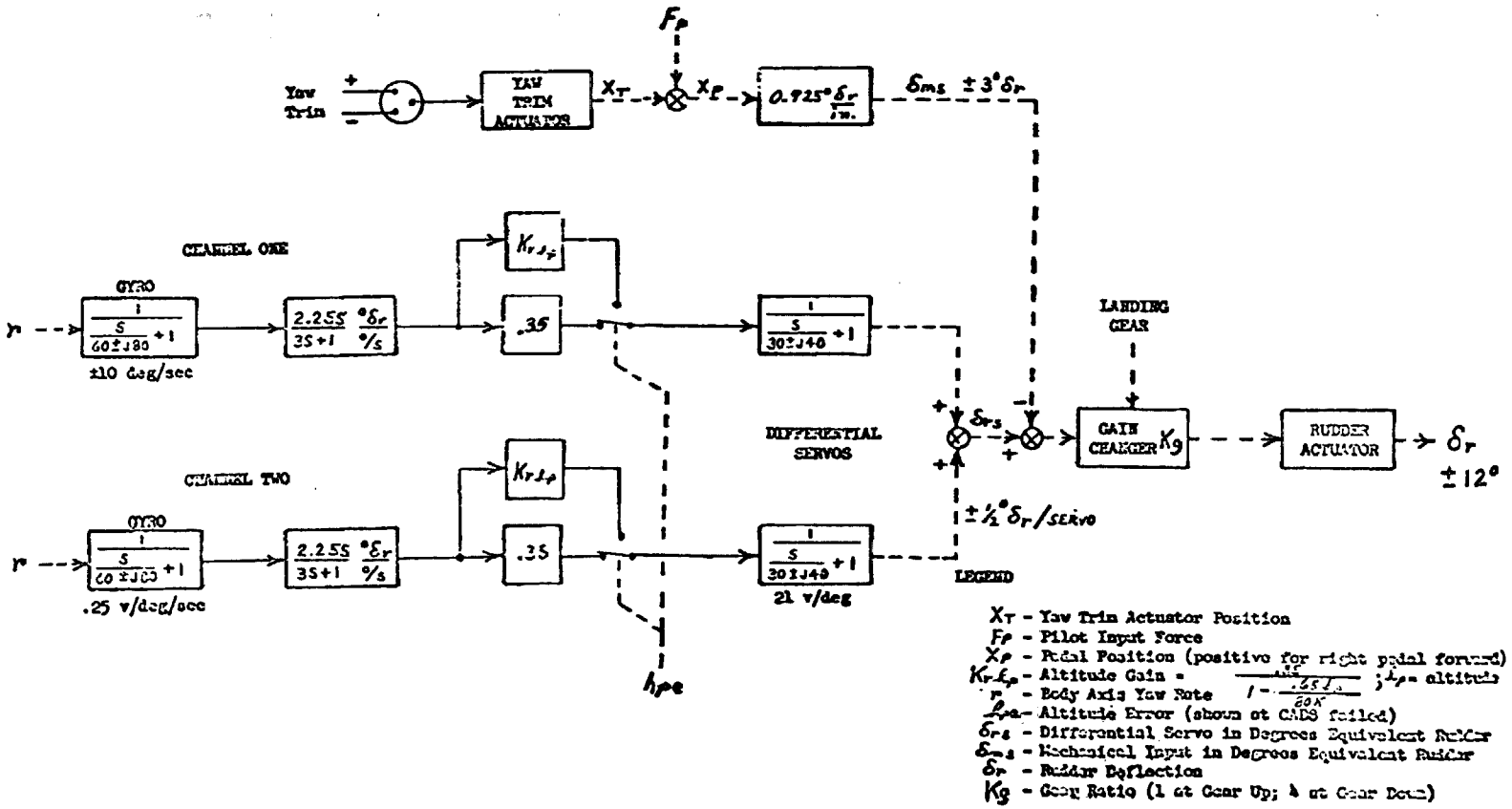
n_{z_1} - Pitch Normal Acceleration at Bobweight Location
n_{z_2} - Pitch Normal Acceleration at Sensor Location
q - Body Axis Pitch Rate
M_∞ - Mach Number
$\dot{M}_\infty$ - Mach Number Rate of Change
K_{h_p} - Altitude Gain Function $= .25 + \frac{.75\,h_p}{60K}$
h_{pe} - CADS Altitude Error
Q_{H_d} - Hydraulic Differential Flow

NOTES:
⊙ - Disengage and Recenter TTO

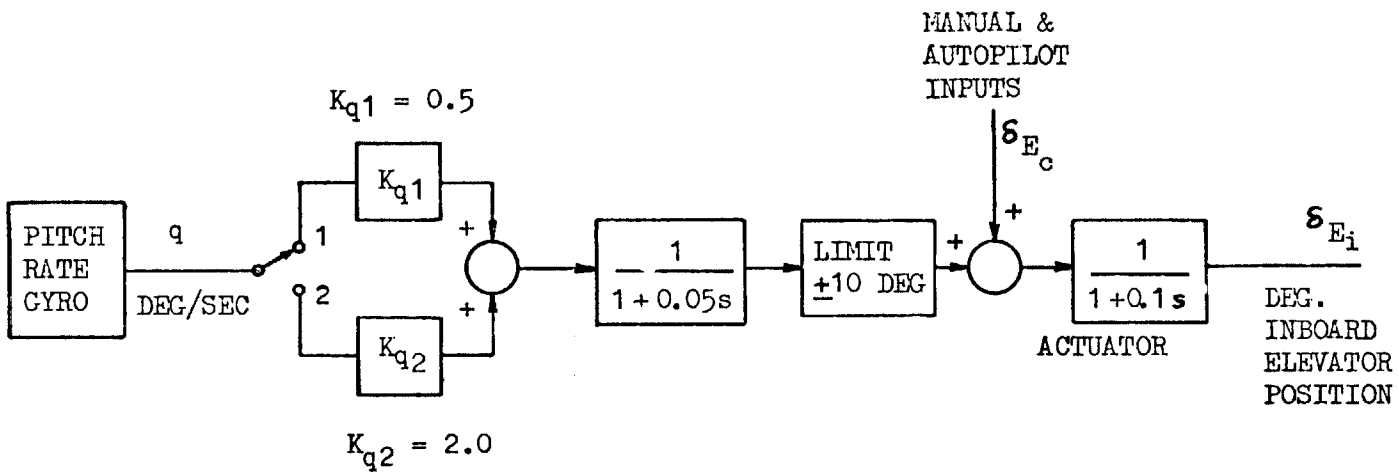
XB-70 Pitch Axis Augmentation



XB-70 Roll Axis Augmentation



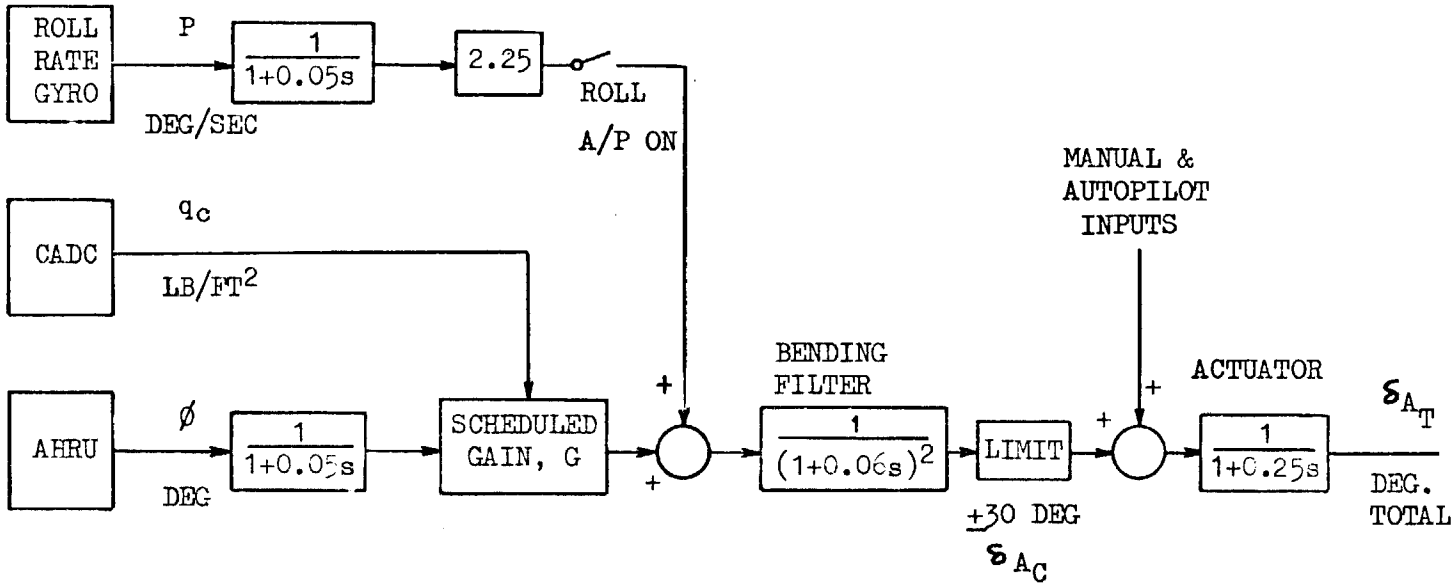
XB-70 Yaw Axis Augmentation

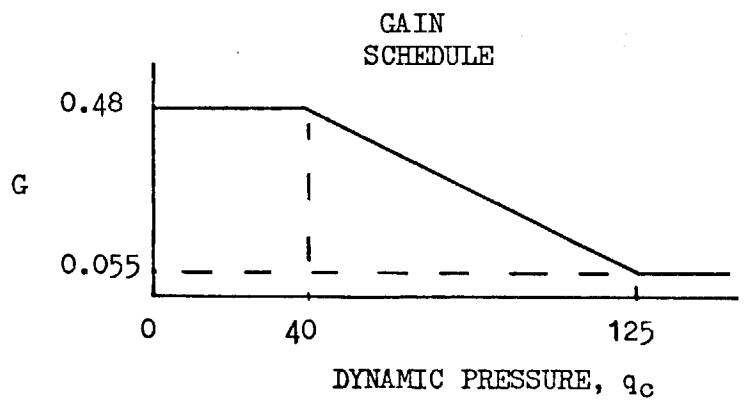


SWITCH POSITION: 1 PITCH AUTOPILOT OFF

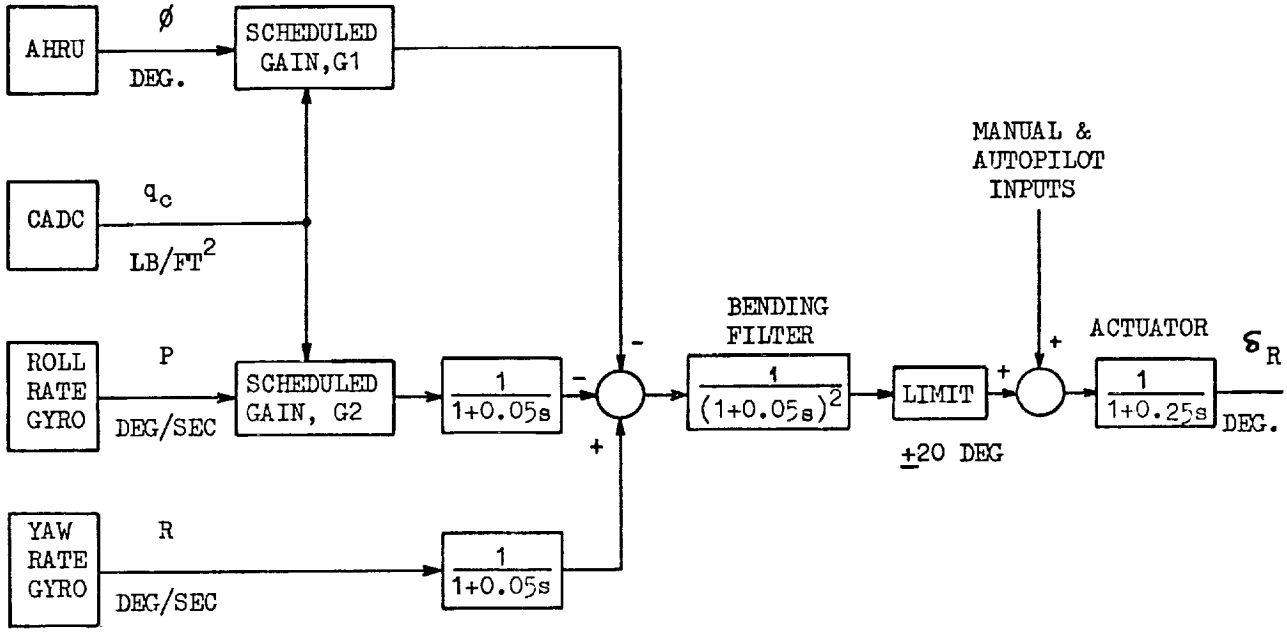
2 PITCH AUTOPILOT ENGAGED

C-5A Pitch Stability Augmentation System

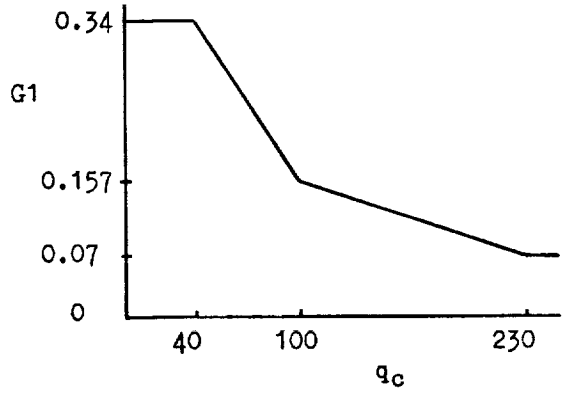


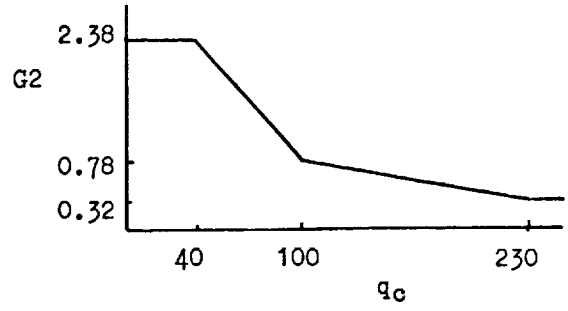


C-5A Roll Stability Augmentation System (SAS)

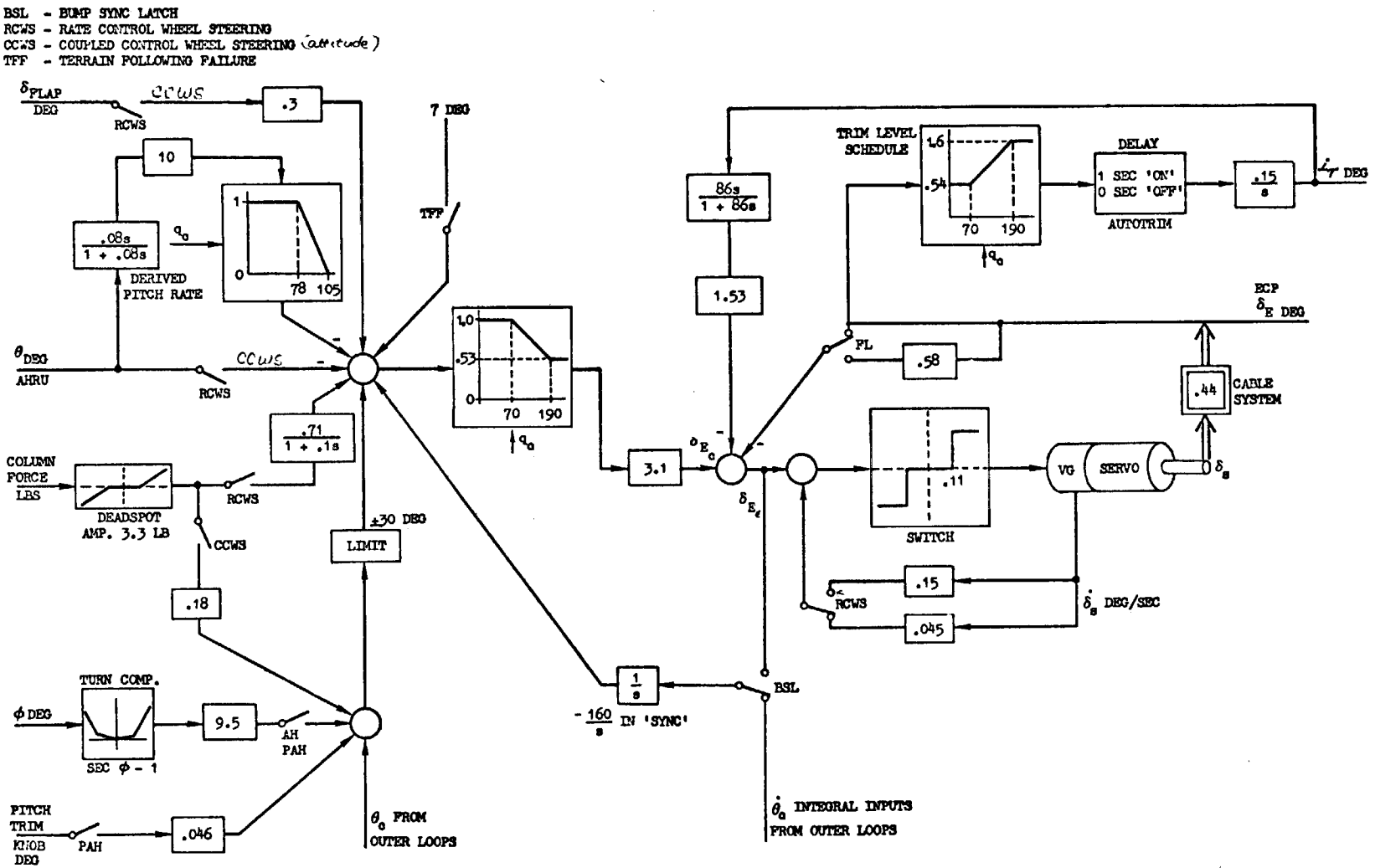


GAIN SCHEDULES

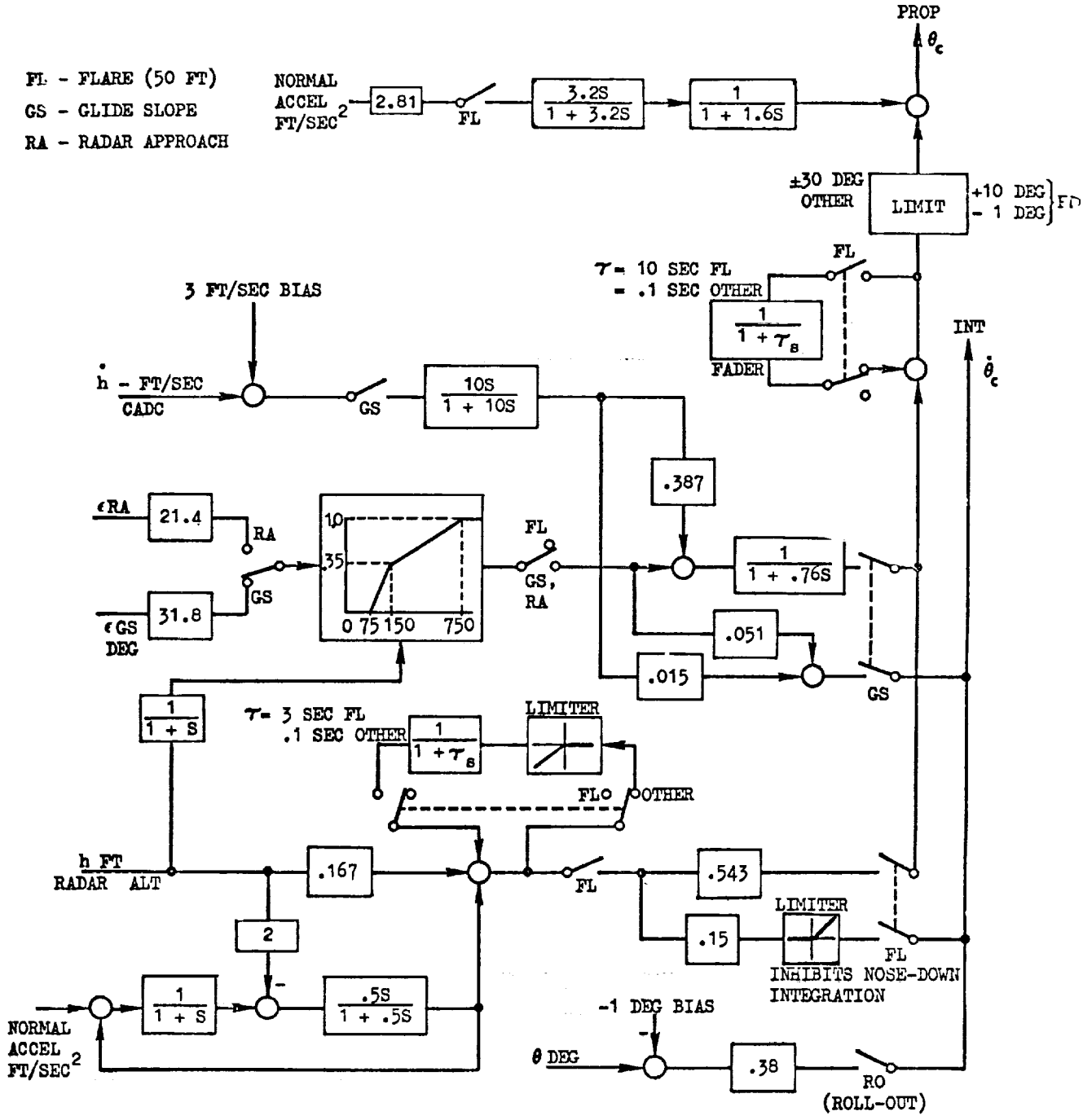




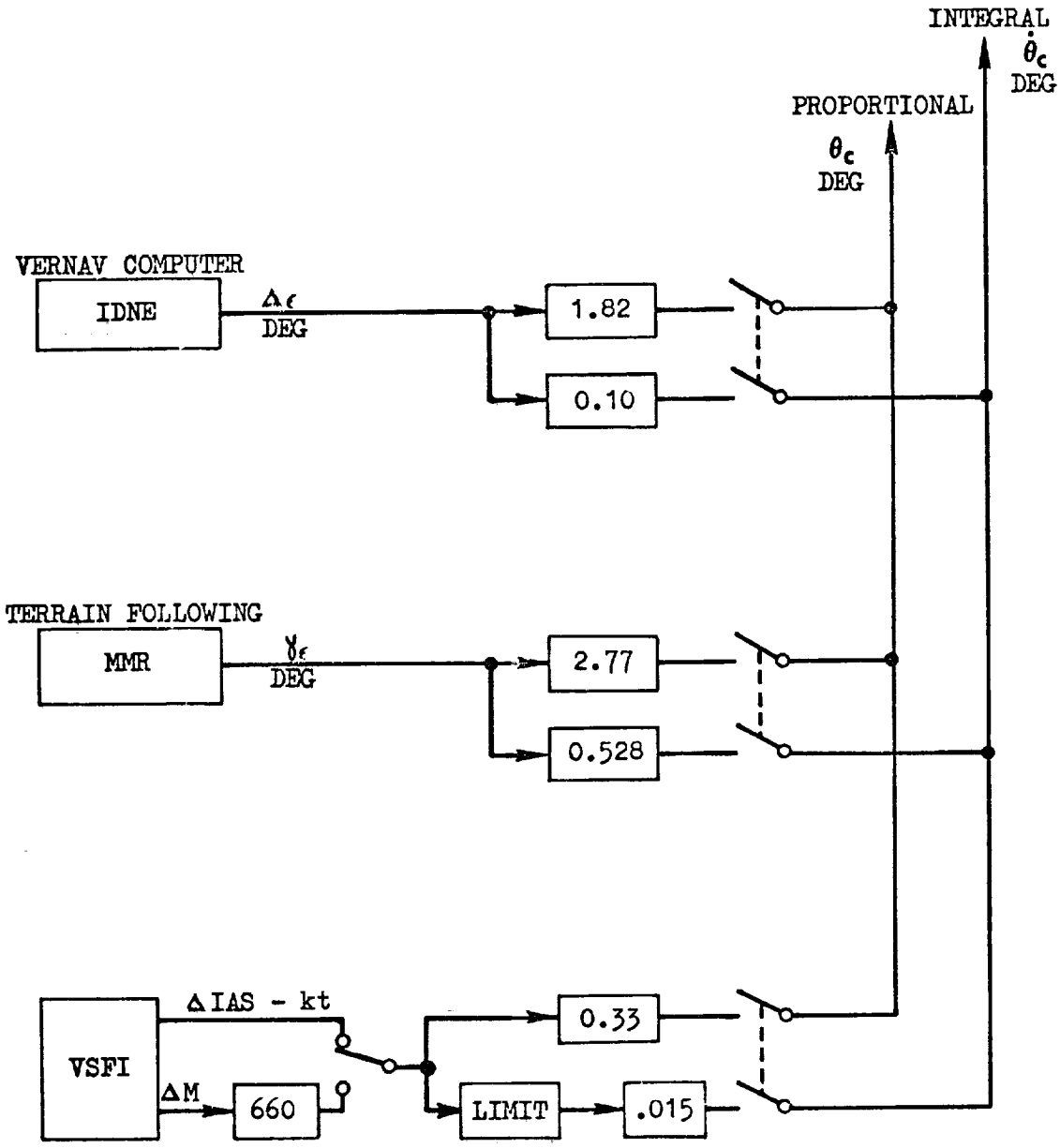
C-5A Yaw Stability Augmentation System (SAS)



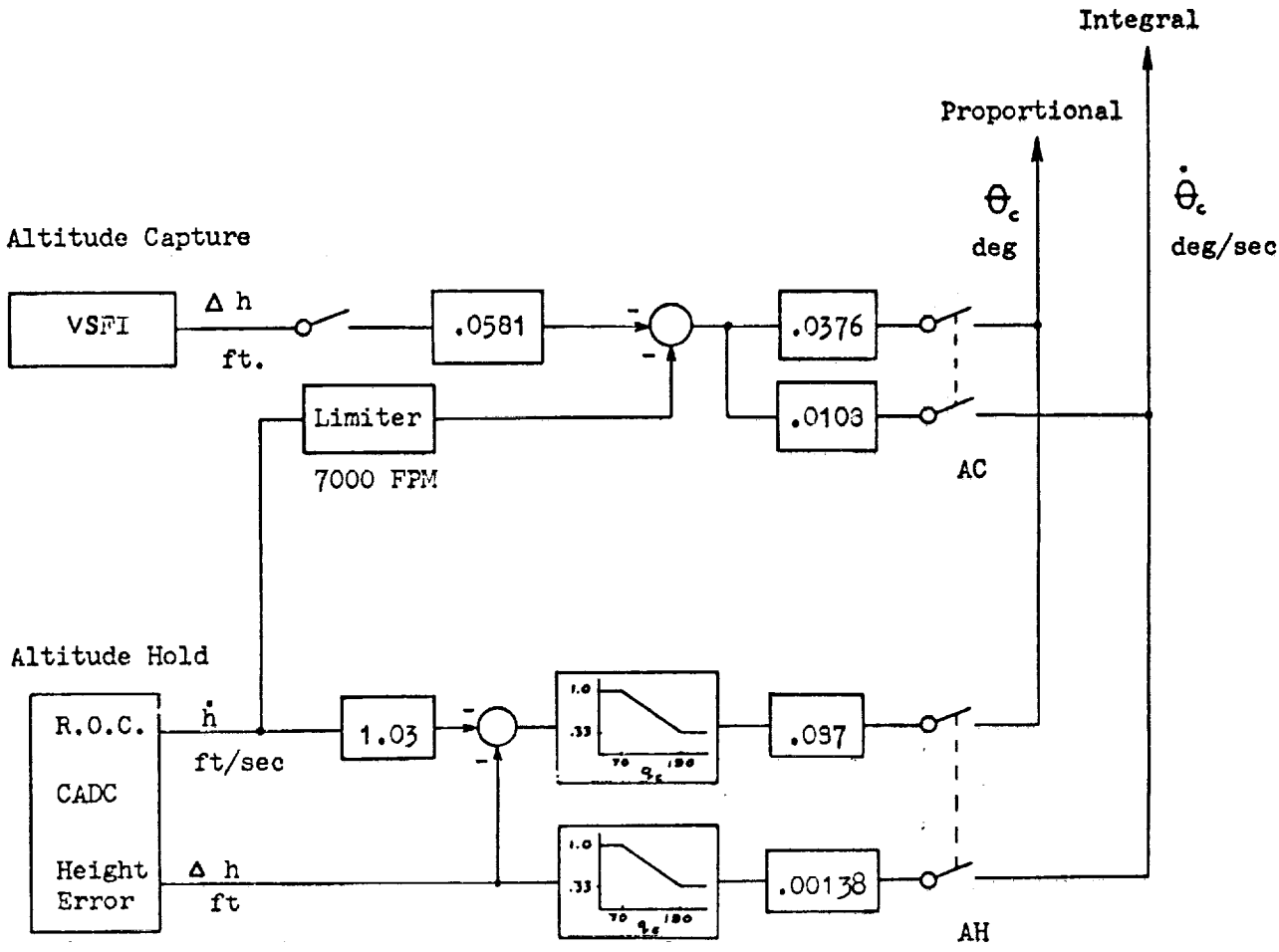
C-5A Pitch Autopilot: Inner Loops



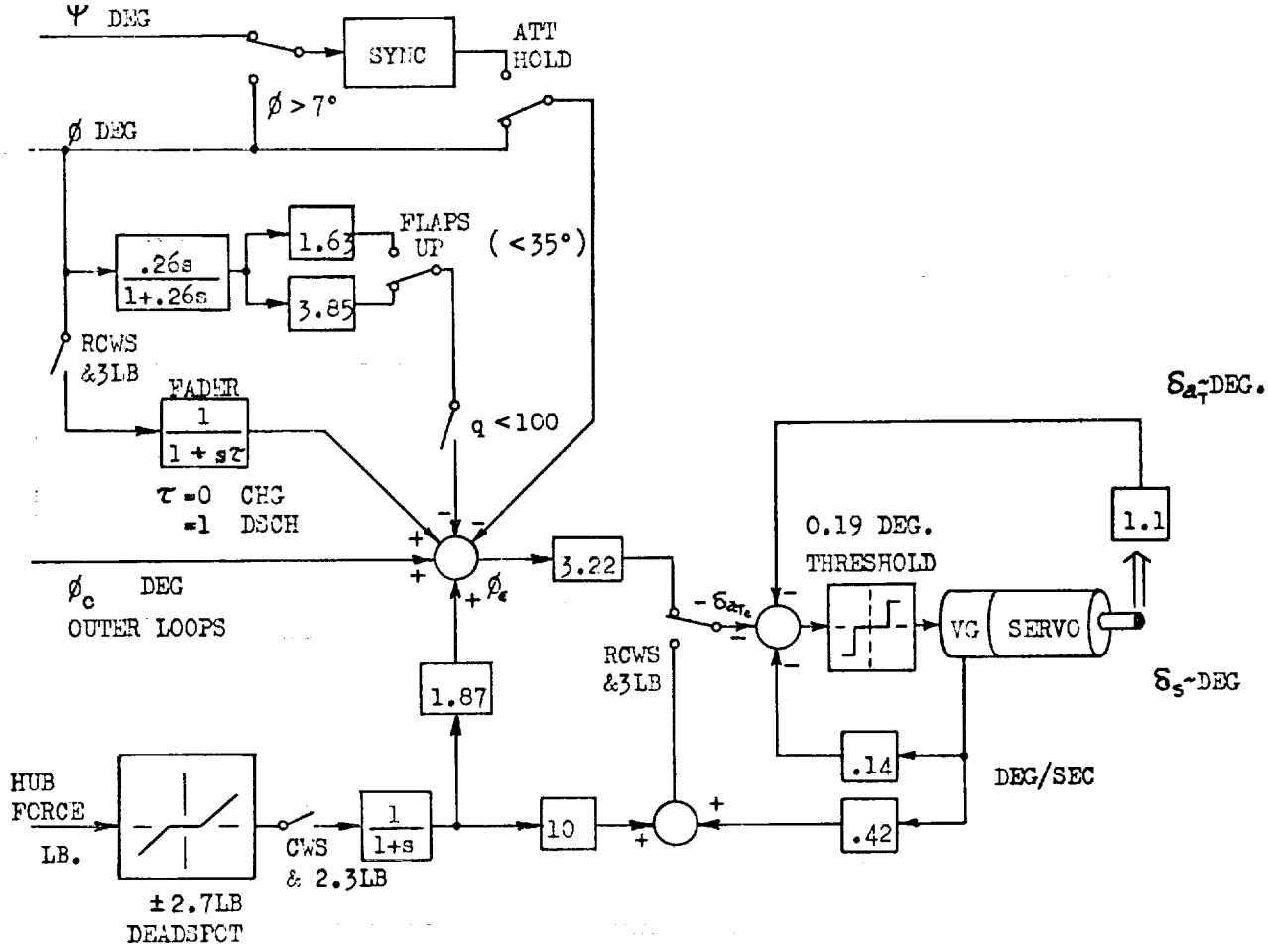
C-5A Pitch Autopilot: Radar Approach,
Glide Slope and Flare Modes



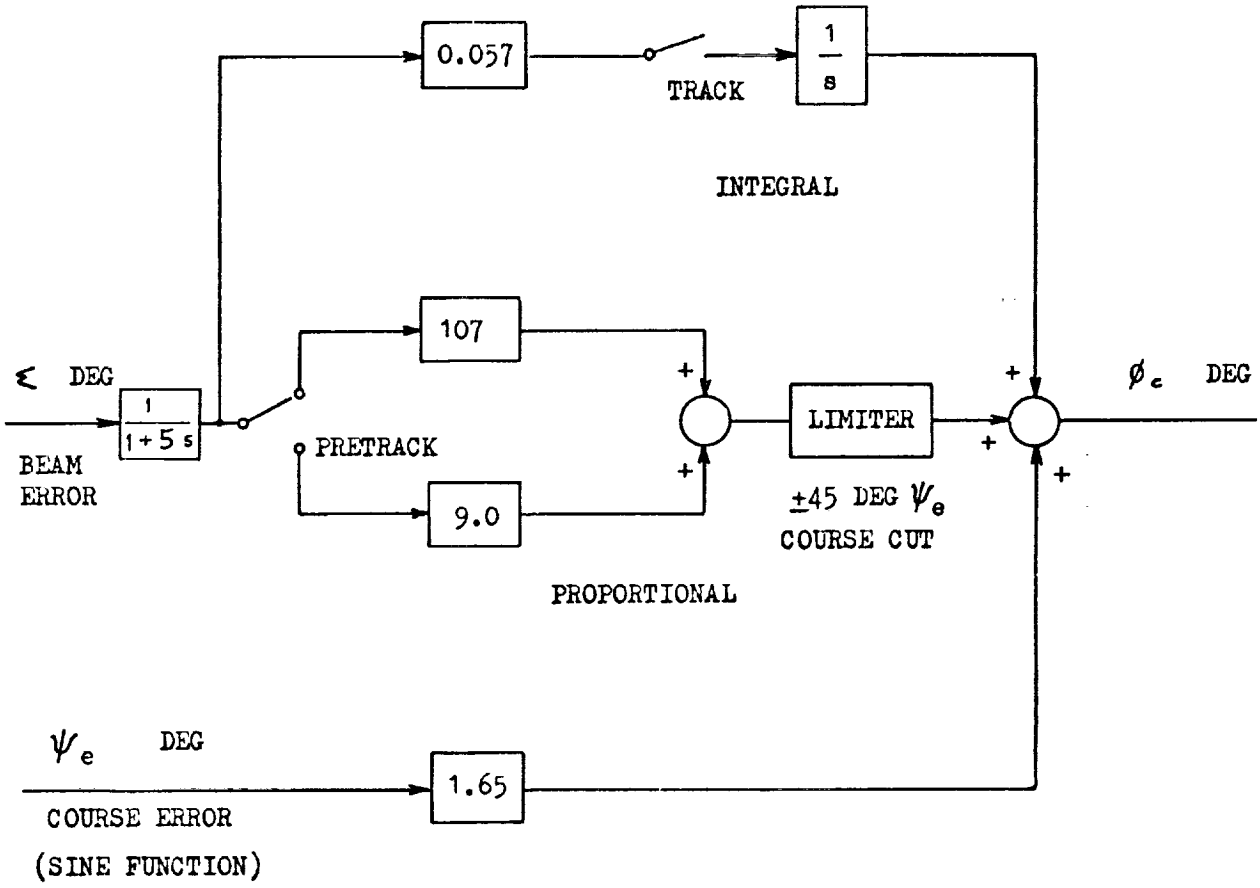
C-5A Pitch Autopilot: Vernav, Terrain Following and Mach/IAS Modes



C-5A Pitch Autopilot: Altitude Capture and Altitude Hold Modes

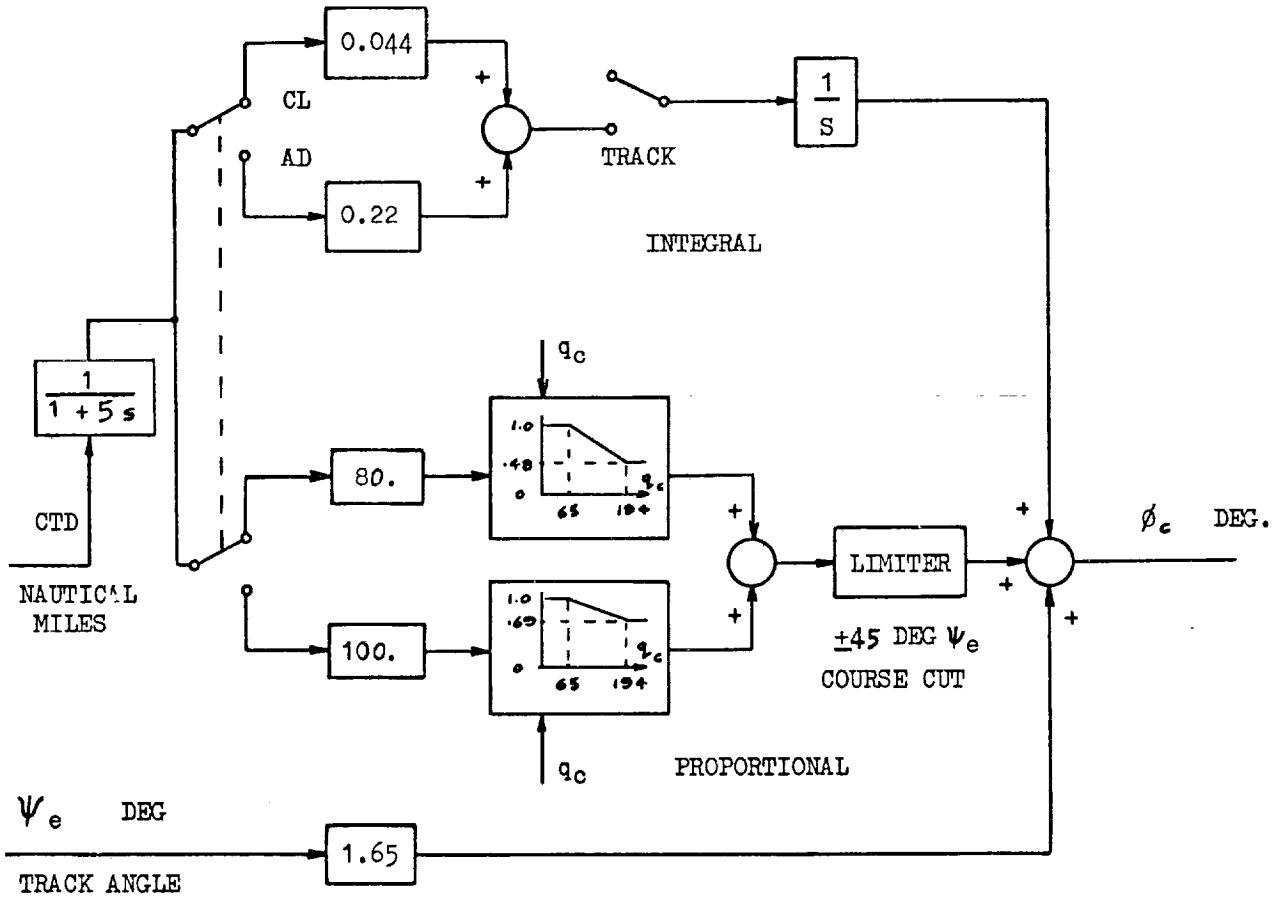


C-5A Roll Autopilot: Inner Loops Including Control Wheel Steering



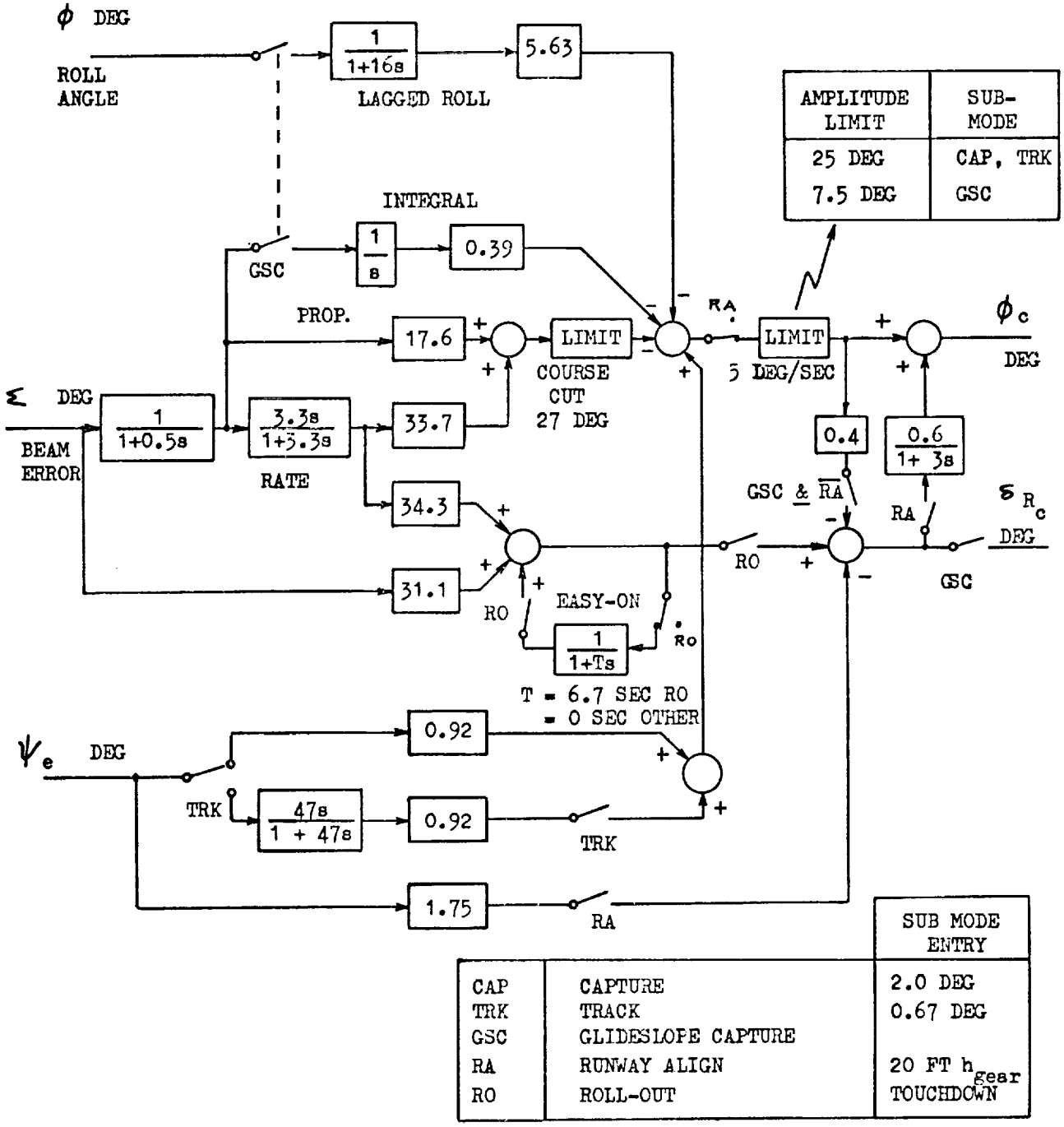
SUB-MODE ENTRY	VOR, TACAN ≤ 62 NM	TACAN > 62 NM
CAPTURE	5.0 DEG	5.4 NM
PRE-TRACK	2.1 DEG	2.3 NM
TRACK	1.2 DEG	1.3 NM

C-5A Roll Autopilot: VOR and TACAN Modes

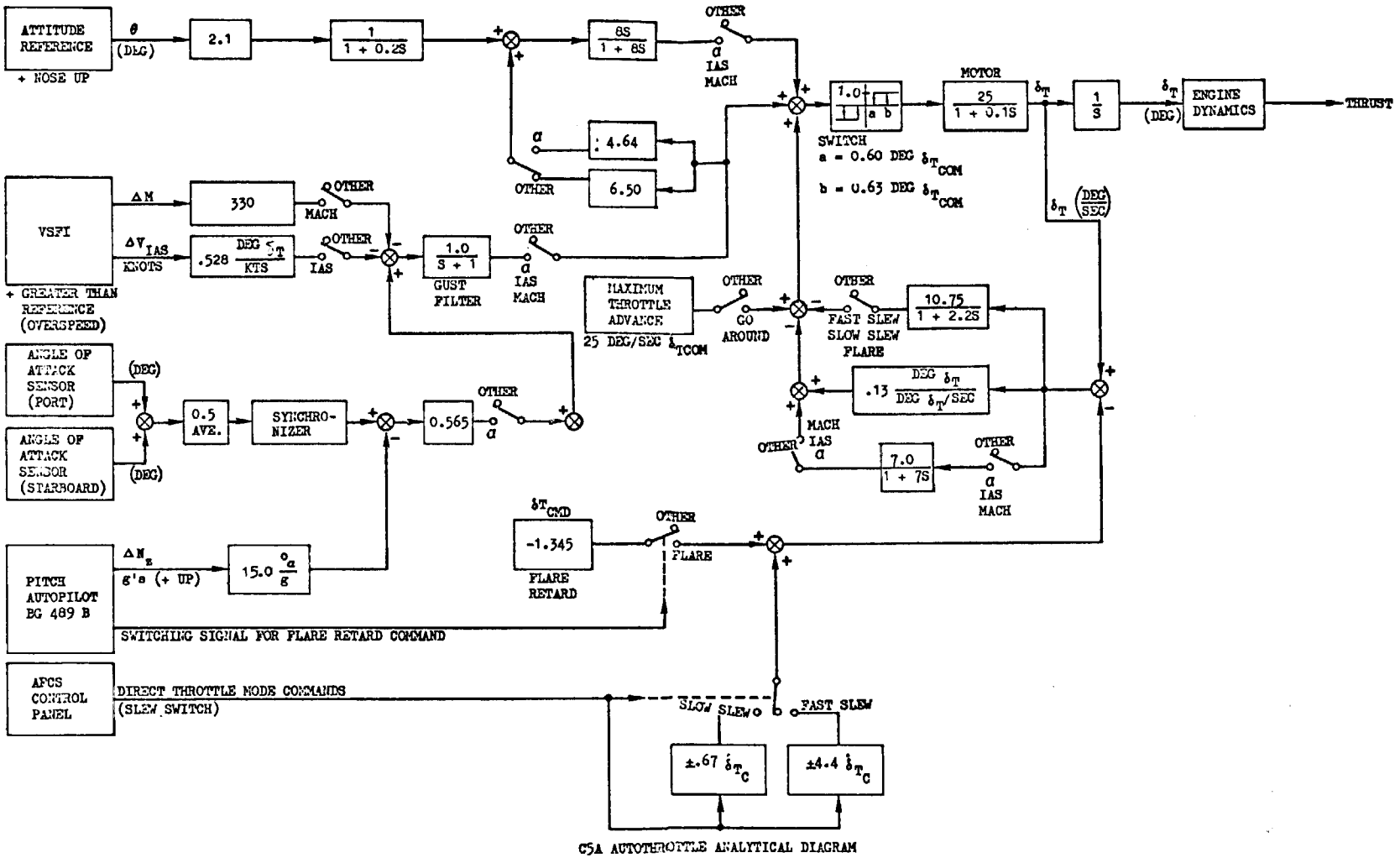


SUB-MODE ENTRY	CROSS-TRACK DEVIATION (CTD)
CAPTURE	5.8 NM
TRACK	0.4 NM

C-5A Roll Autopilot: Courseline and Air-Drop Modes

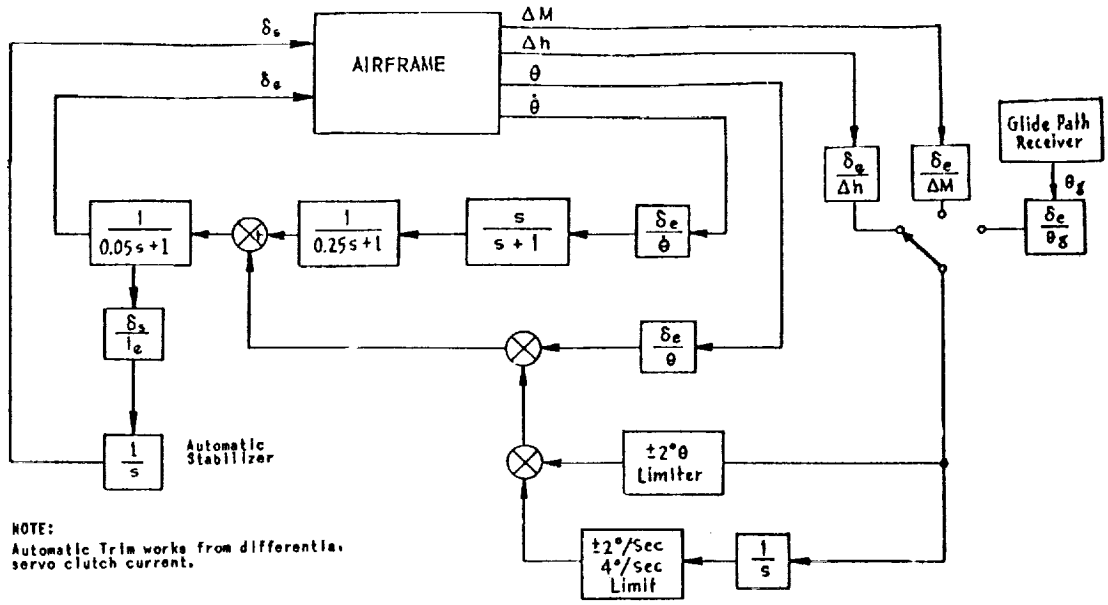


C-5A Roll Autopilot: Localizer Mode, Including Autoland

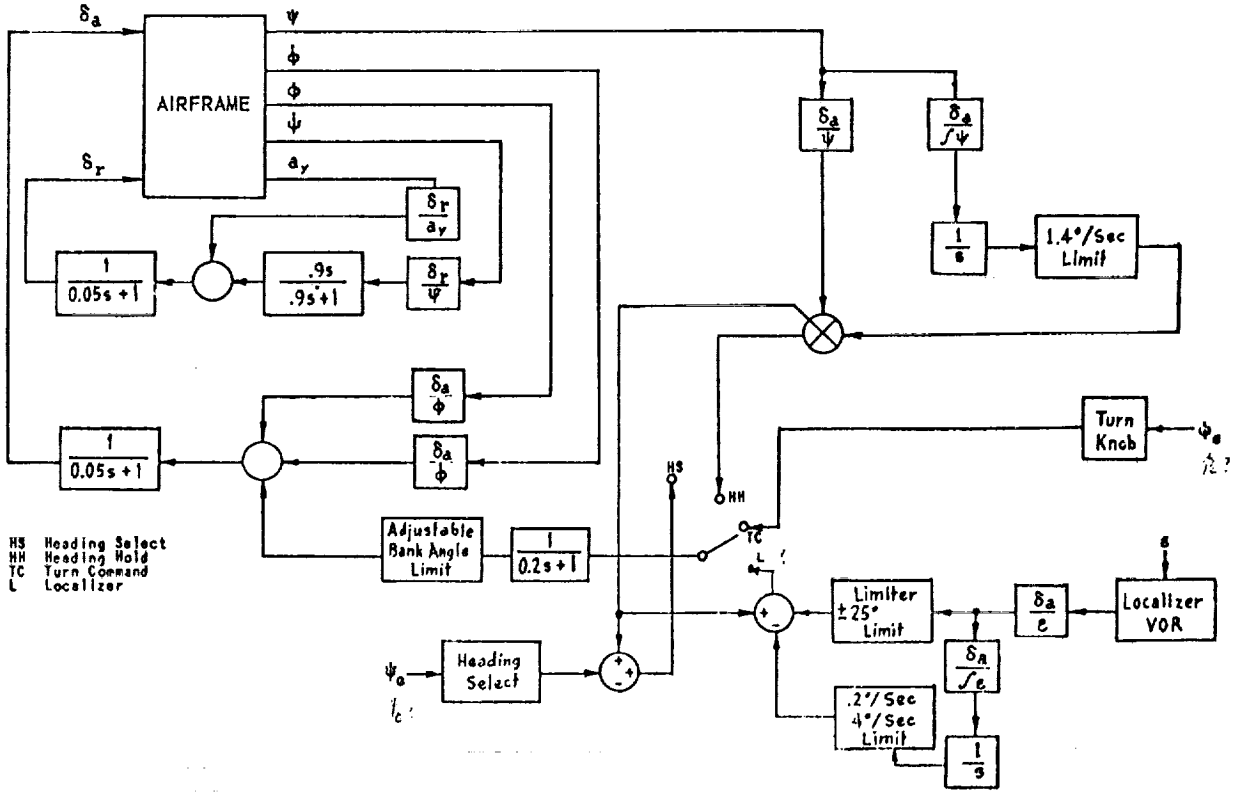


C5A AUTOTHROTTLE ANALYTICAL DIAGRAM

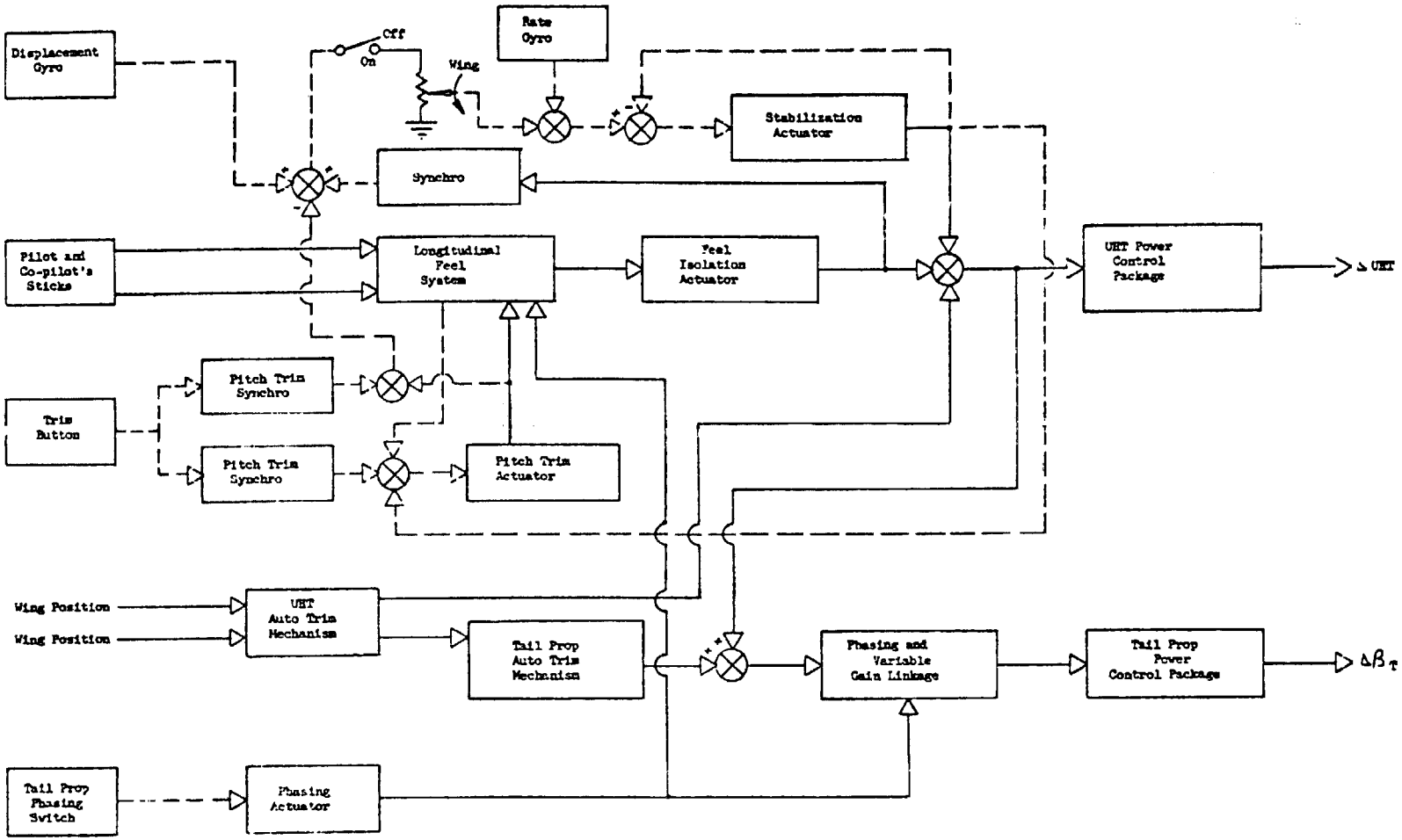
C-5A Autothrottle Analtyical Diagram



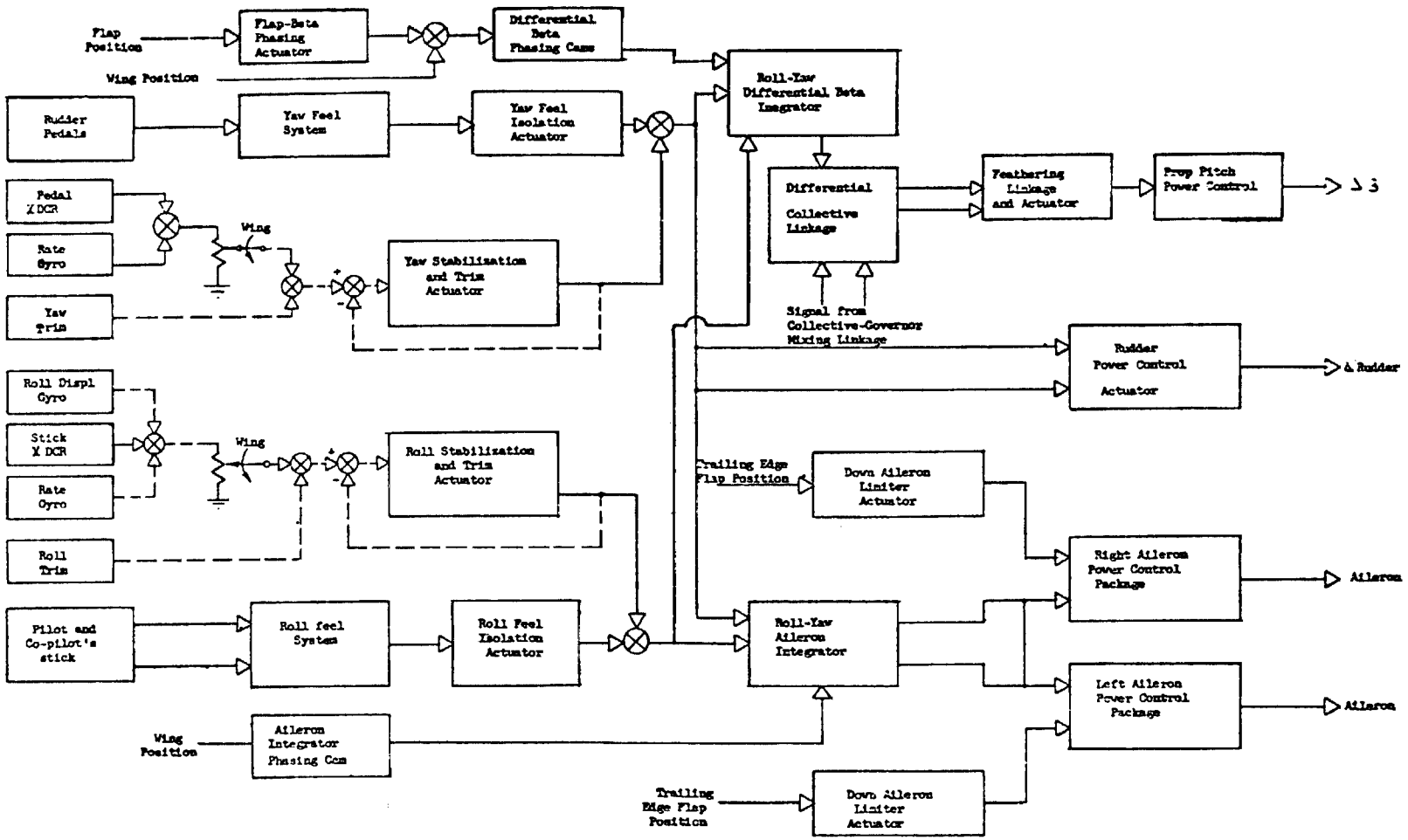
KC-135 Pitch Diagram



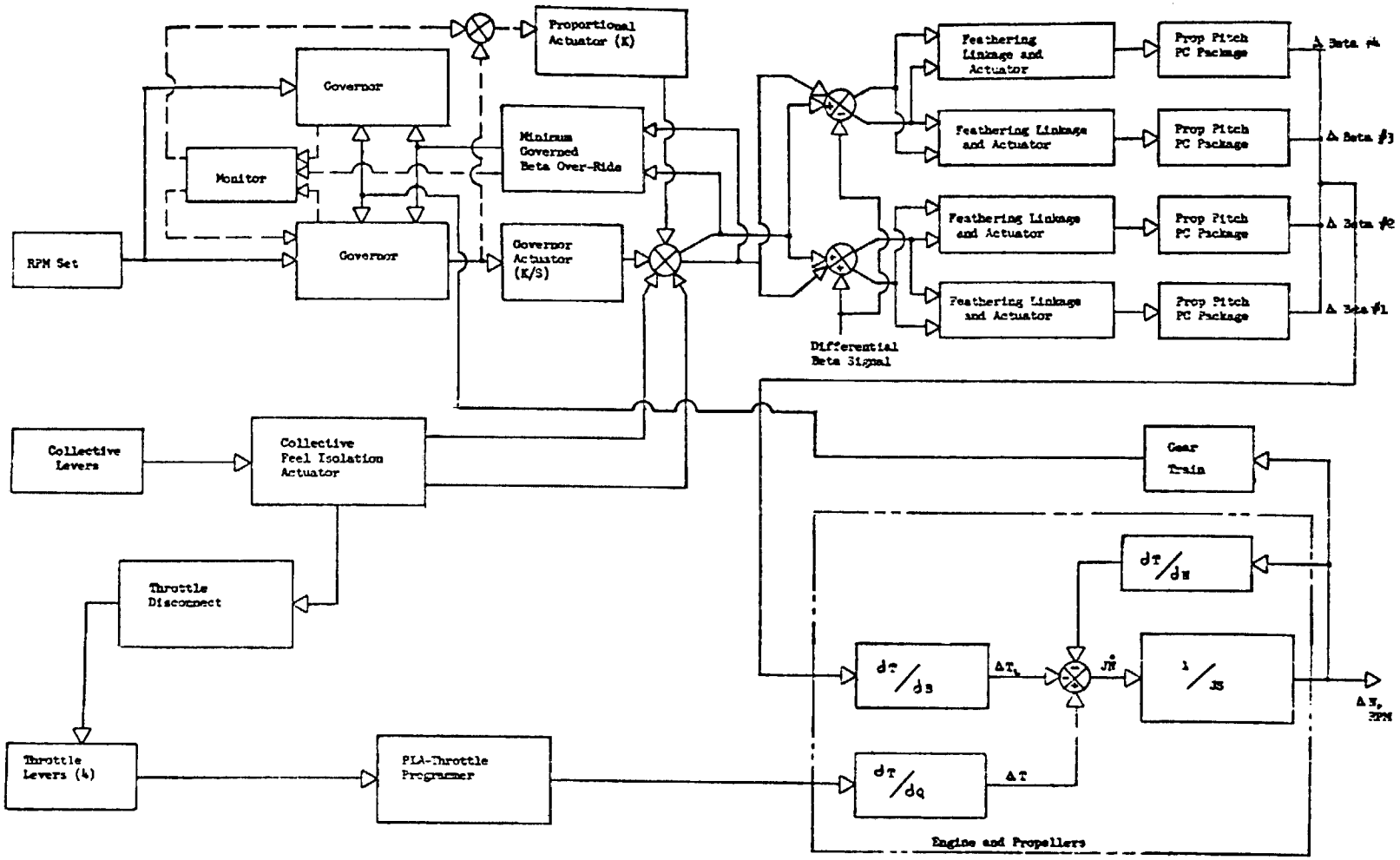
KC-135 Lateral-Directional Axis Diagram



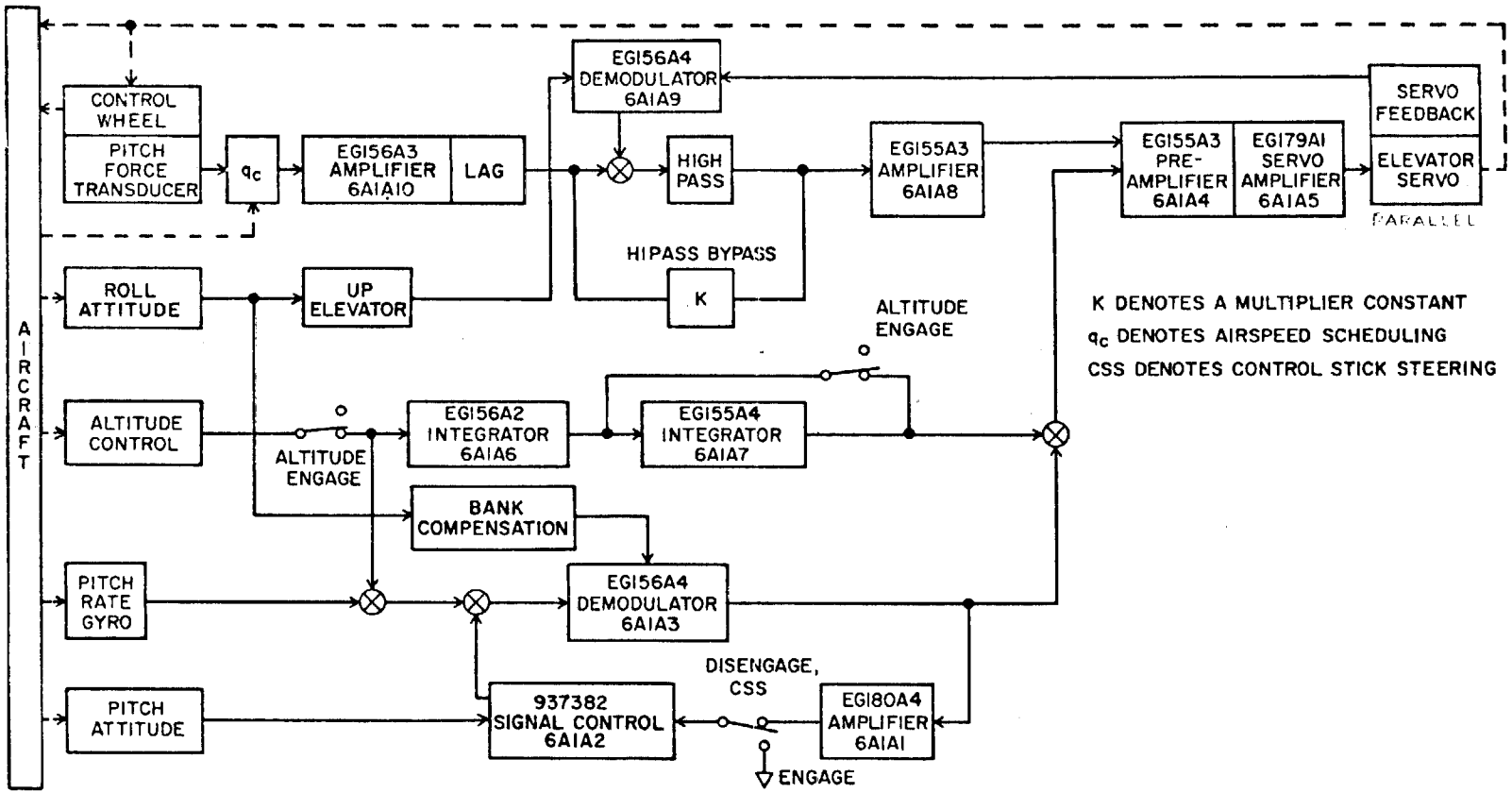
XC-142A Pitch Control System Block Diagram



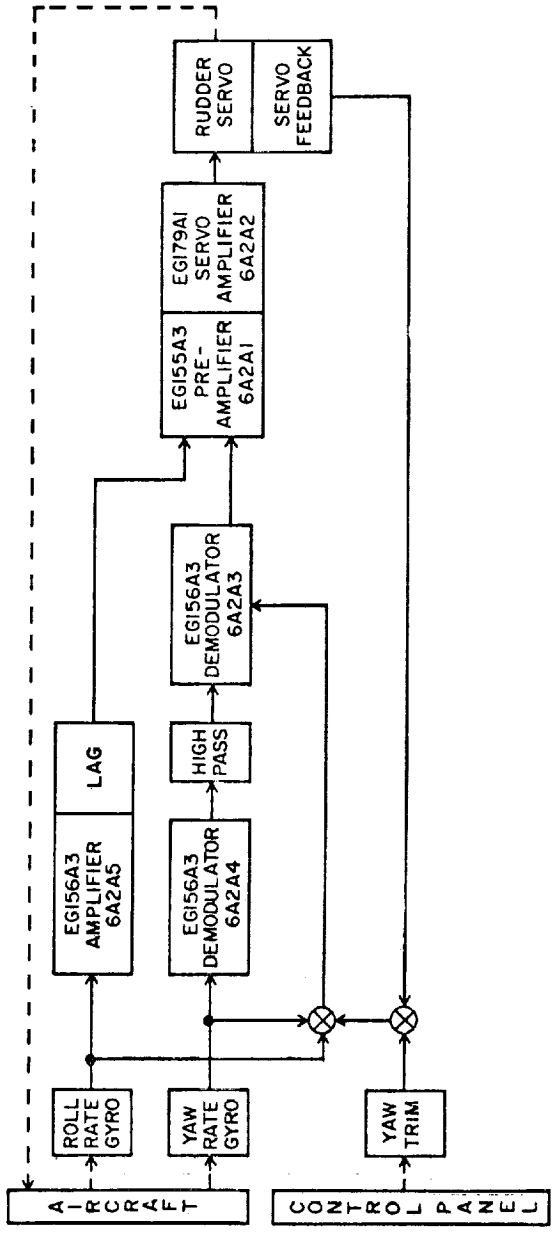
XC-142A Roll and Yaw Control System Block Diagram



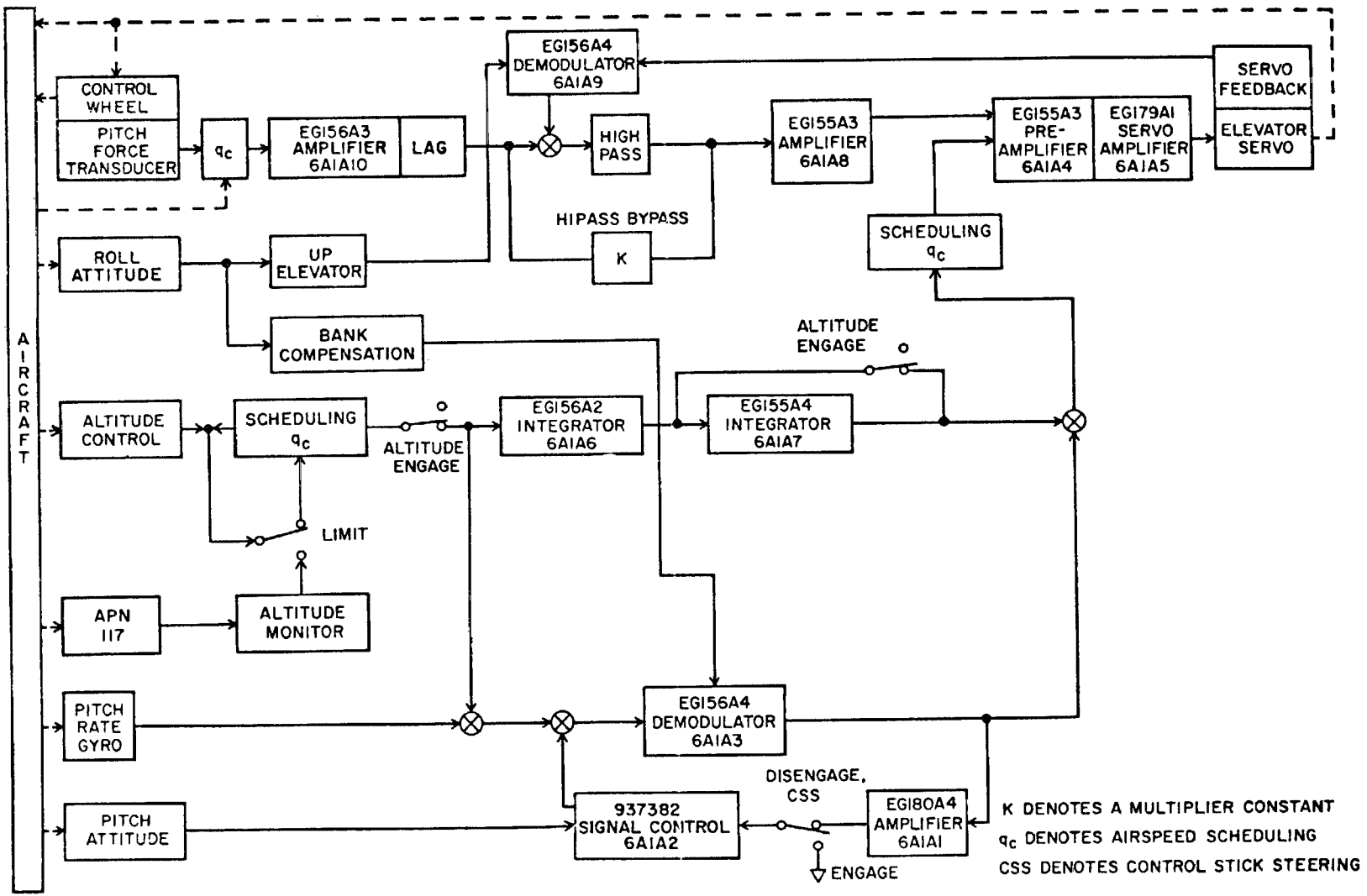
XC-142A Collective-Throttle System Block Diagram



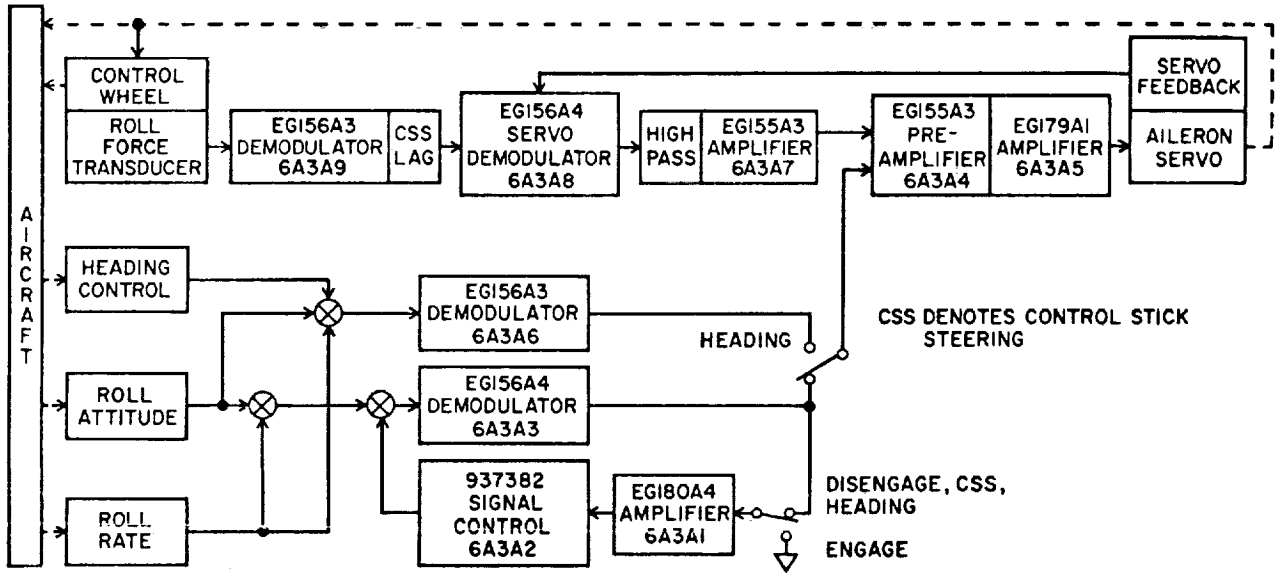
E-1B Pitch Axis



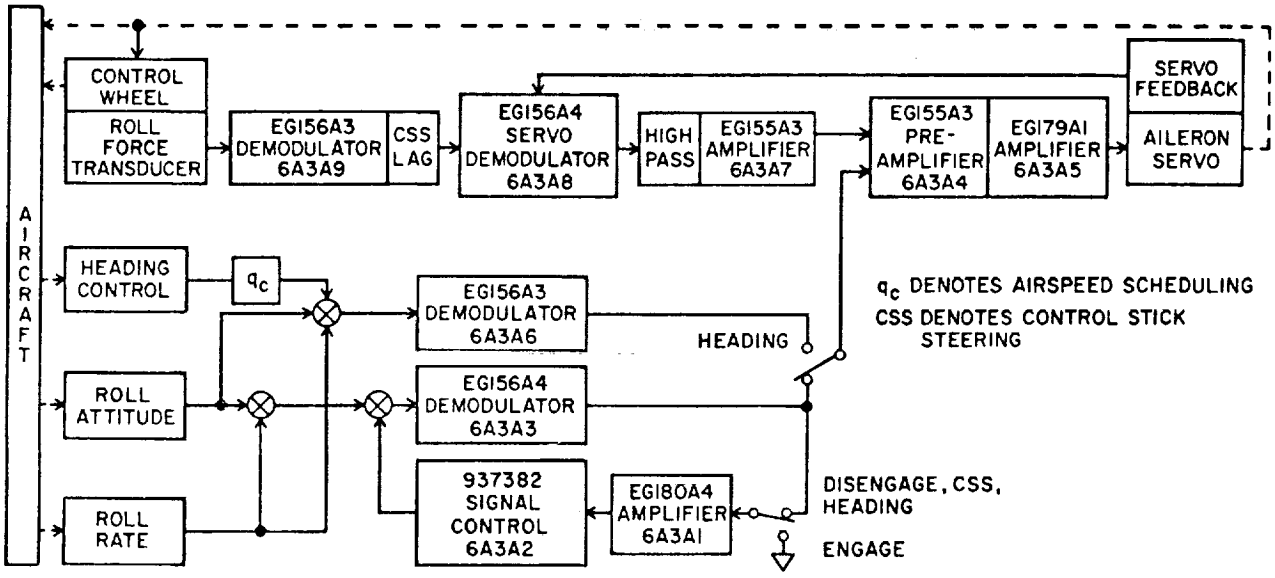
E-1B Yaw Axis Block Diagram



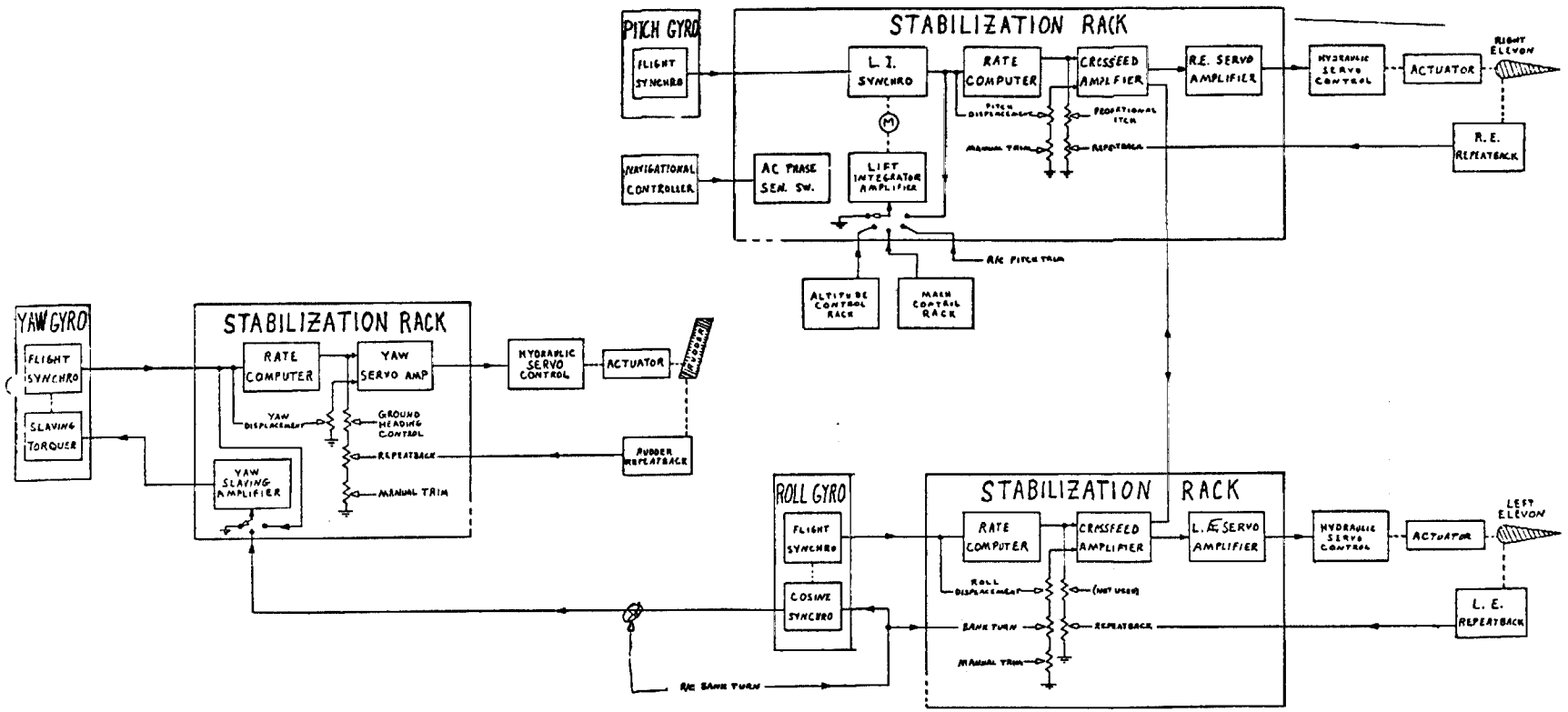
S-2D/S-2E Pitch Axis

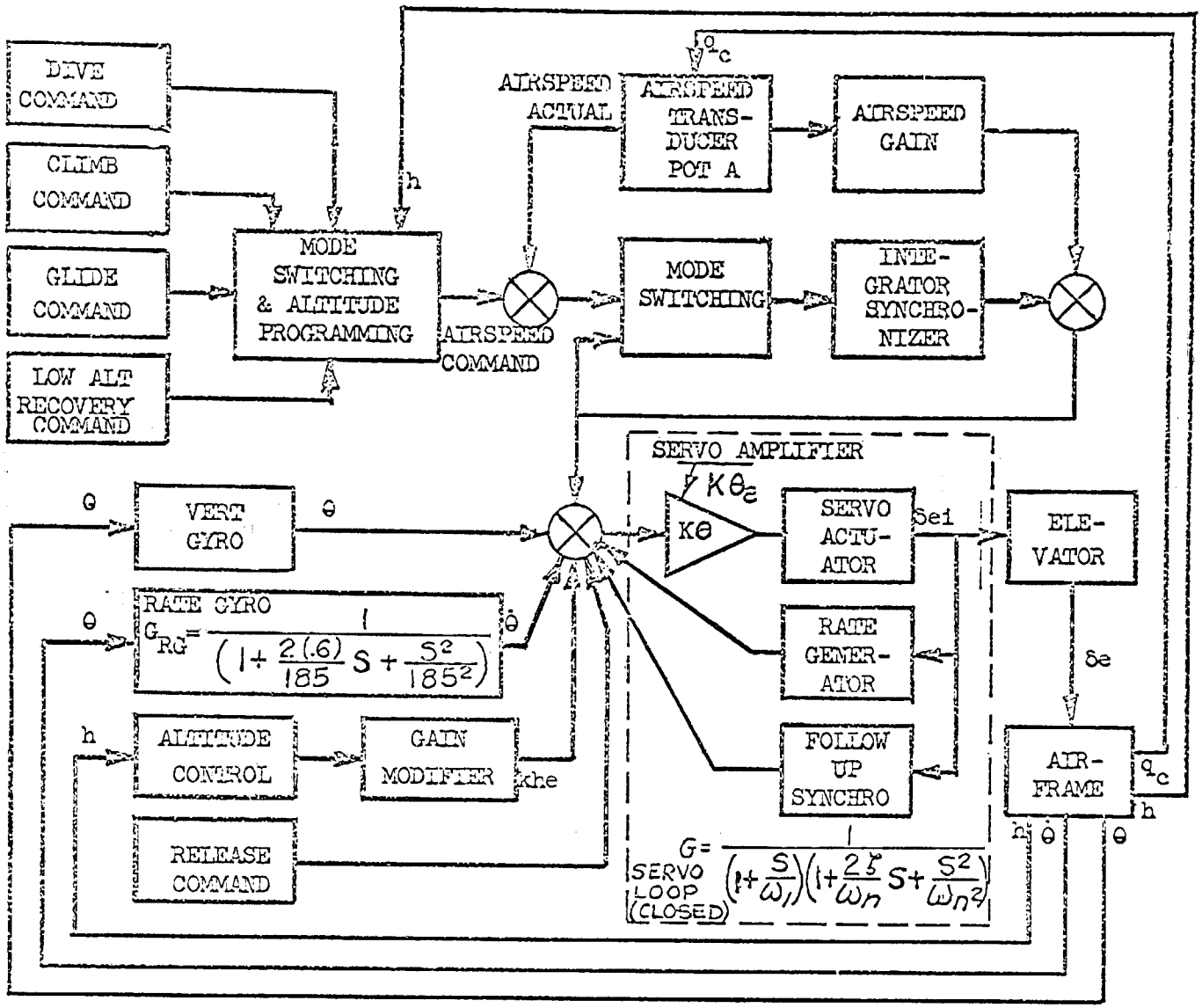


E-1B Roll Axis

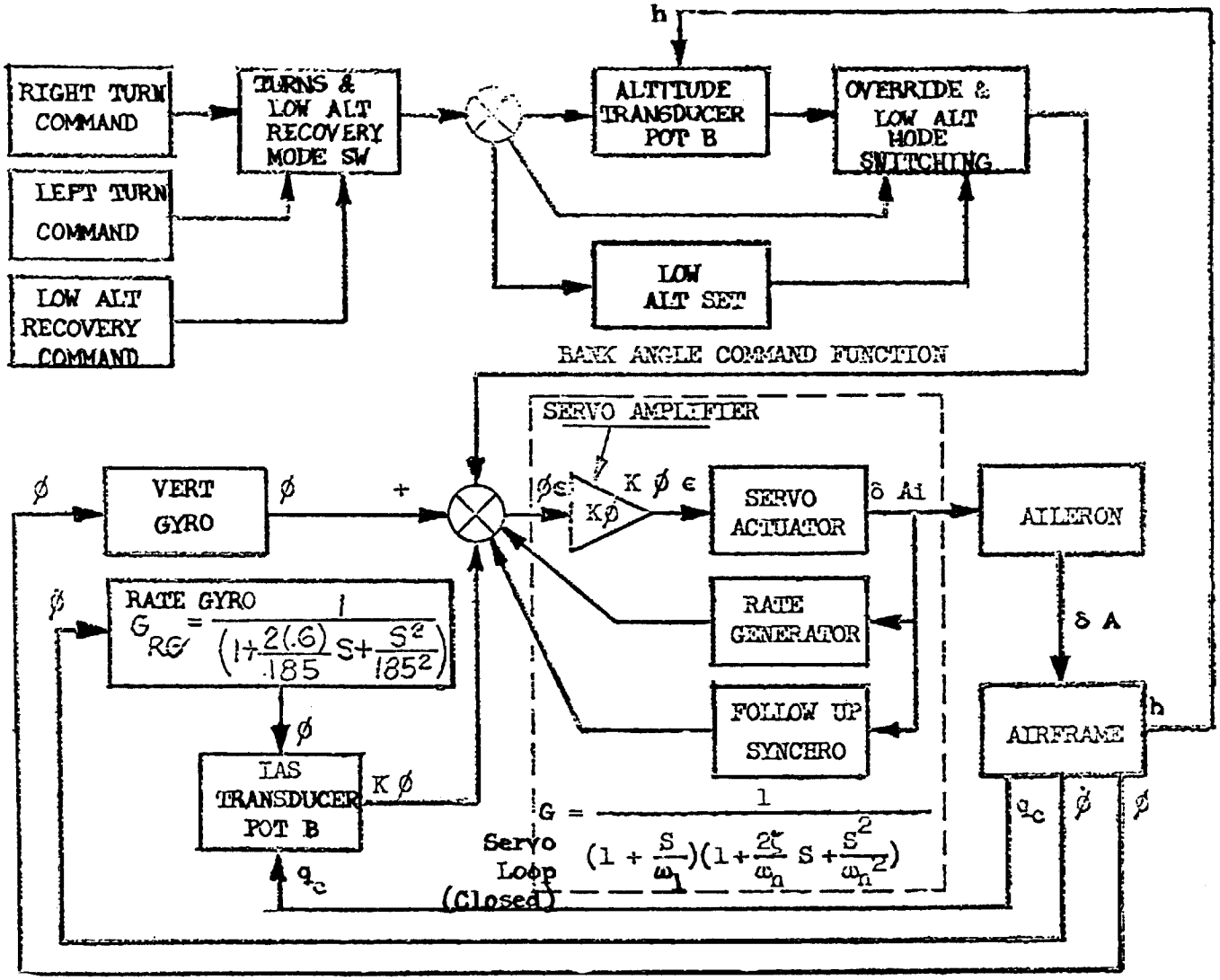


S-2D/S-2E Roll Axis

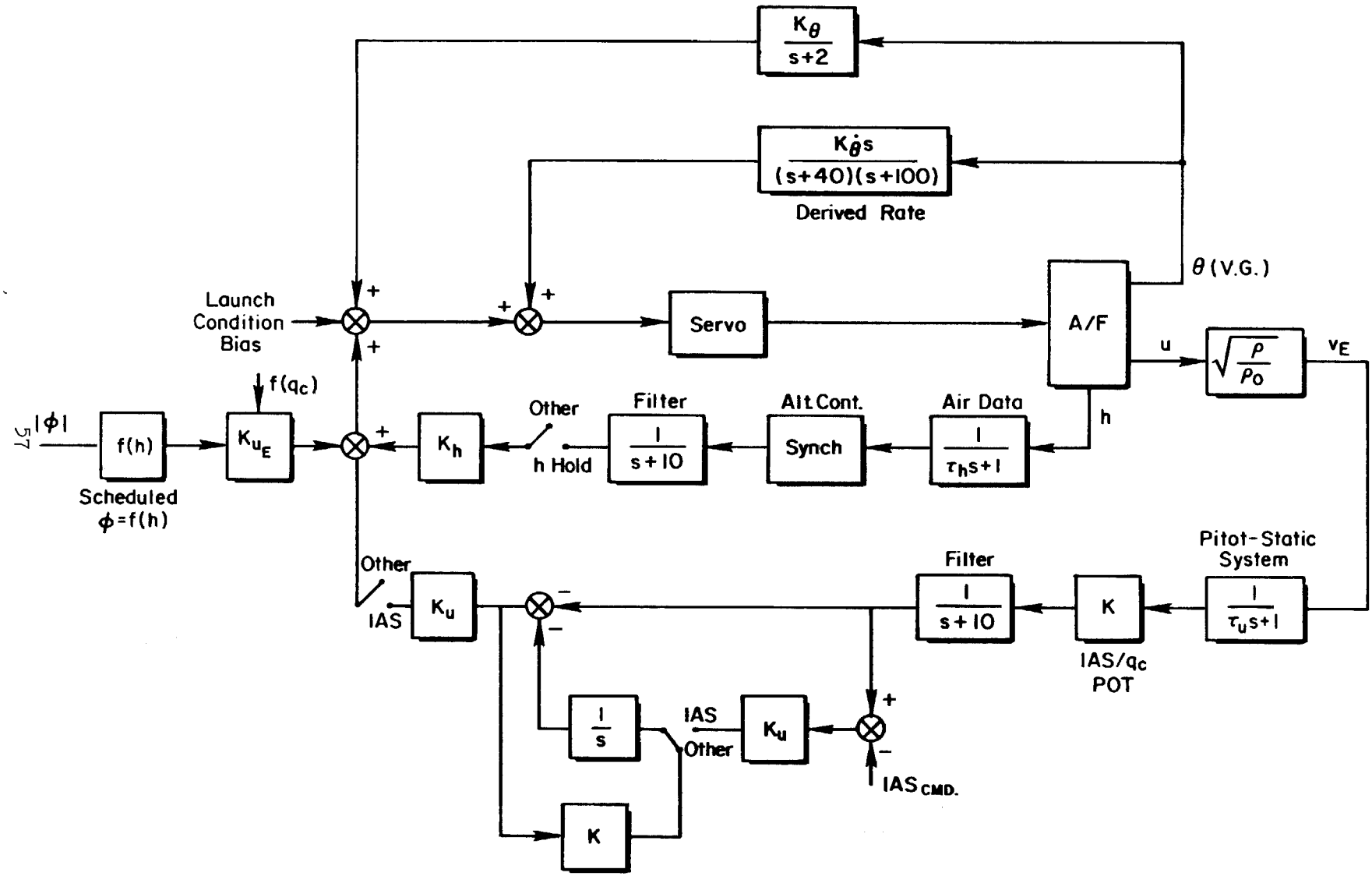

PITCH GYRO
FLIGHT SYNCHRO
STABILIZATION RACK
L.I. SYNCHRO
RATE COMPUTER
CROSSFEED AMPLIFIER
R.E. SERVO AMPLIFIER
HYDRAULIC SERVO CONTROL
ACTUATOR
RIGHT ELEVON
R.E. REPEATBACK
NAVIGATIONAL CONTROLLER
AC PHASE SEN. SW.
LIFT INTEGRATOR AMPLIFIER
PROPORTIONAL PITCH
REPEATBACK
R/C PITCH TRIM
ALTITUDE CONTROL RACK
MACH CONTROL RACK
YAW GYRO
FLIGHT SYNCHRO
SLAVING TORQUER
STABILIZATION RACK
RATE COMPUTER
YAW SERVO AMP
HYDRAULIC SERVO CONTROL
ACTUATOR
RUDDER
YAW DISPLACEMENT
GROUND HEADING CONTROL
REPEATBACK
MANUAL TRIM
RUDDER REPEATBACK
YAW SLAVING AMPLIFIER
ROLL GYRO
FLIGHT SYNCHRO
COSINE SYNCHRO
STABILIZATION RACK
RATE COMPUTER
CROSSFEED AMPLIFIER
L.E. SERVO AMPLIFIER
HYDRAULIC SERVO CONTROL
ACTUATOR
LEFT ELEVON
ROLL DISPLACEMENT
(NOT USED)
BANK TURN
REPEATBACK
MANUAL TRIM
L.E. REPEATBACK
R/C BANK TURN



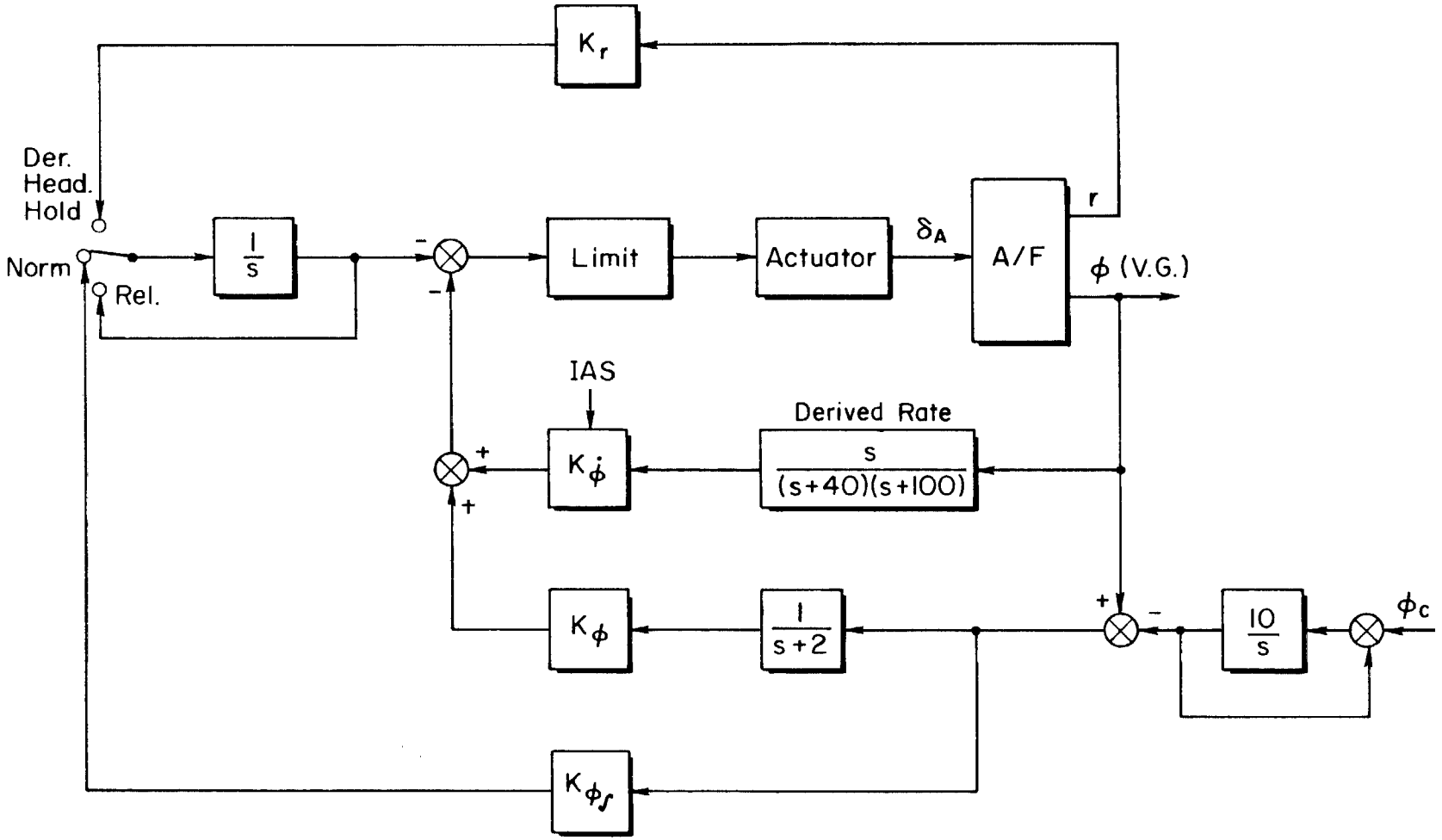
Q-2C Longitudinal Control System



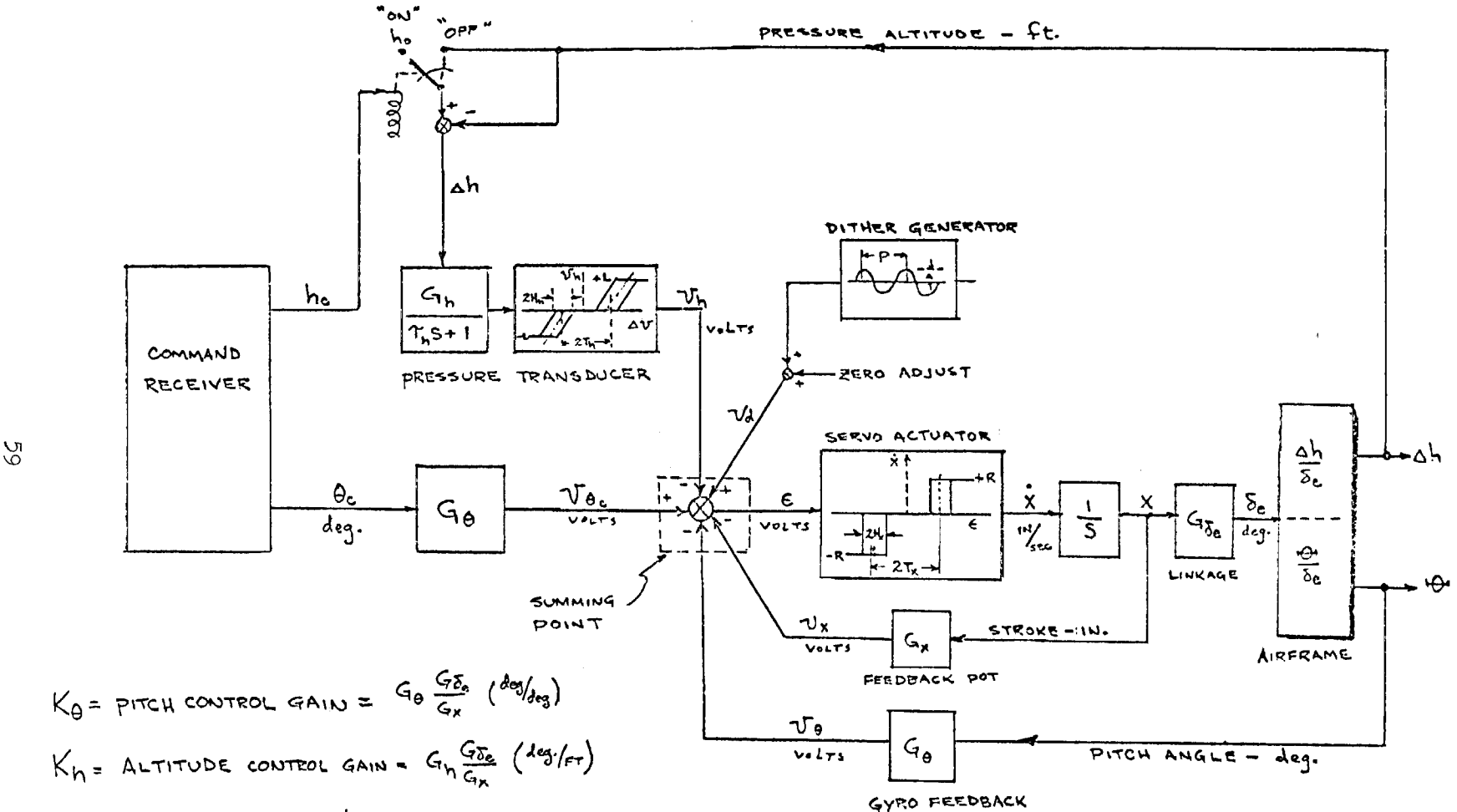
Q-2C Roll Control System



BQM-34 Pitch Axis



BQM-34 Roll Axis



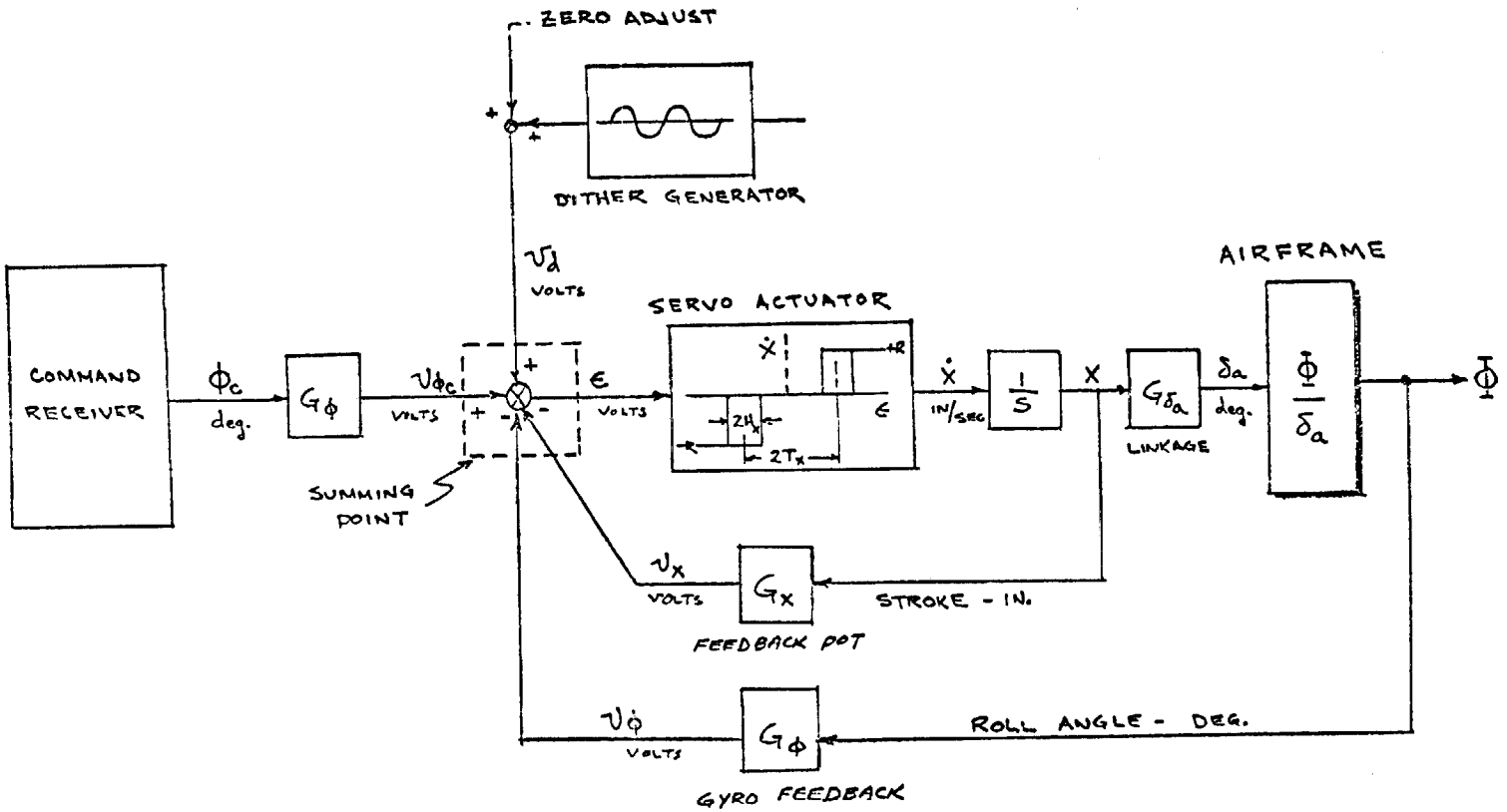
K_θ = PITCH CONTROL GAIN = $G_\theta \frac{G_{\delta_e}}{G_x}$ $(\frac{deg}{deg})$

K_h = ALTITUDE CONTROL GAIN = $G_h \frac{G_{\delta_e}}{G_x}$ $(\frac{deg.}{FT})$

NOTE: G_h IS FUNCTION OF h_o

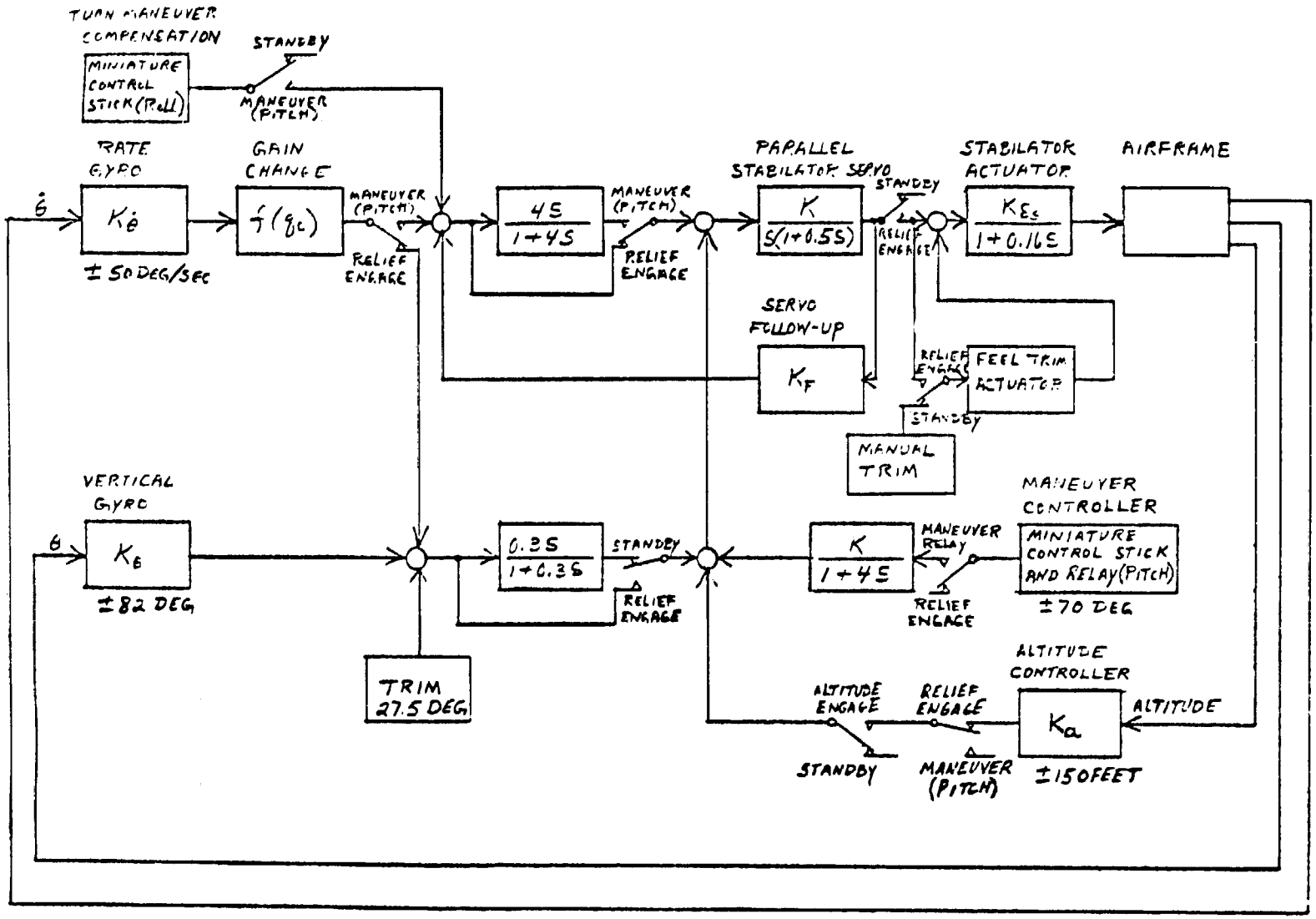
(i.e. $G_h = \frac{\Delta V}{\Delta P} \cdot \frac{dp}{dh}\Big|_{h=h_o}$)

MQM-74A Elevator Control System

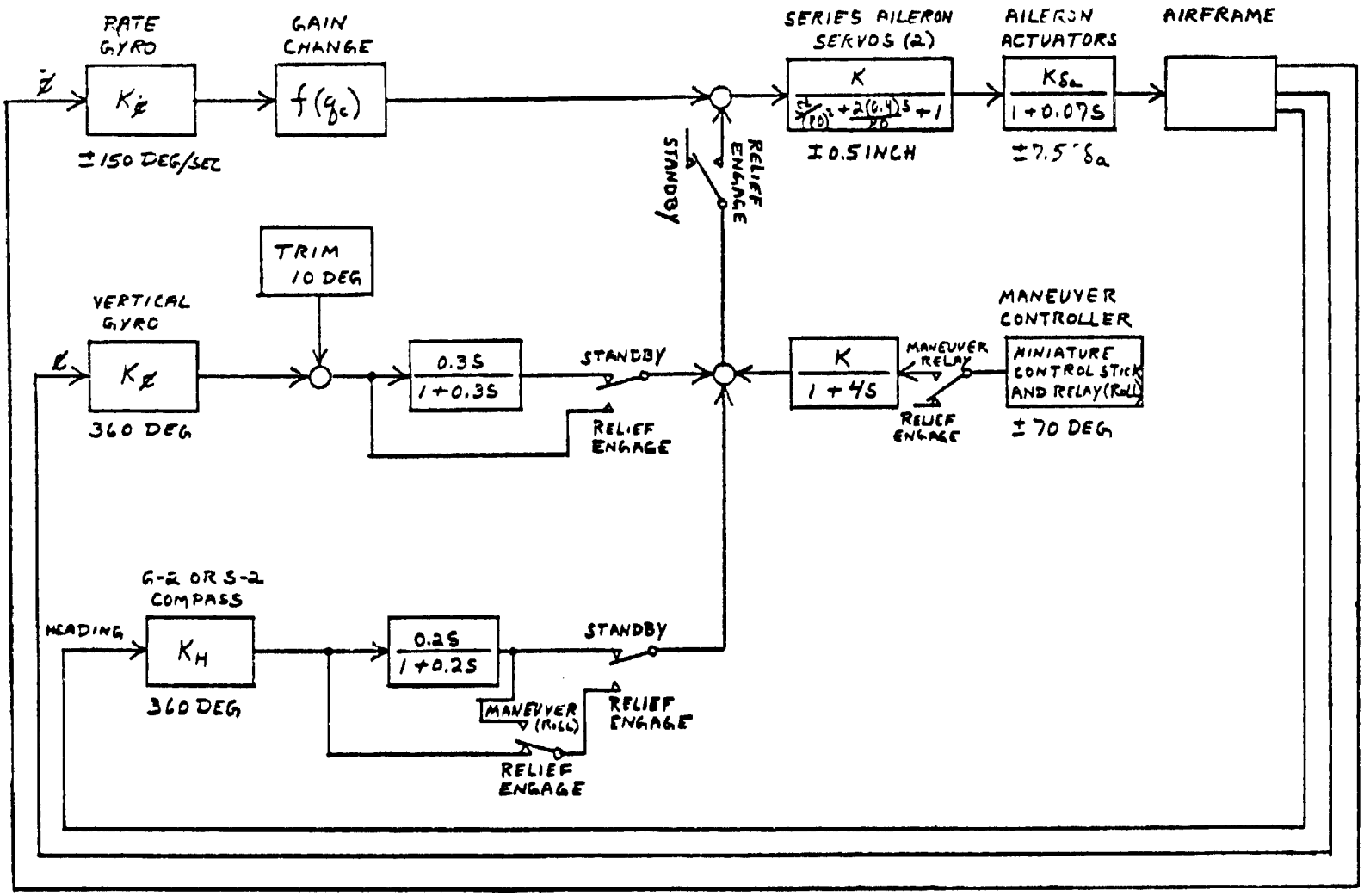


K_ϕ = ROLL CONTROL GAIN = $G_\phi \frac{G_{\delta_a}}{G_x}$

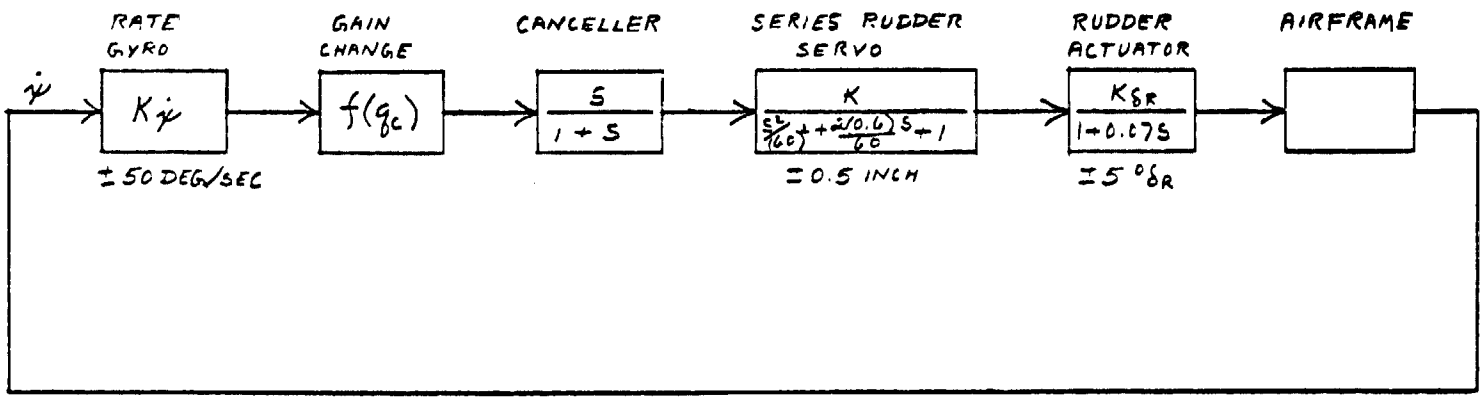
MQM-74A Aileron Control System



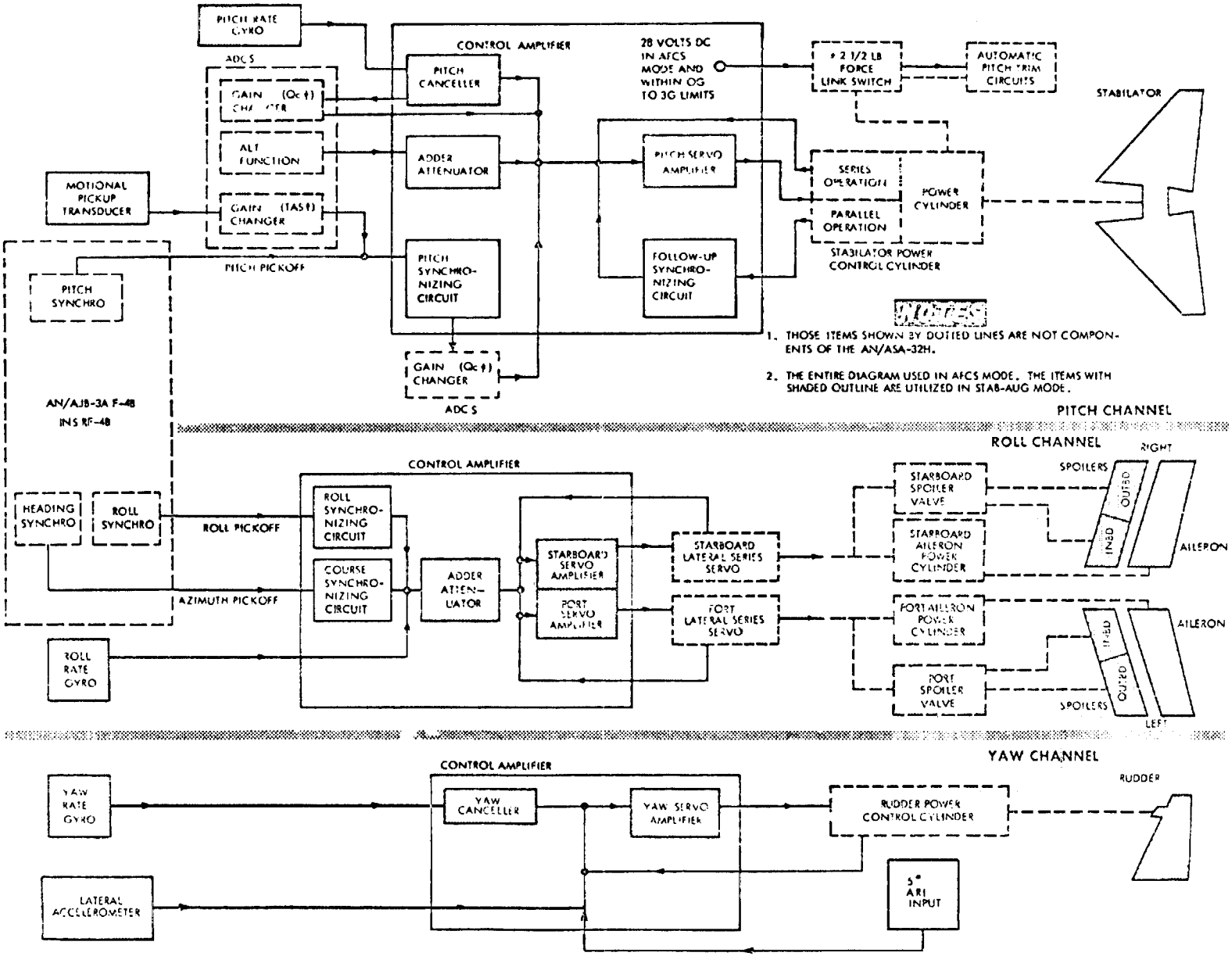
F3H PITCH CHANNEL

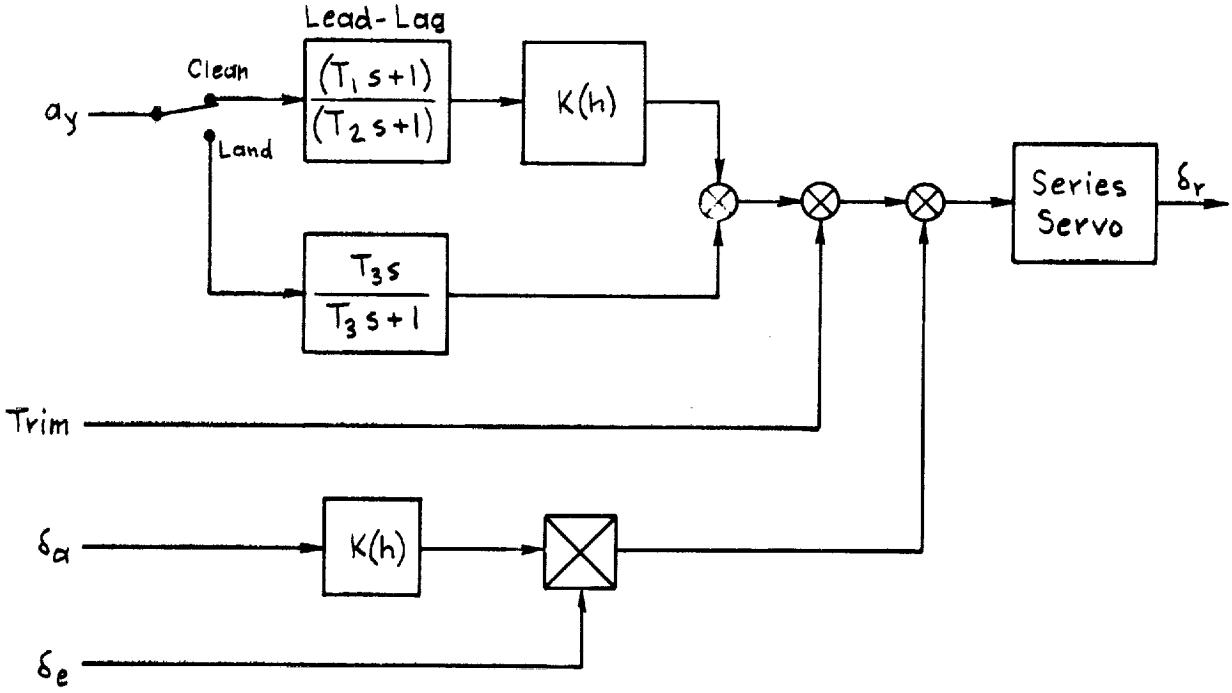


F3H ROLL CHANNEL

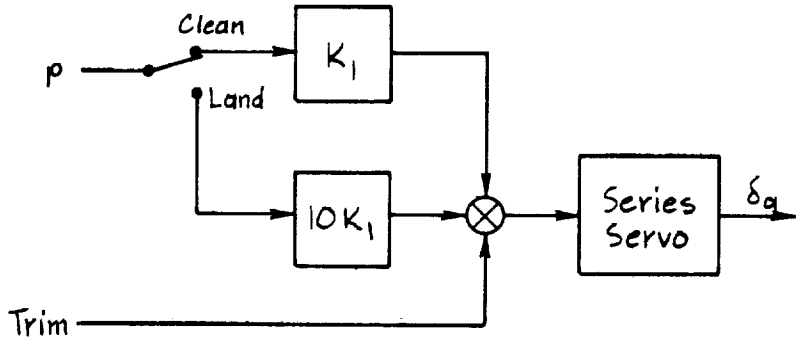


F3H YAW CHANNEL

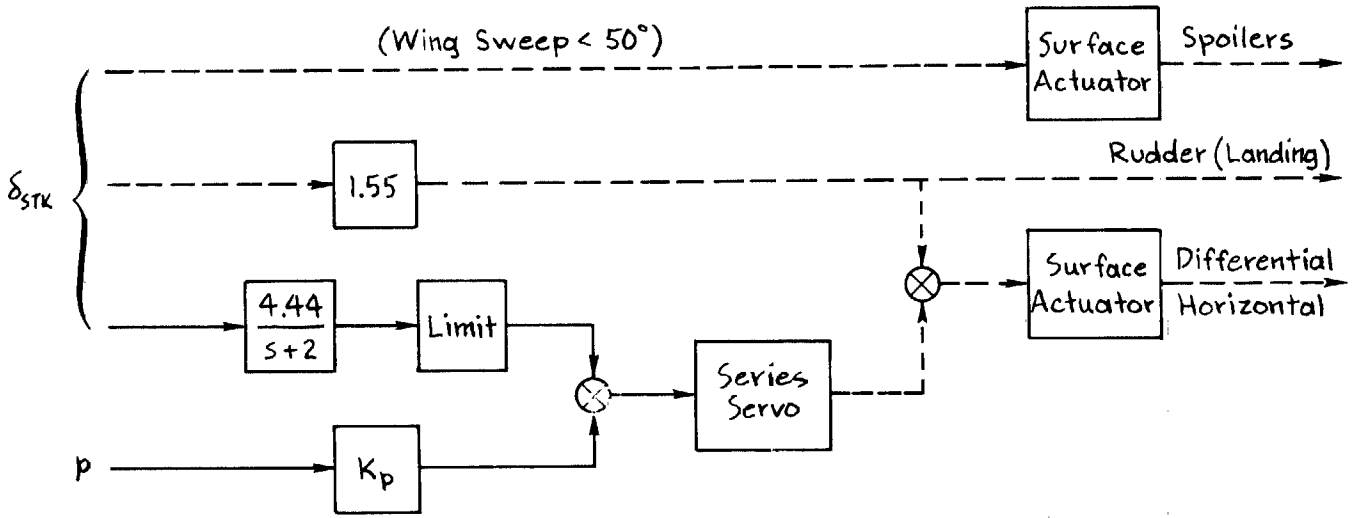

PITCH RATE GYRO
CONTROL AMPLIFIER
ADC'S
GAIN (Qc ÷) CHANGER
ALT FUNCTION
GAIN (TAS ÷) CHANGER
PITCH CANCELLER
ADDER ATTENUATOR
28 VOLTS DC IN AFCS MODE AND WITHIN OG TO 3G LIMITS
± 2 1/2 LB FORCE LINK SWITCH
AUTOMATIC PITCH TRIM CIRCUITS
STABILATOR
PITCH SERVO AMPLIFIER
SERIES OPERATION
PARALLEL OPERATION
POWER CYLINDER
STABILATOR POWER CONTROL CYLINDER
MOTIONAL PICKUP TRANSDUCER
PITCH PICKOFF
PITCH SYNCHRO-NIZING CIRCUIT
FOLLOW-UP SYNCHRO-NIZING CIRCUIT
PITCH SYNCHRO
GAIN (Qc ÷) CHANGER
ADC'S
1. THOSE ITEMS SHOWN BY DOTTED LINES ARE NOT COMPONENTS OF THE AN/ASA-32H.
2. THE ENTIRE DIAGRAM USED IN AFCS MODE. THE ITEMS WITH SHADED OUTLINE ARE UTILIZED IN STAB-AUG MODE.
AN/AJB-3A F-4B
INS RF-4B
PITCH CHANNEL
ROLL CHANNEL
CONTROL AMPLIFIER
HEADING SYNCHRO
ROLL SYNCHRO
ROLL PICKOFF
AZIMUTH PICKOFF
ROLL SYNCHRO-NIZING CIRCUIT
COURSE SYNCHRO-NIZING CIRCUIT
ADDER ATTEN-UATOR
STARBOARD SERVO AMPLIFIER
PORT SERVO AMPLIFIER
STARBOARD LATERAL SERIES SERVO
PORT LATERAL SERIES SERVO
STARBOARD SPOILER VALVE
STARBOARD AILERON POWER CYLINDER
PORT AILERON POWER CYLINDER
PORT SPOILER VALVE
RIGHT
SPOILERS
OUTBD
INBD
AILERON
LEFT
ROLL RATE GYRO
YAW CHANNEL
CONTROL AMPLIFIER
YAW RATE GYRO
YAW CANCELLER
YAW SERVO AMPLIFIER
RUDDER POWER CONTROL CYLINDER
RUDDER
5° ARI INPUT
LATERAL ACCELEROMETER



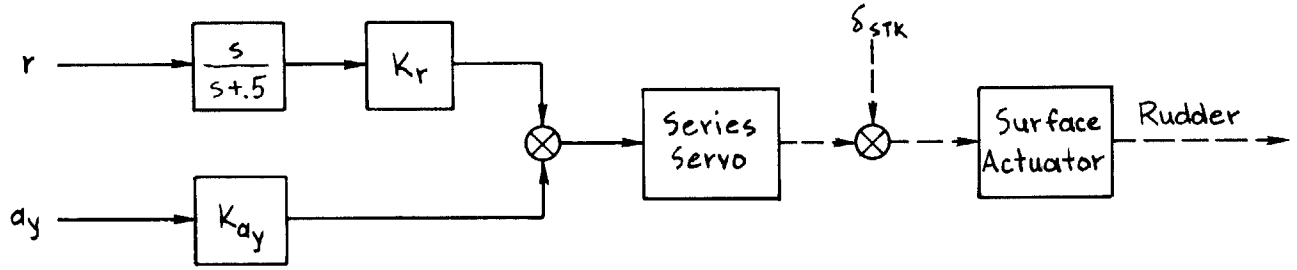
YAW AXIS DAMPER



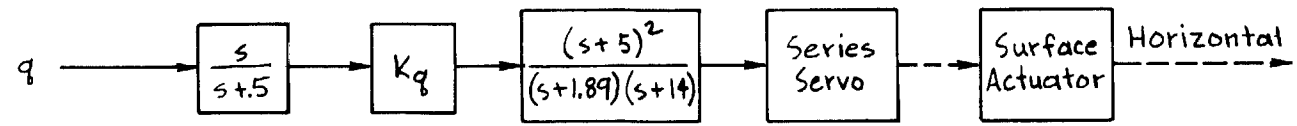
ROLL AXIS DAMPER



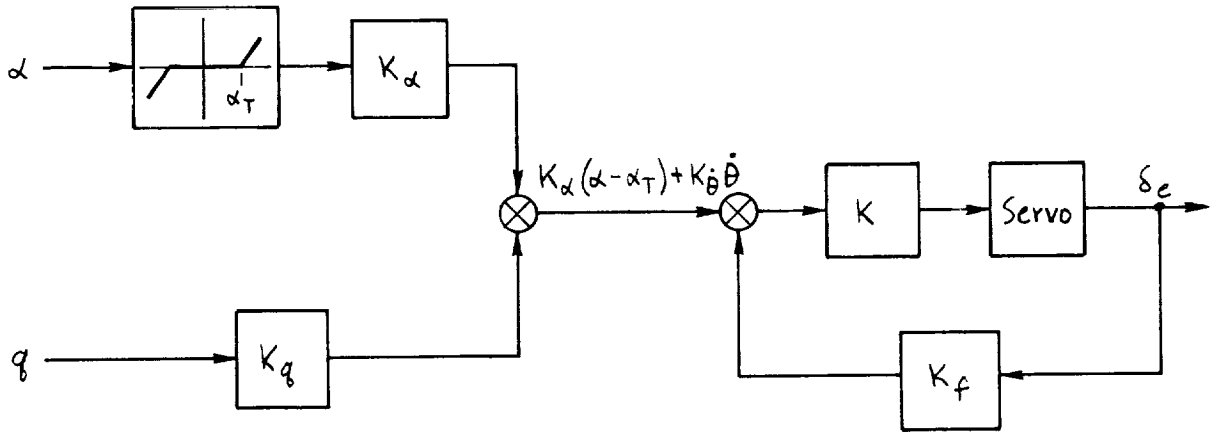
ROLL RATE COMMAND AUGMENTER



YAW DAMPER



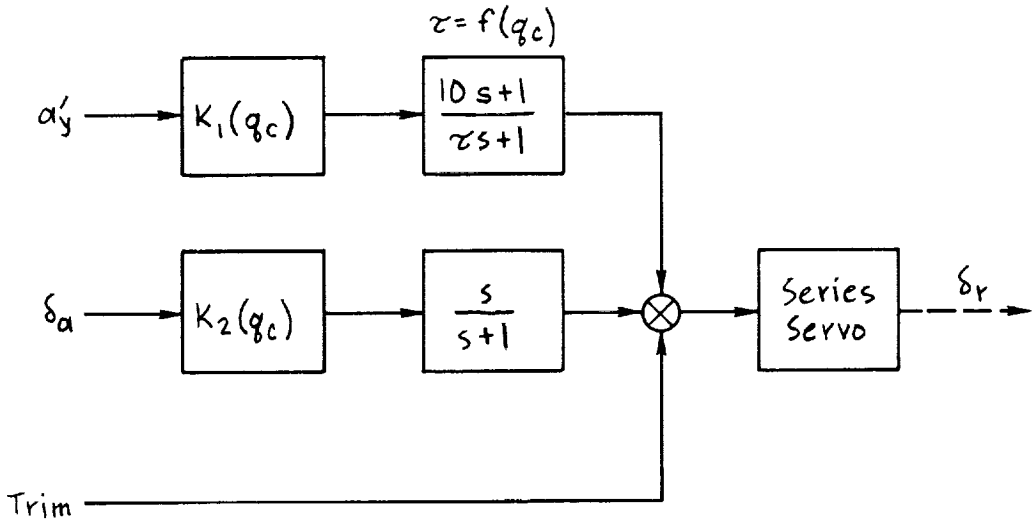
PITCH DAMPER



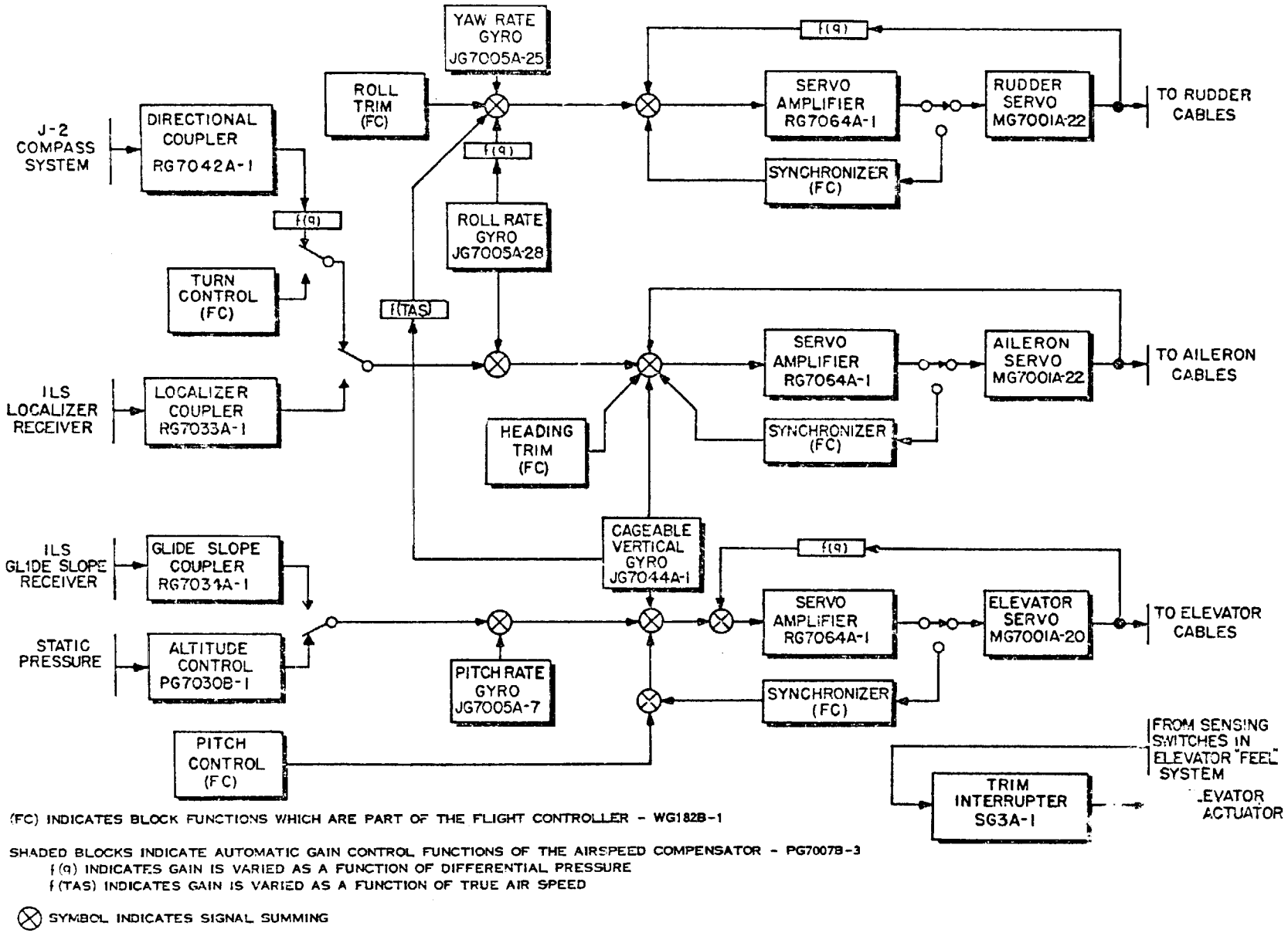
$\delta_e = K_\alpha(\alpha-\alpha_T) + K_{\dot\theta}\dot\theta$ when $K_\alpha(\alpha-\alpha_T)+K_{\dot\theta}\dot\theta > 0$

$\delta_e = 0$ when $K_\alpha(\alpha-\alpha_T)+K_{\dot\theta}\dot\theta < 0$

F-86 Pitch-up Preventer



F-89 Sideslip Stability Augmenter



(FC) INDICATES BLOCK FUNCTIONS WHICH ARE PART OF THE FLIGHT CONTROLLER - WG182B-1

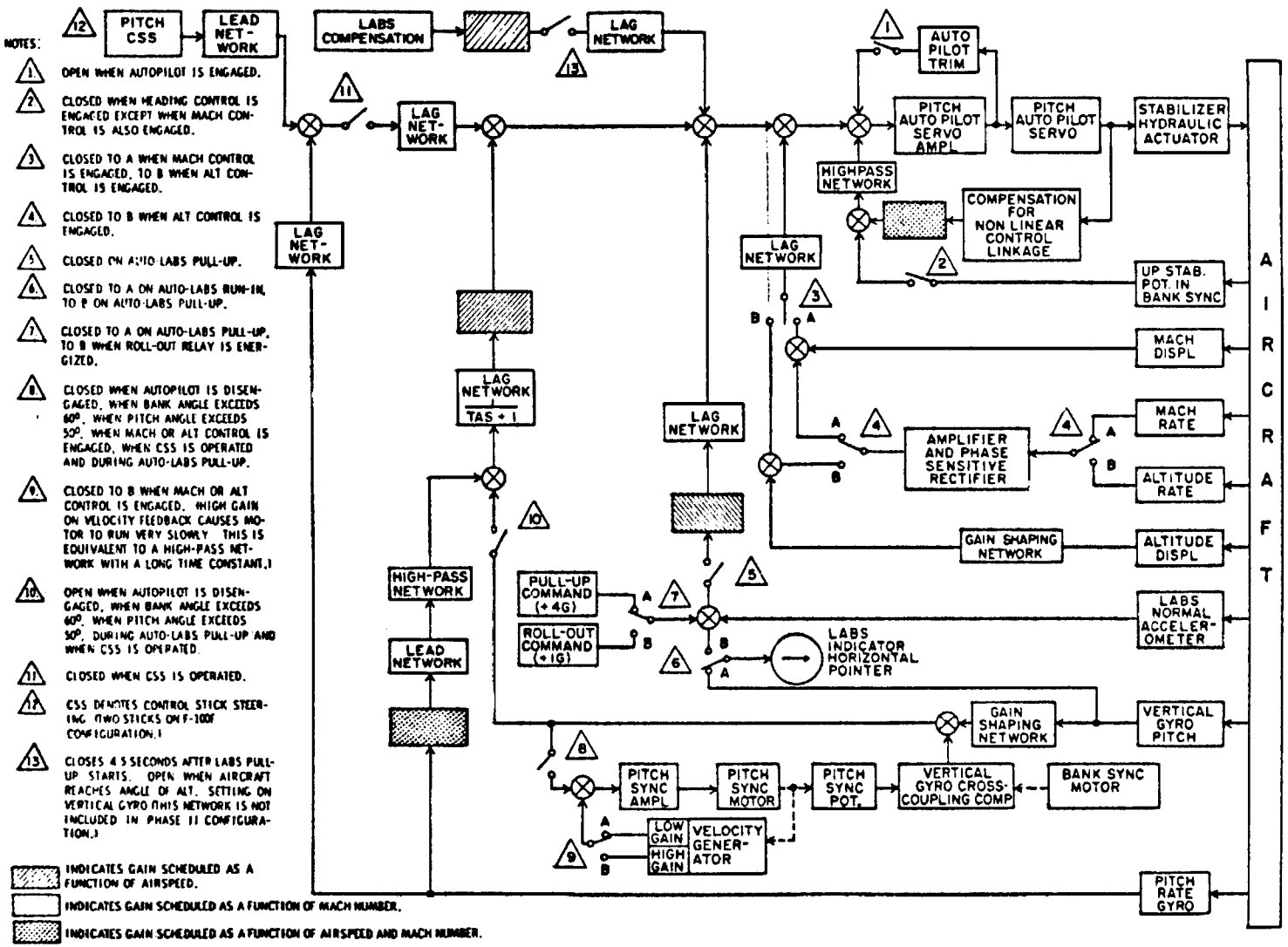
SHADED BLOCKS INDICATE AUTOMATIC GAIN CONTROL FUNCTIONS OF THE AIRSPEED COMPENSATOR - PG7007B-3

f(q) INDICATES GAIN IS VARIED AS A FUNCTION OF DIFFERENTIAL PRESSURE

f(TAS) INDICATES GAIN IS VARIED AS A FUNCTION OF TRUE AIR SPEED

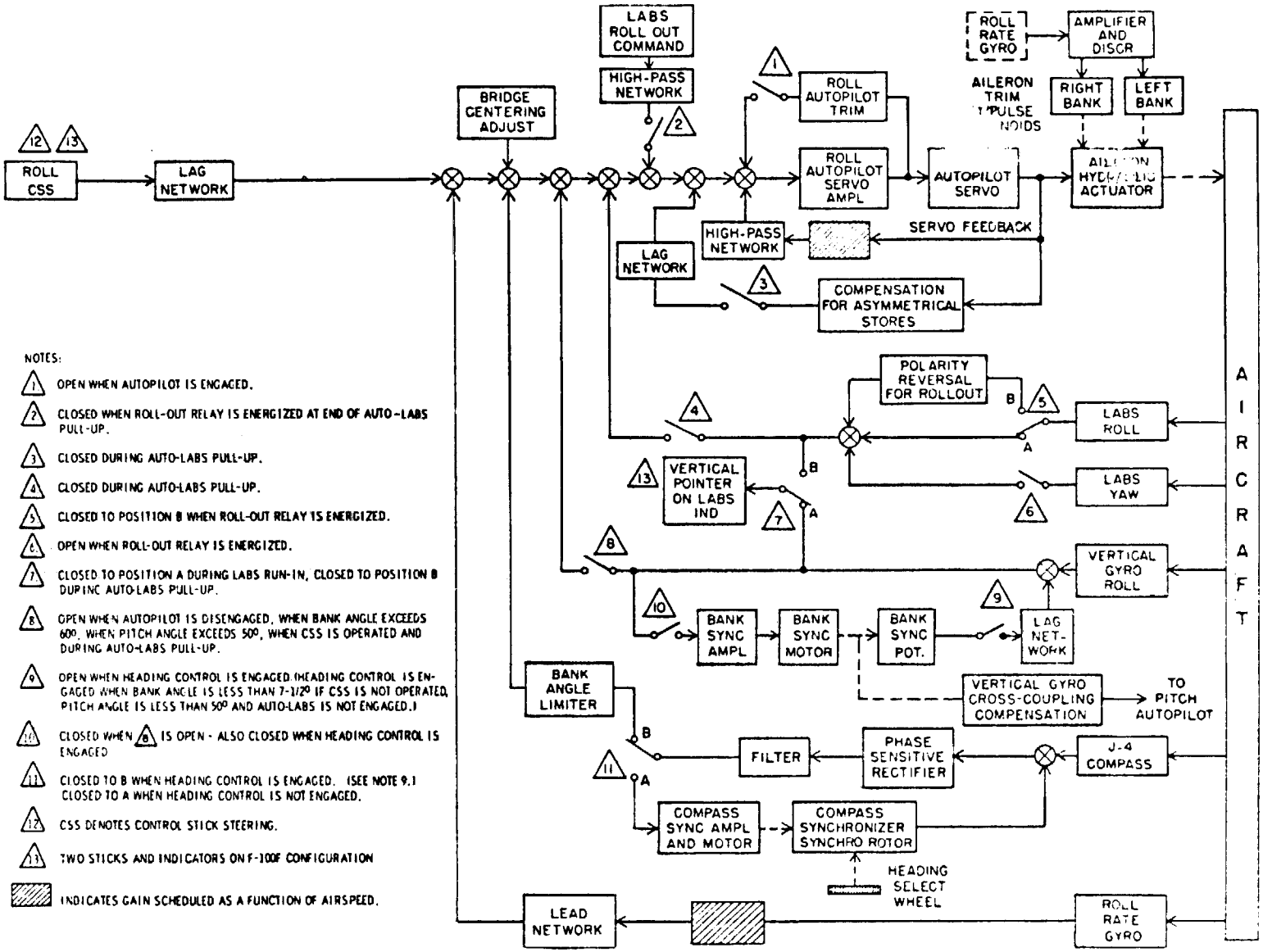
⊗ SYMBOL INDICATES SIGNAL SUMMING

F-89 Autopilot



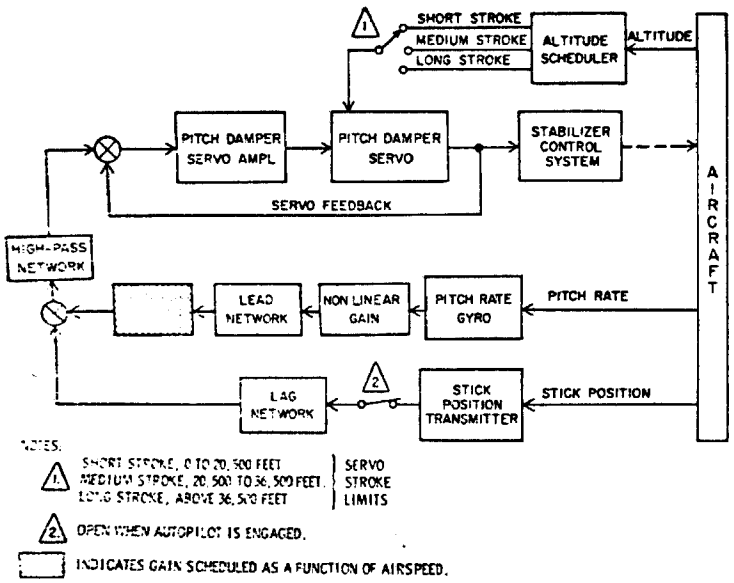
PITCH CHANNEL

F-100 D/F Autopilot

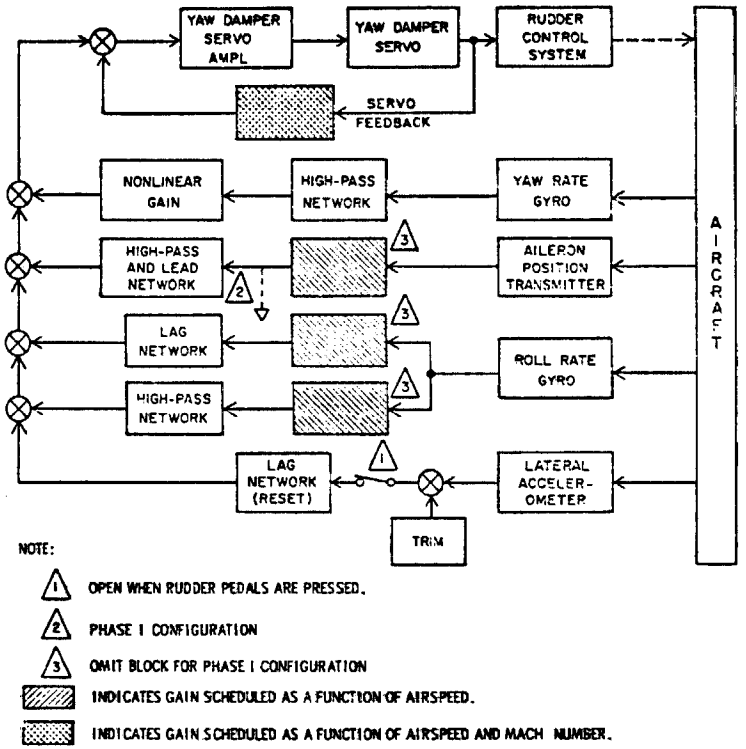


ROLL CHANNEL

F-100 D/F Autopilot

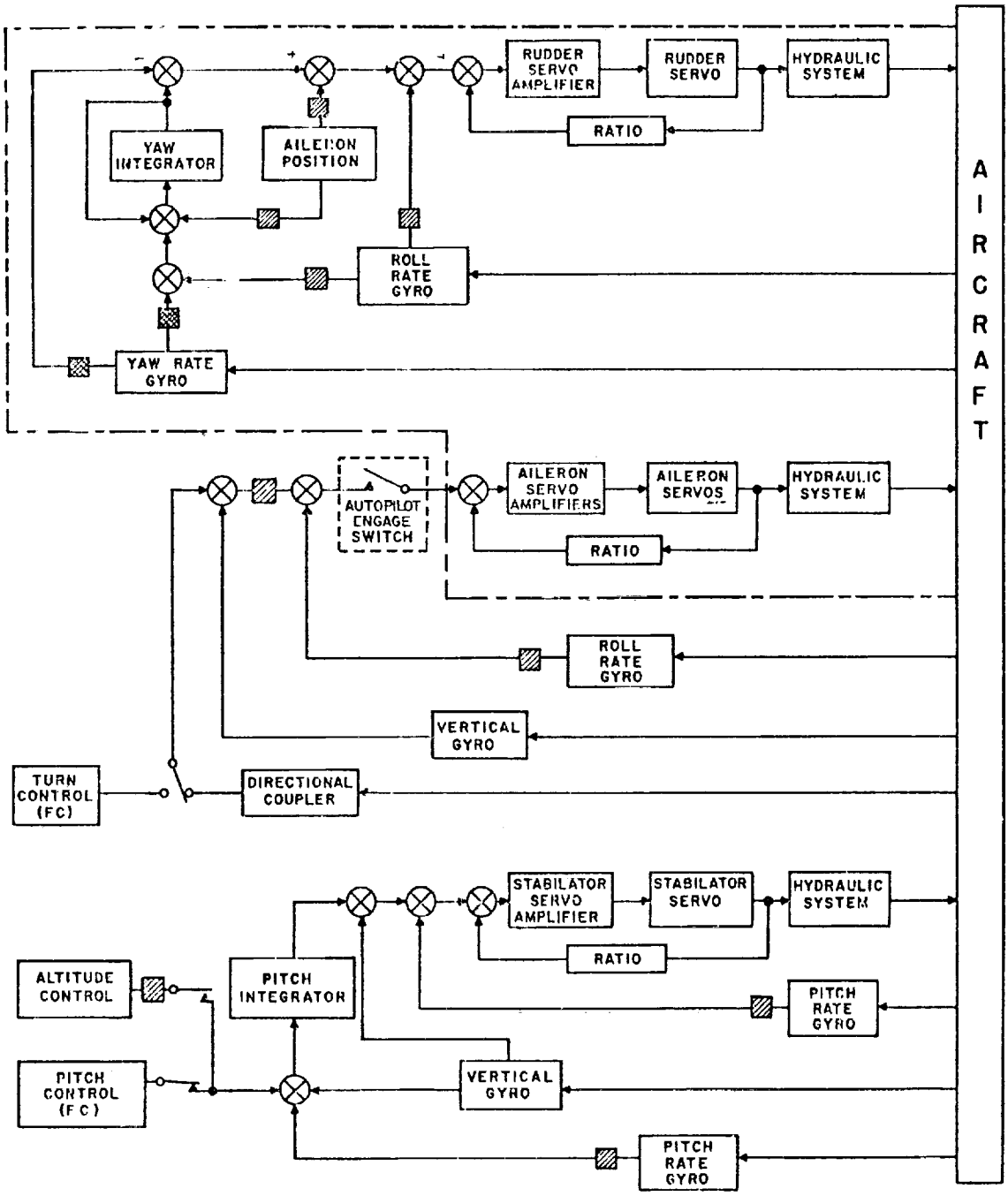


PITCH DAMPER

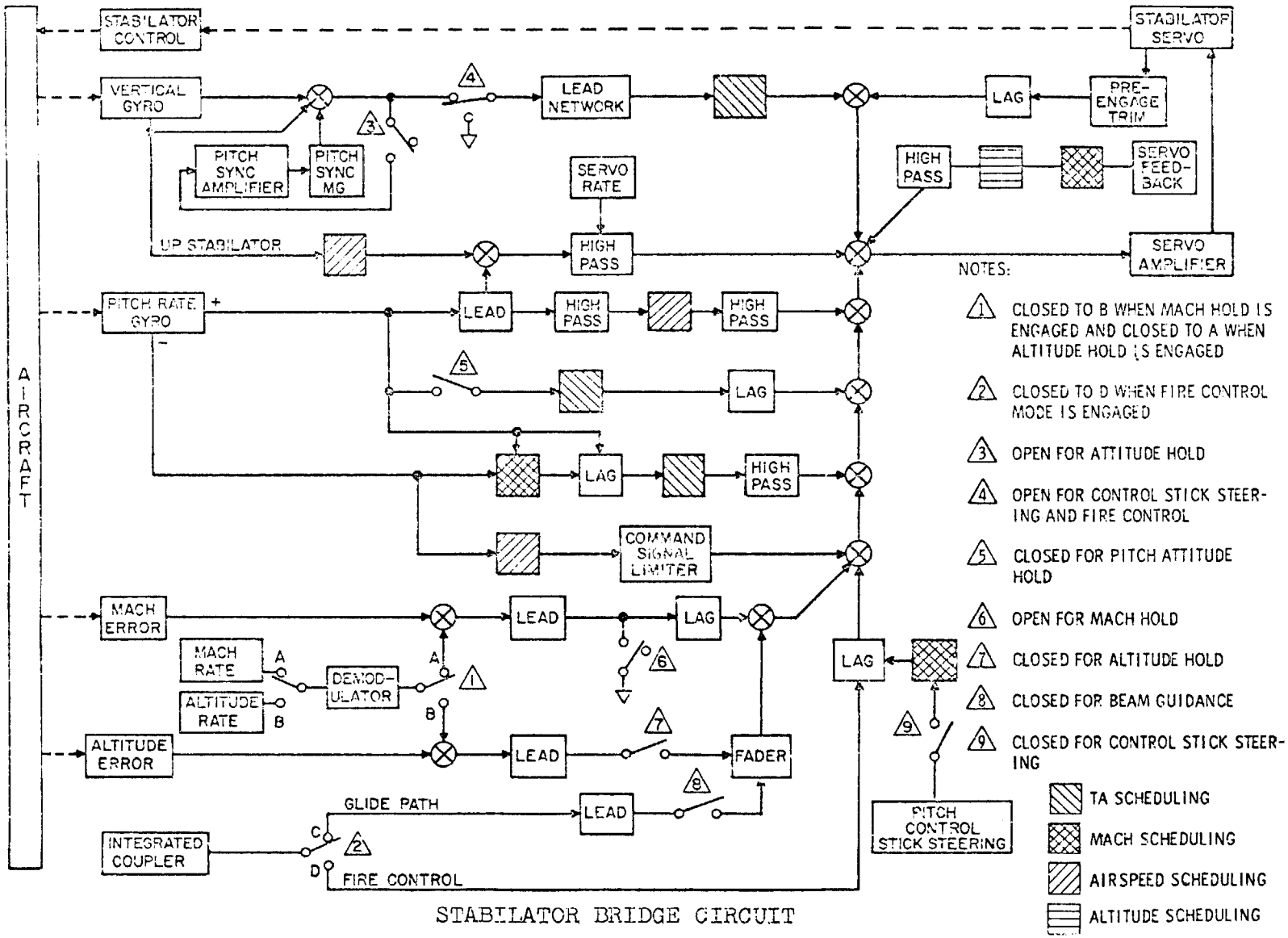


YAW DAMPER

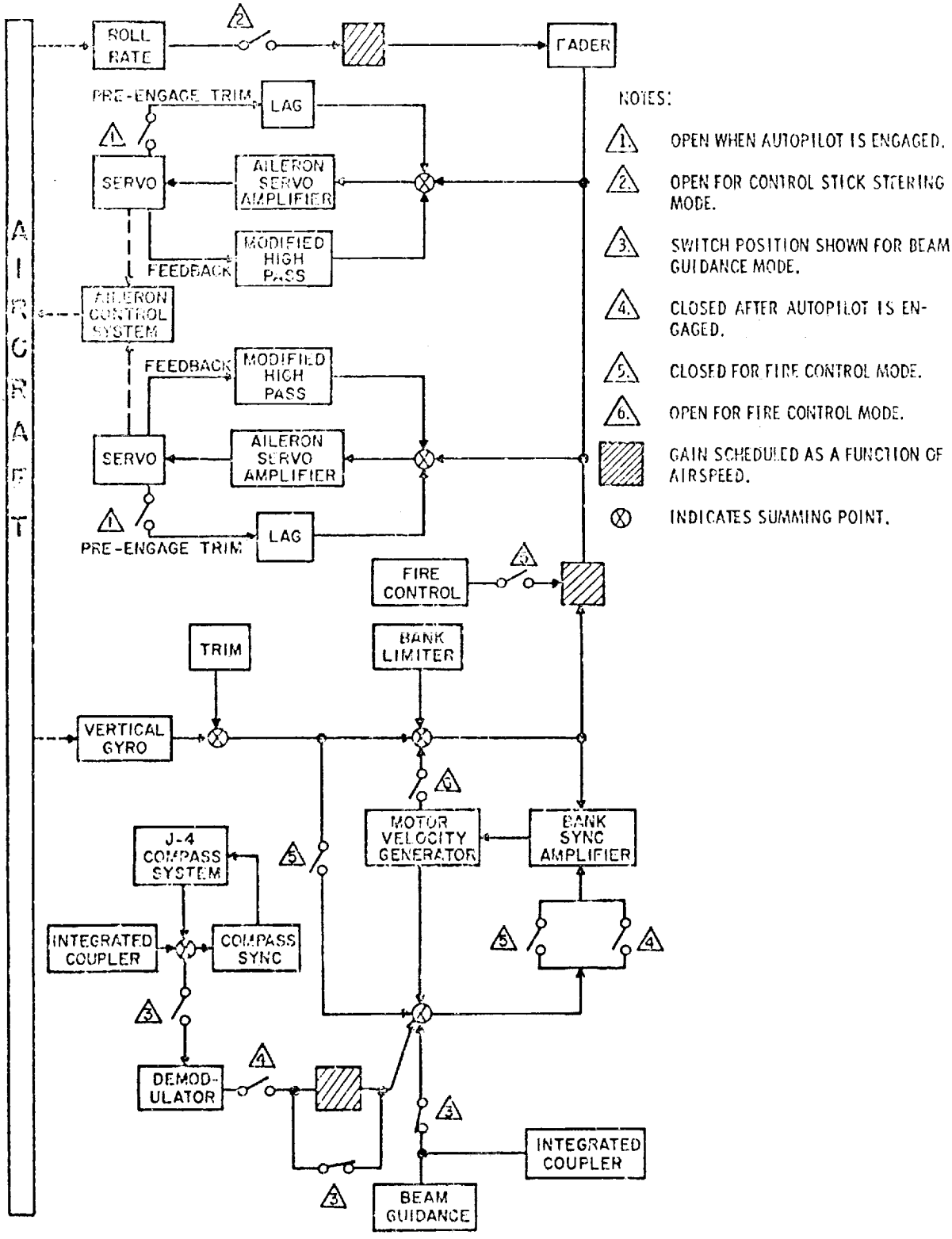
F-100 D/F Autopilot



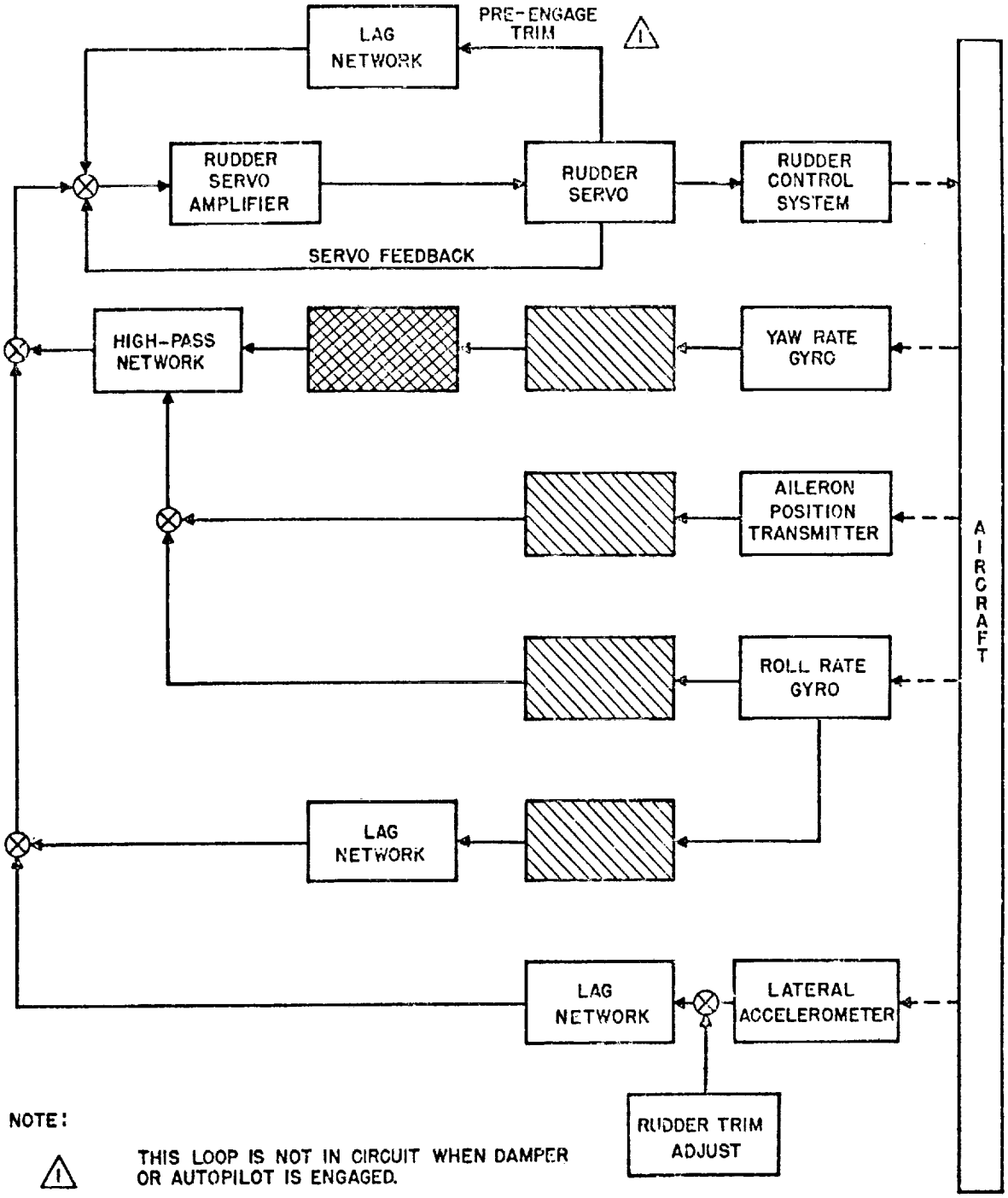
F-101A Autopilot



STABILATOR BRIDGE CIRCUIT



AILERON BRIDGE CIRCUIT



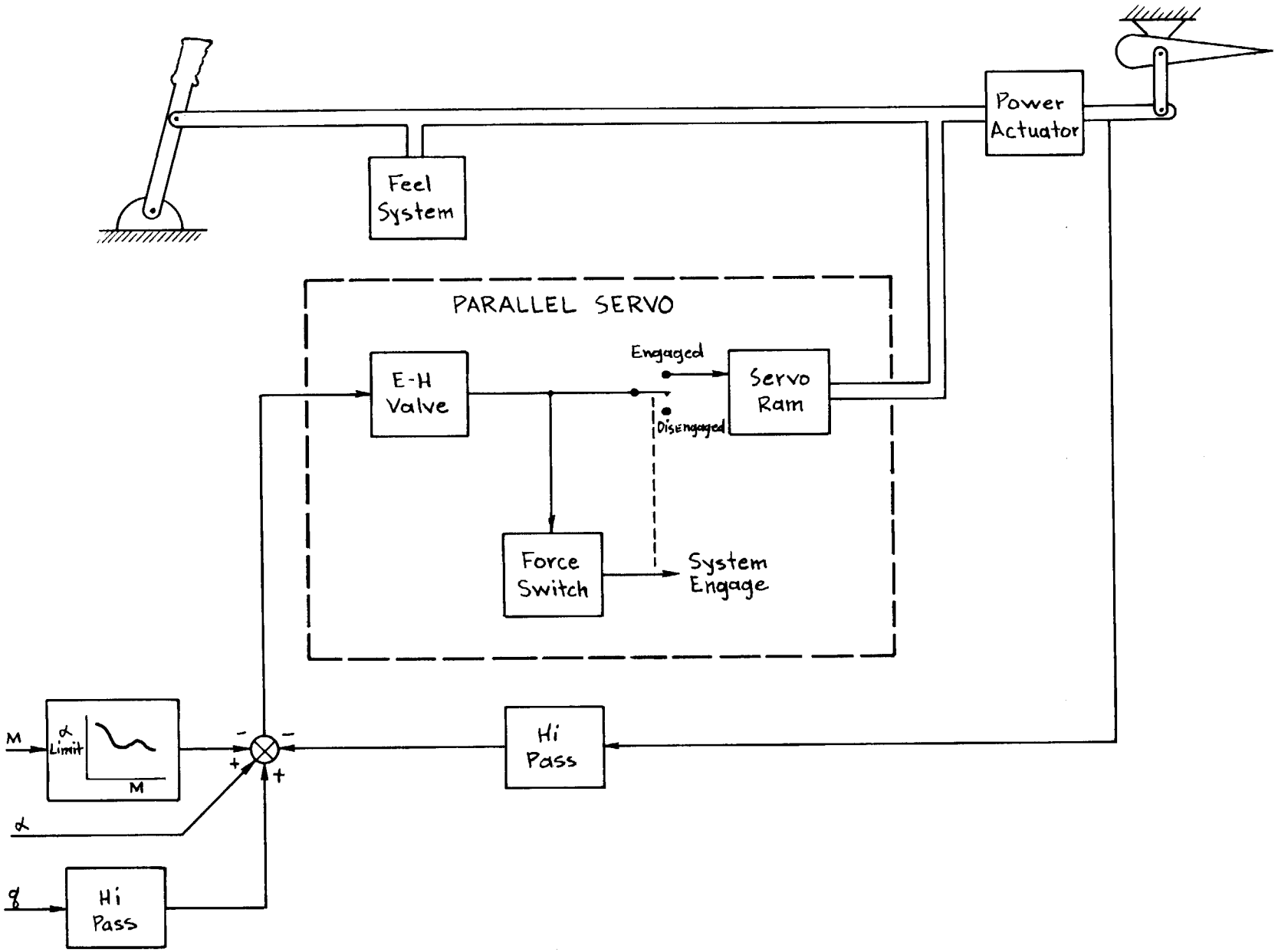
NOTE:

△1 THIS LOOP IS NOT IN CIRCUIT WHEN DAMPER OR AUTOPILOT IS ENGAGED.

INDICATES GAIN SCHEDULED AS FUNCTION OF AIRSPEED.

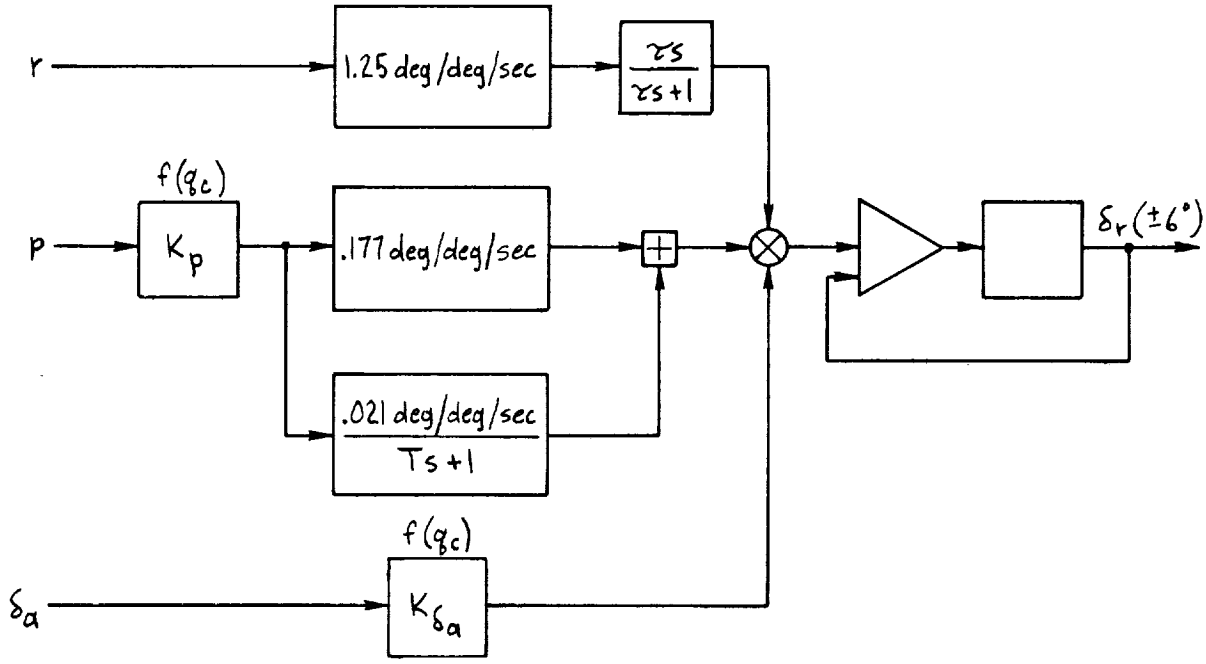
INDICATES GAIN SCHEDULED AS FUNCTION OF MACH NUMBER.

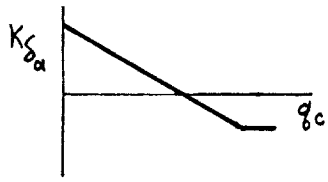
RUDDER BRIDGE CIRCUIT

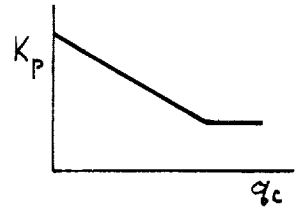


F-101B Stick Pusher

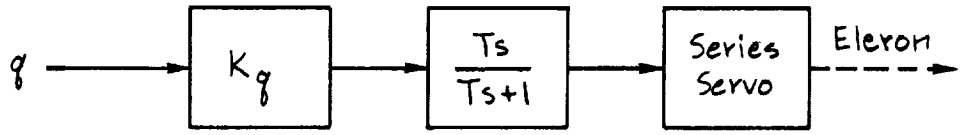
F-102 YAW DAMPER

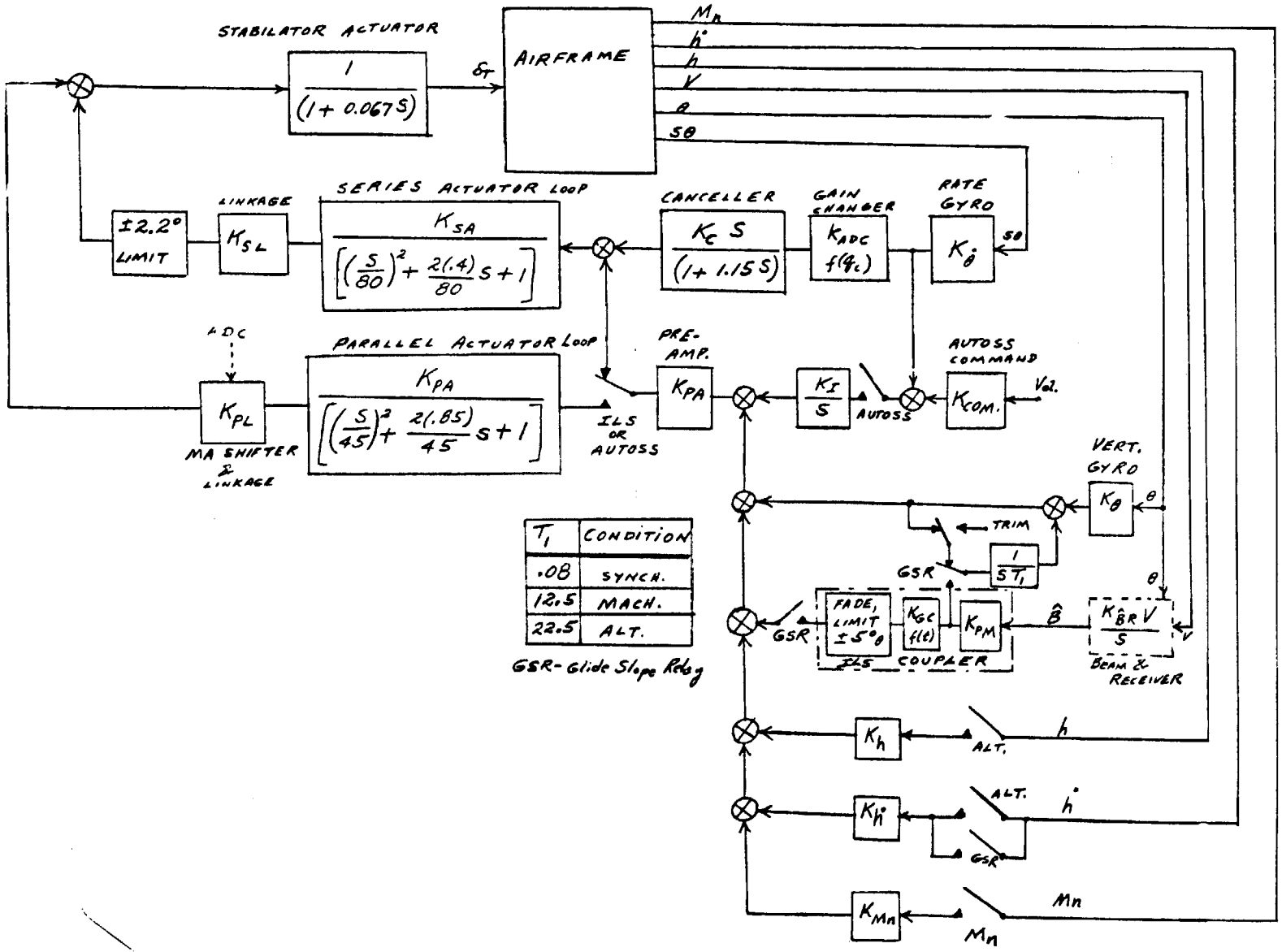






F-102 PITCH DAMPER

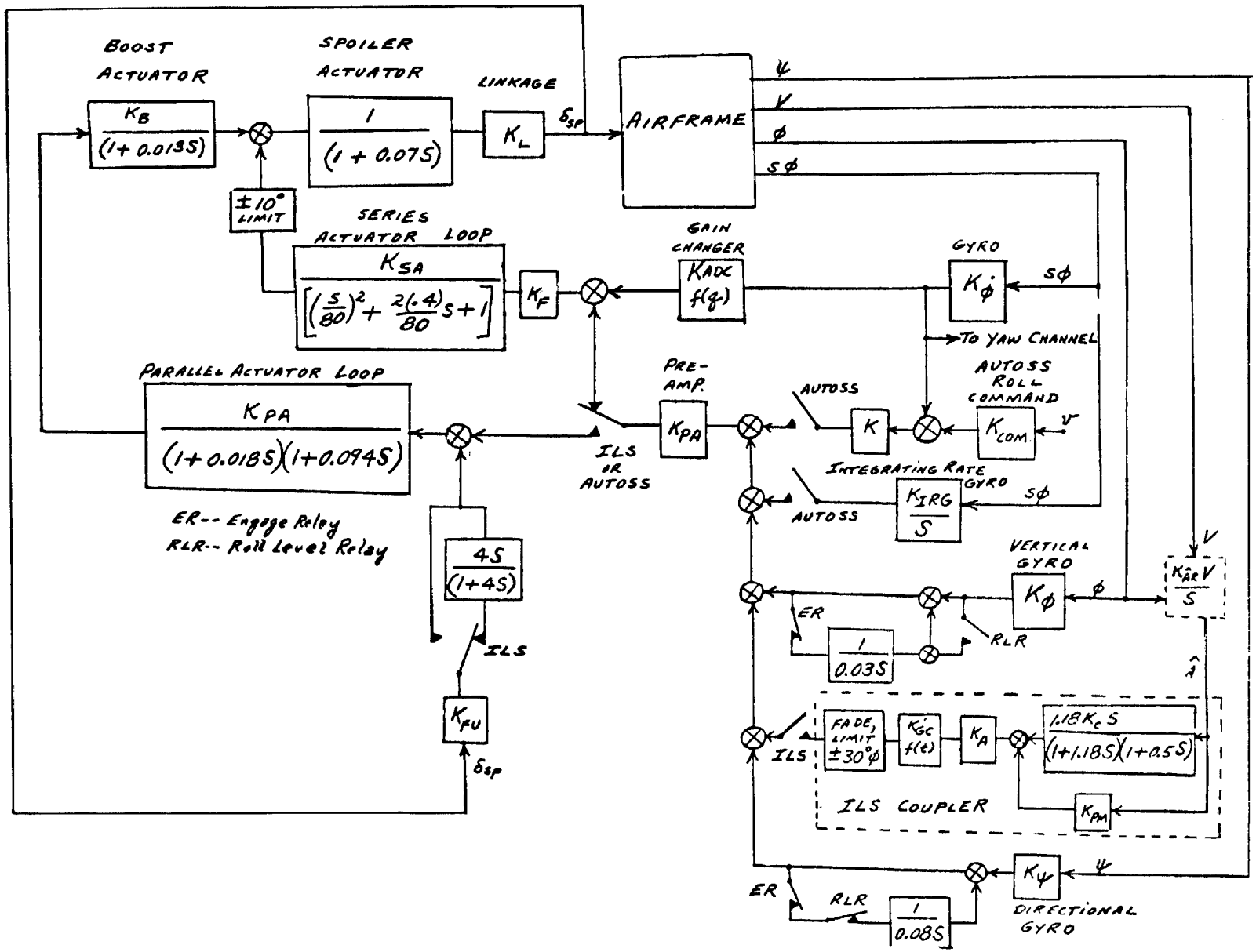




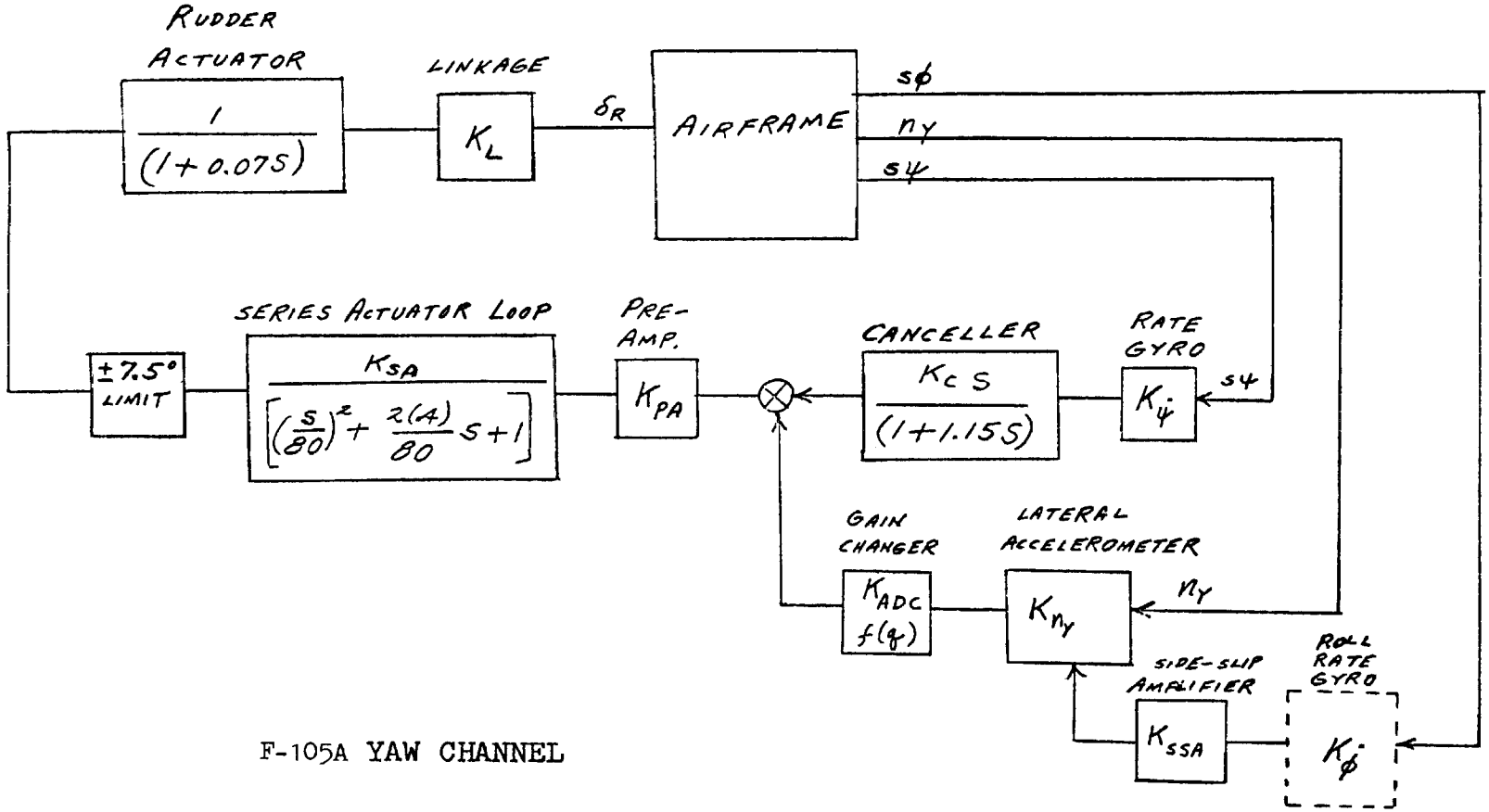
T_1	CONDITION
.08	SYNCH.
12.5	MACH.
22.5	ALT.

GSR- Glide Slope Relay

F-105A PITCH CHANNEL

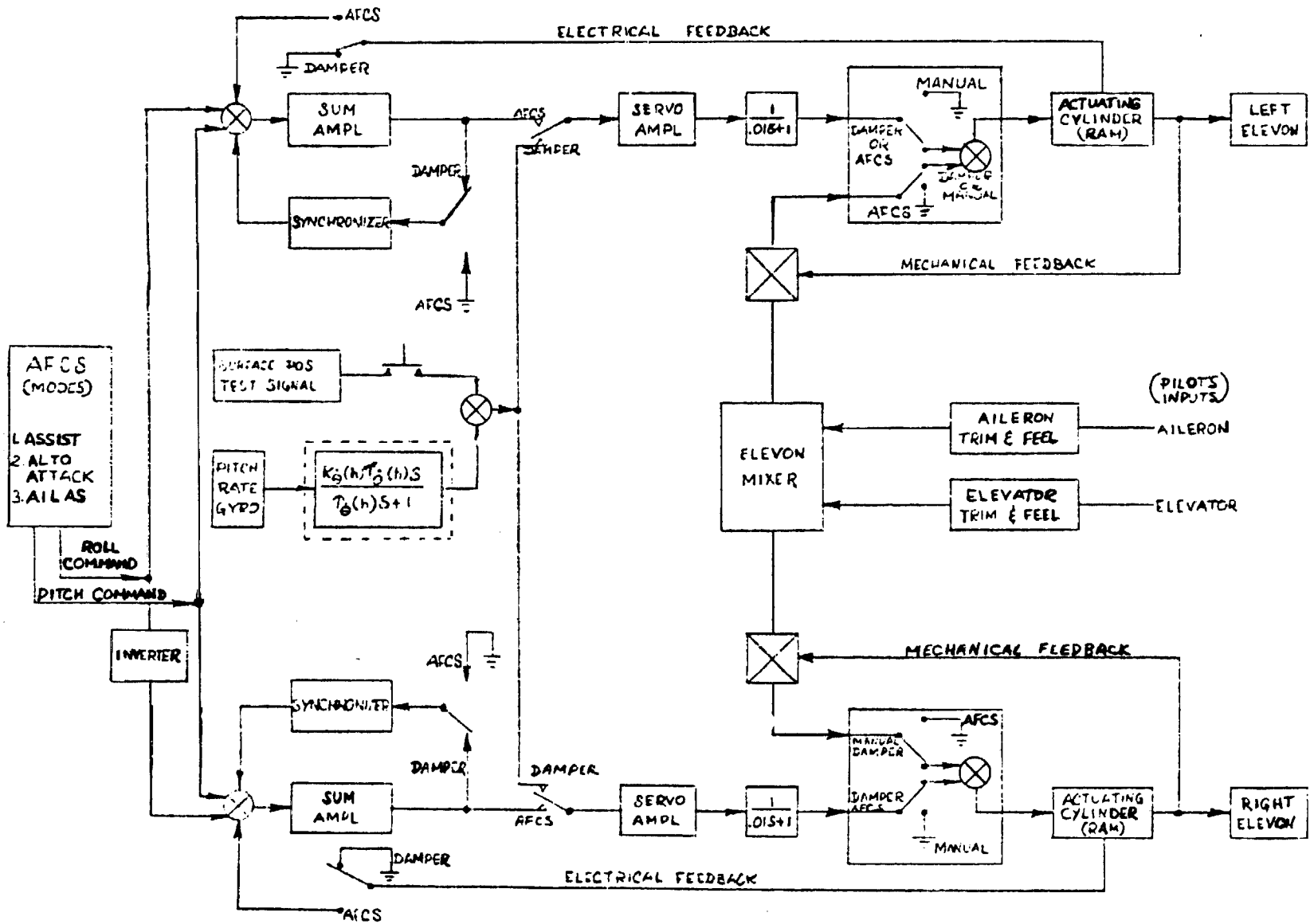


F-105A ROLL CHANNEL

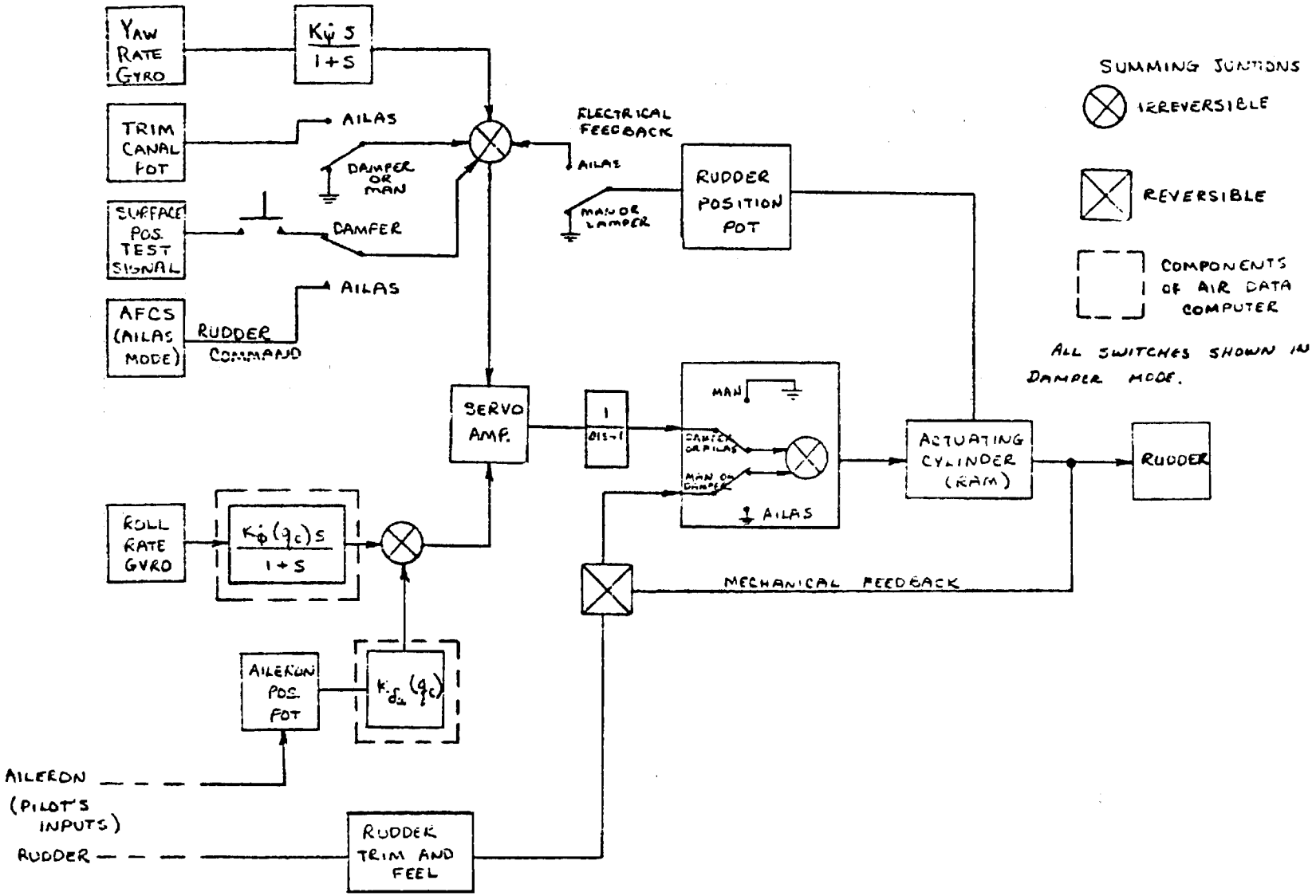


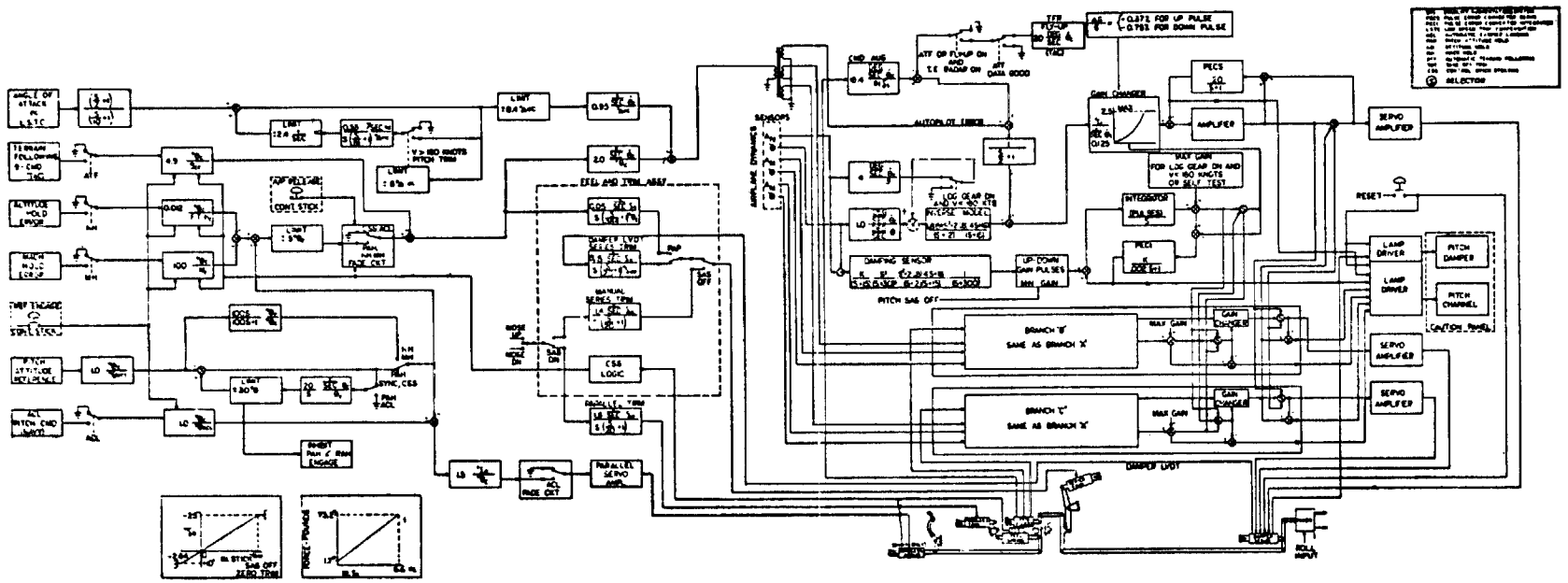
F-105A YAW CHANNEL

MANUAL MODE, PITCH DAMPER MODE AND AFCS MODE

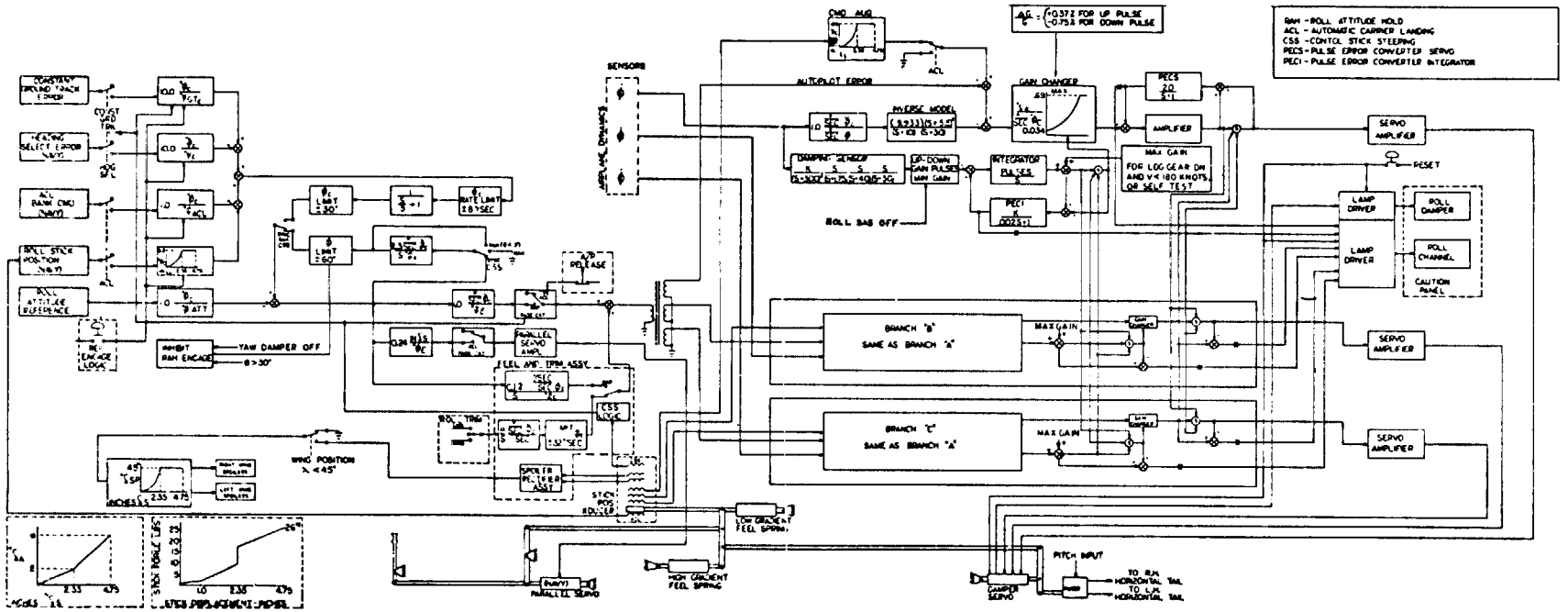


MANUAL MODE, YAW DAMPER AND TURN COORDINATOR MODE, AND AILAS MODE

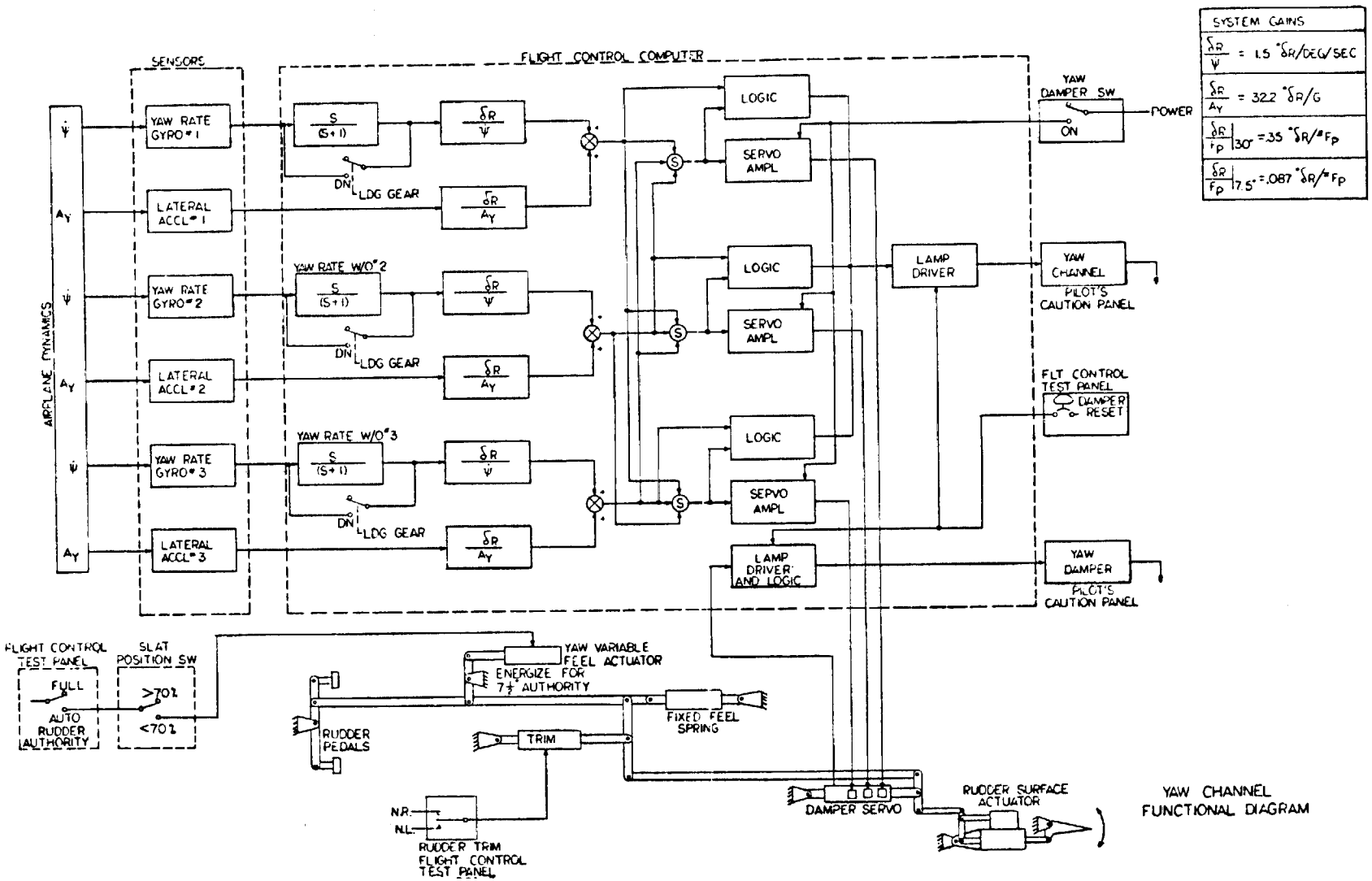




F-111 Pitch Channel Functional Diagram

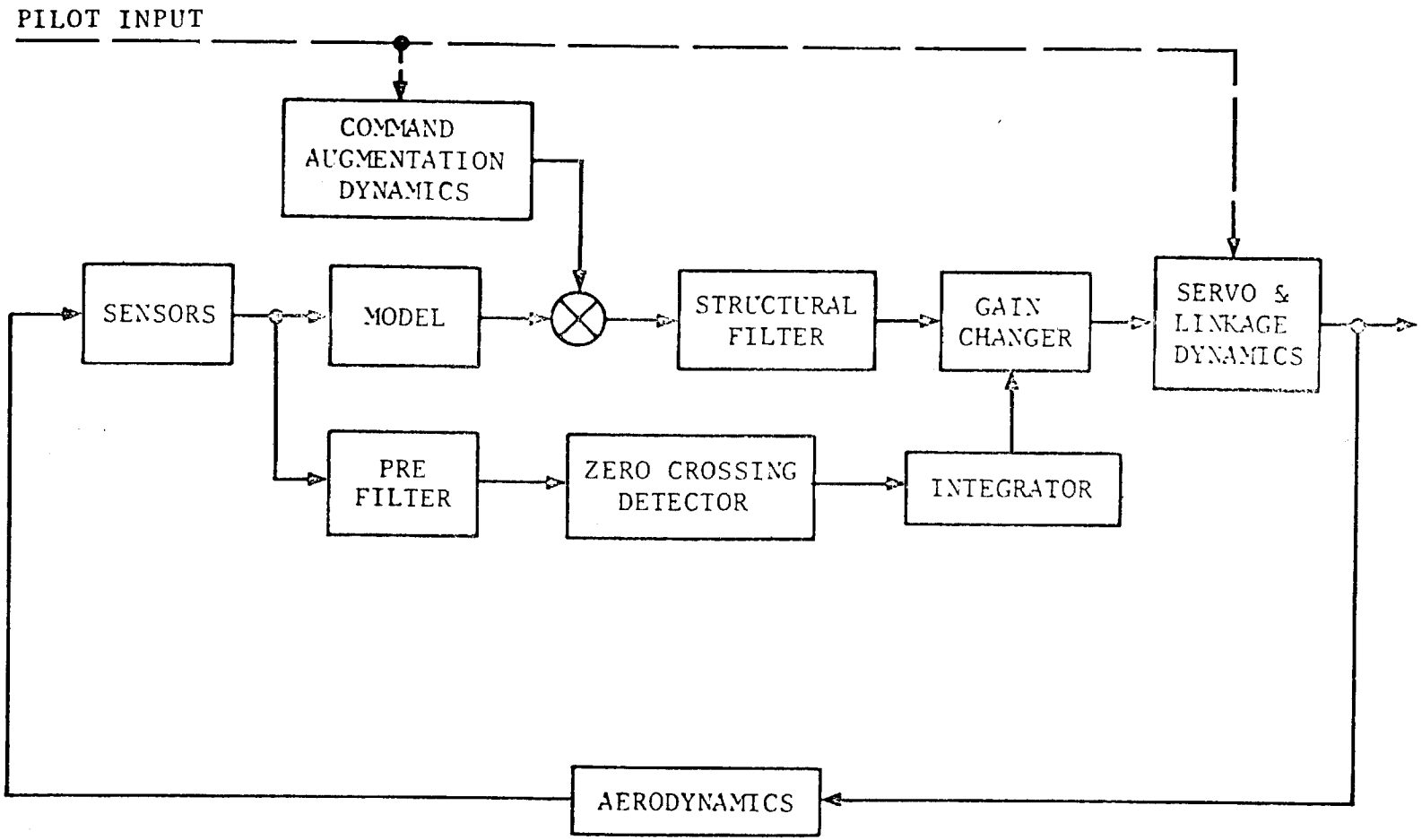


F-111 Roll Channel Functional Diagram

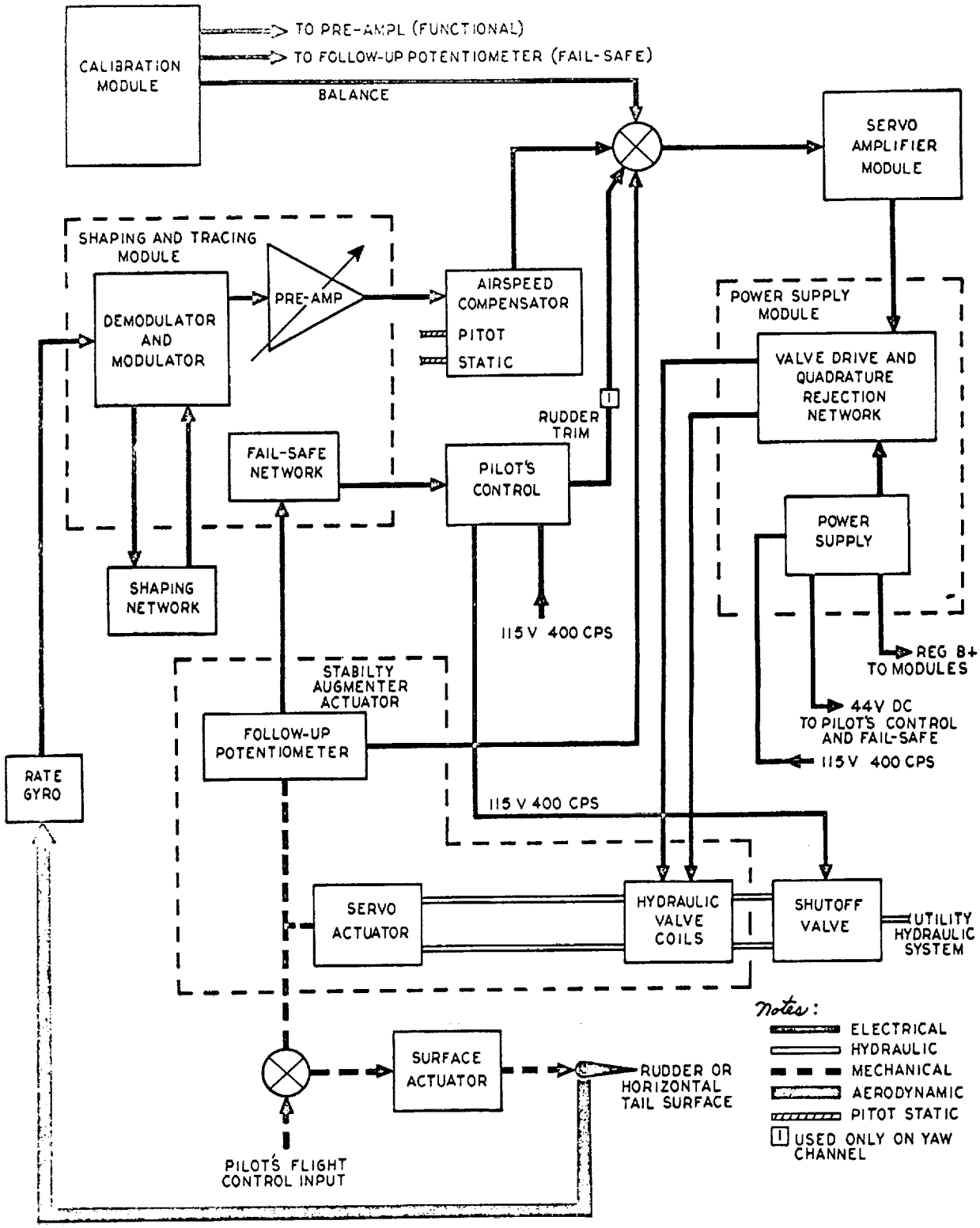


YAW CHANNEL FUNCTIONAL DIAGRAM

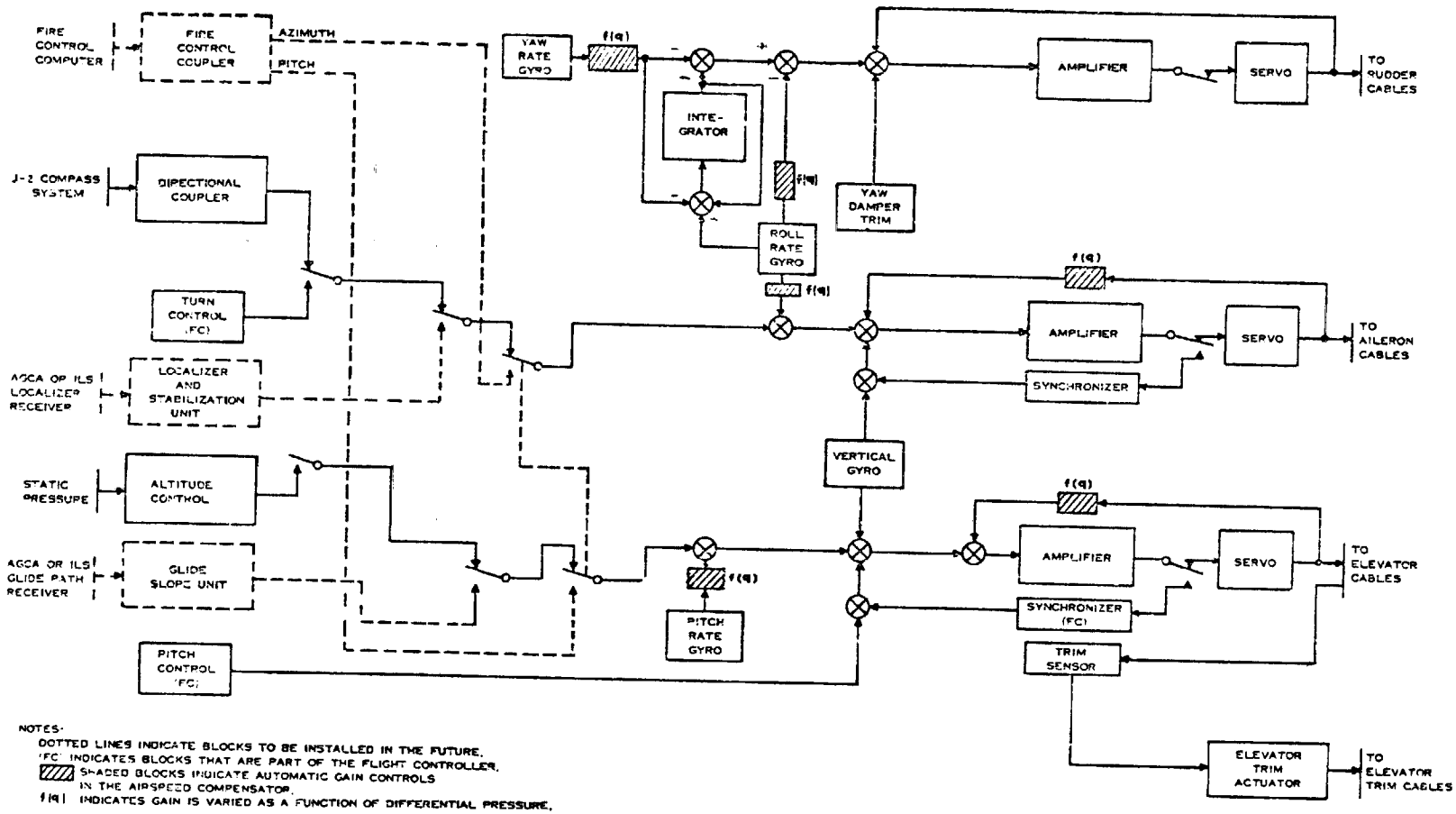
F-111 Yaw Channel Functional Diagram



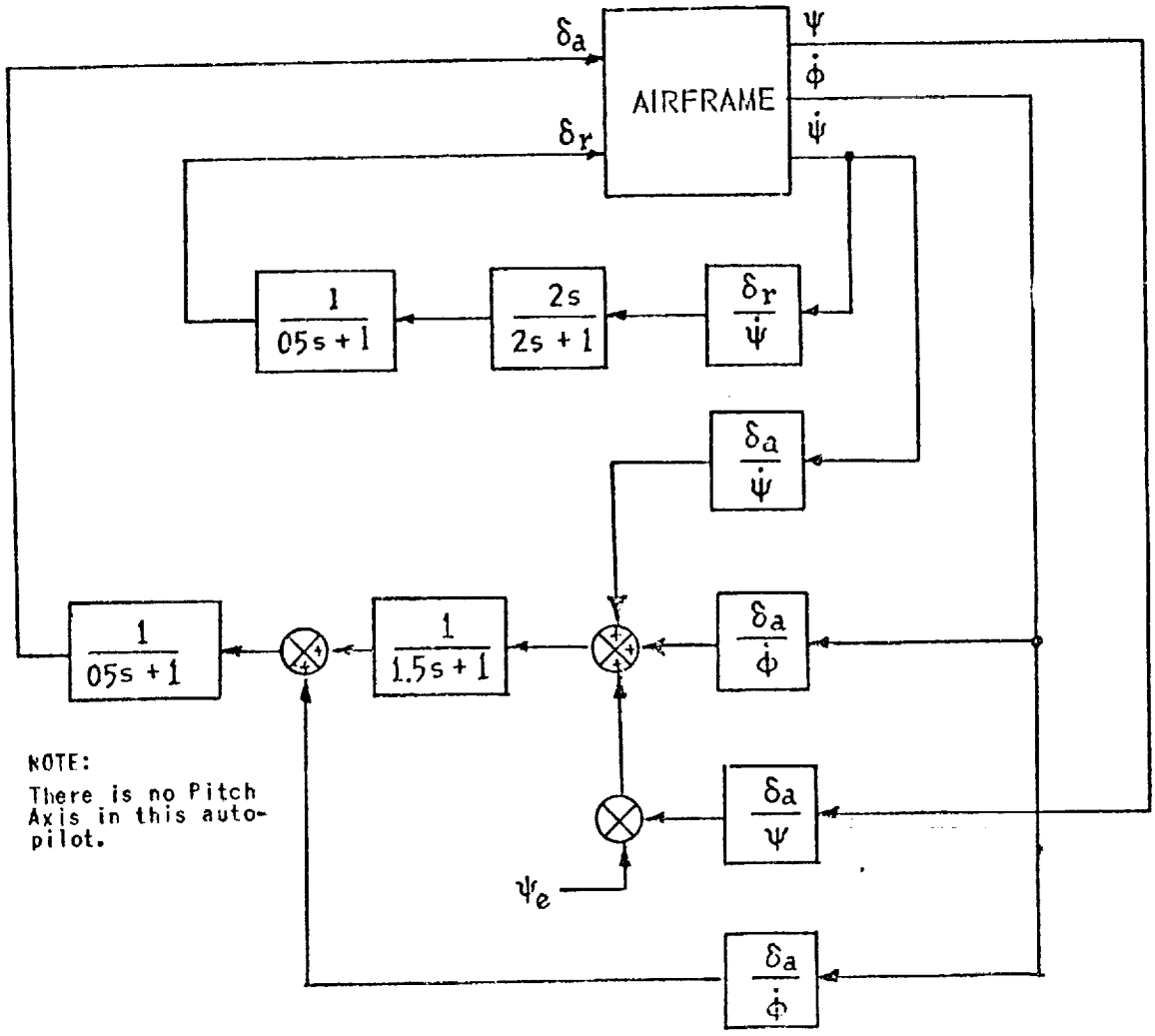
F-111 Adaptive Principle



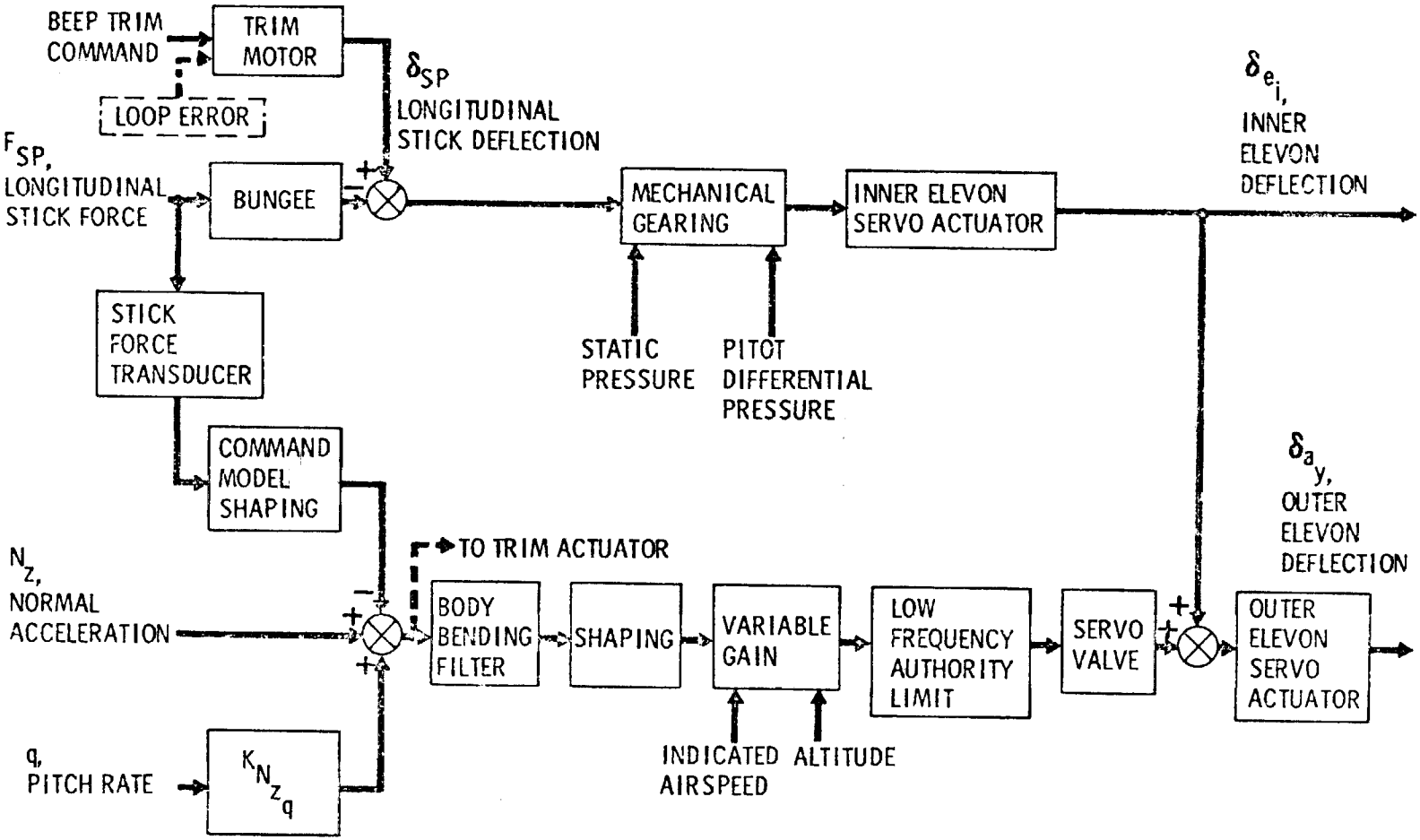
T-38 Stability Augmentation System



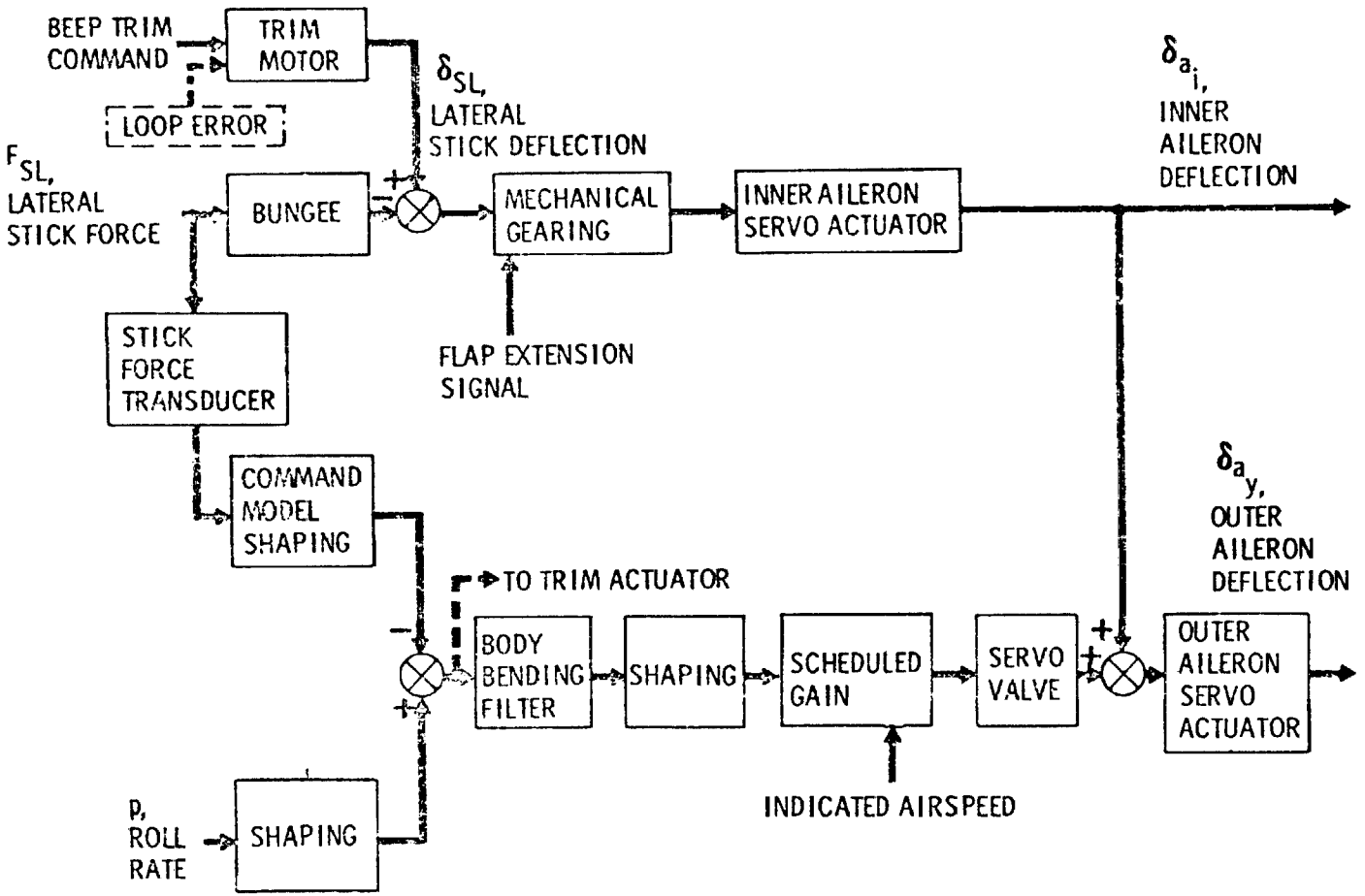
AVRO CF-100 Autopilot



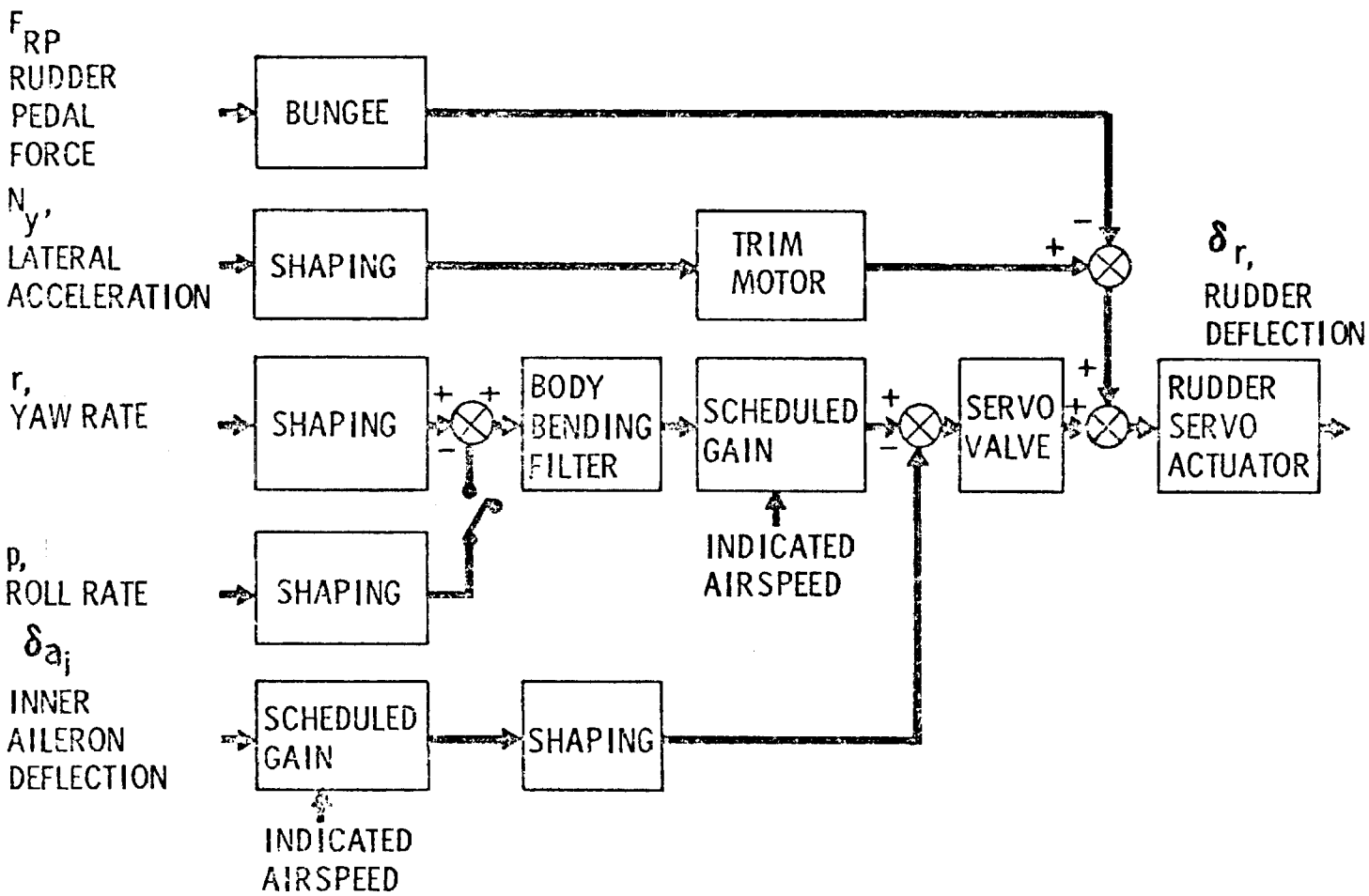
FIAT G-91 Lateral Diagram



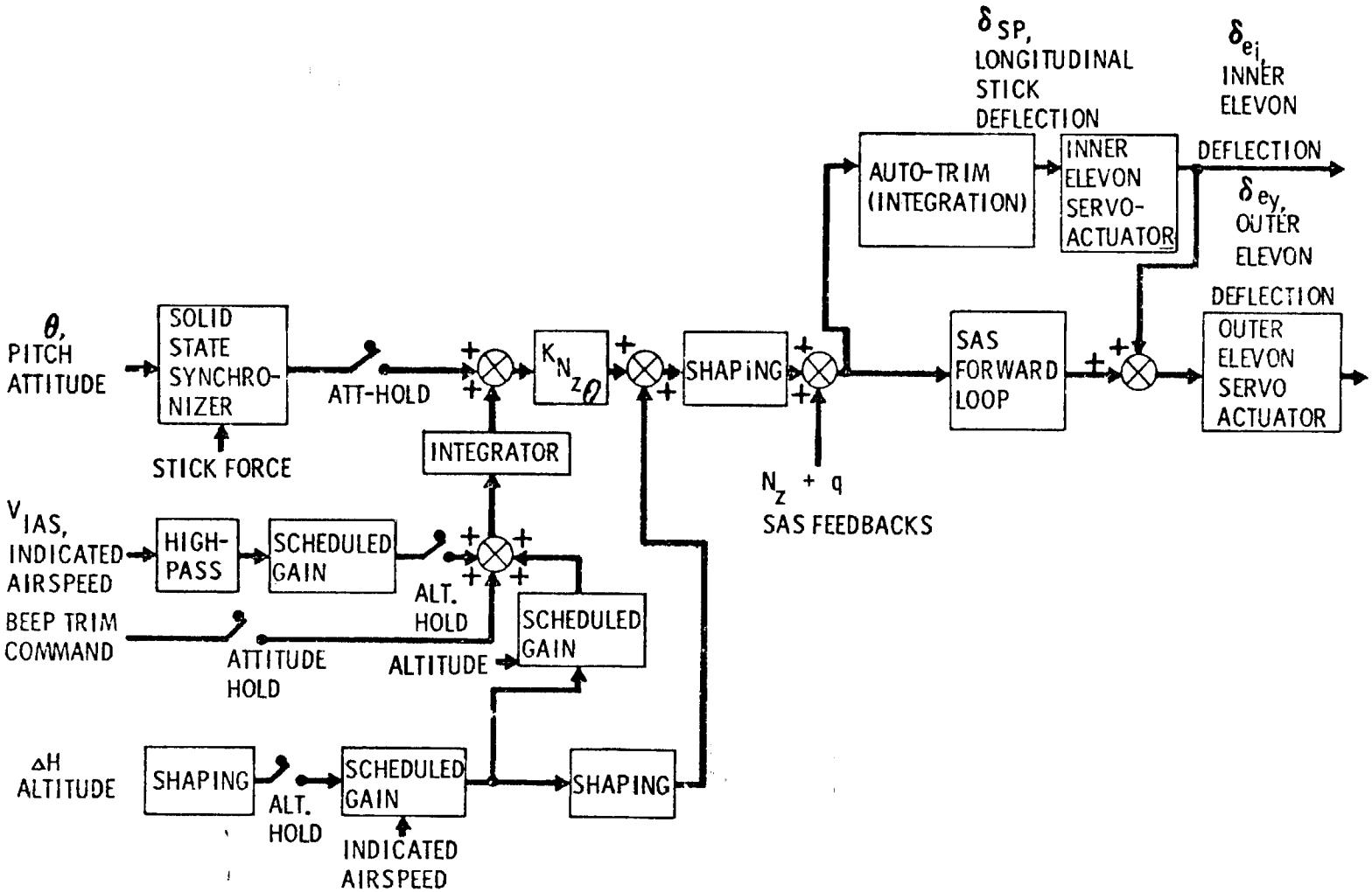
Viggen Pitch Axis Stability Augmentation and Control Stick Steering Mode



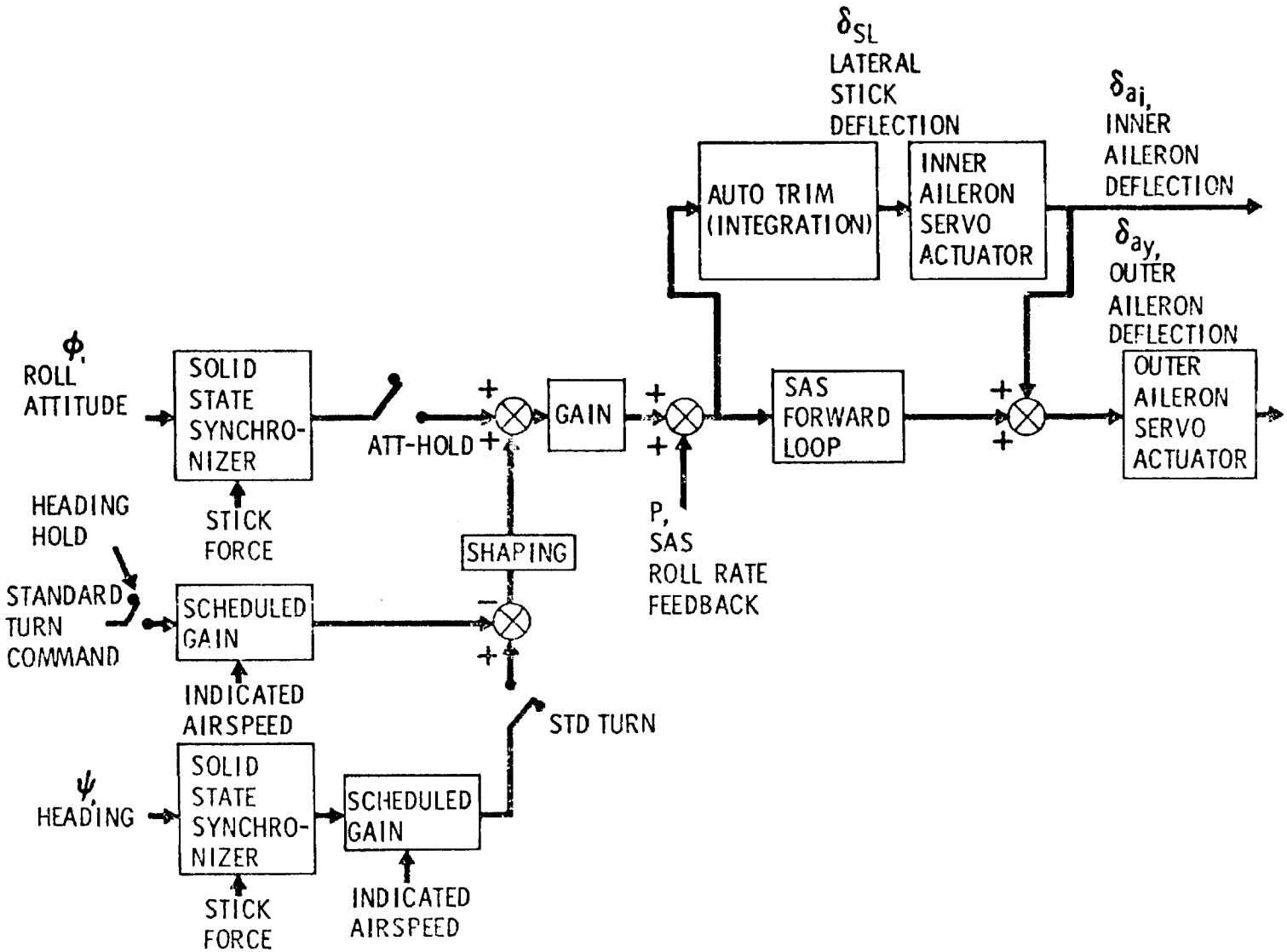
Viggen Roll SAS-CSS Loop



Viggen Yaw Axis Stability Augmentation System

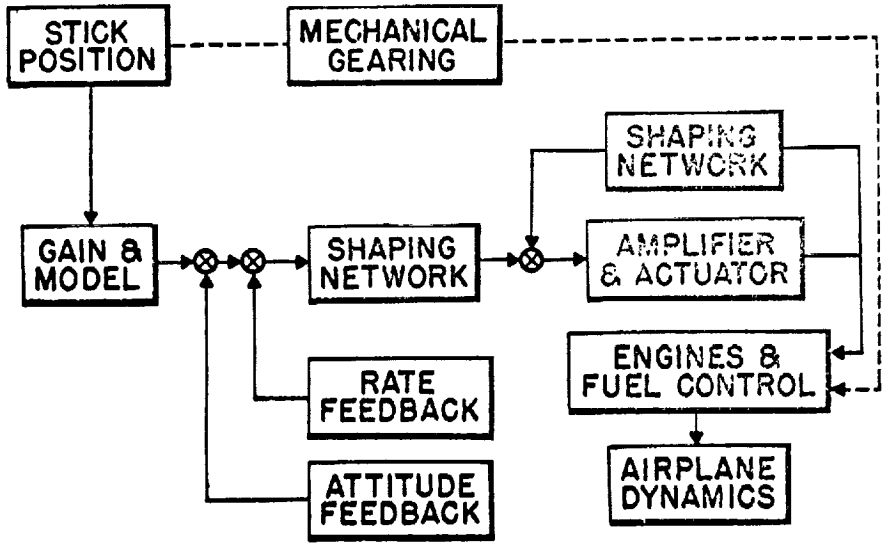


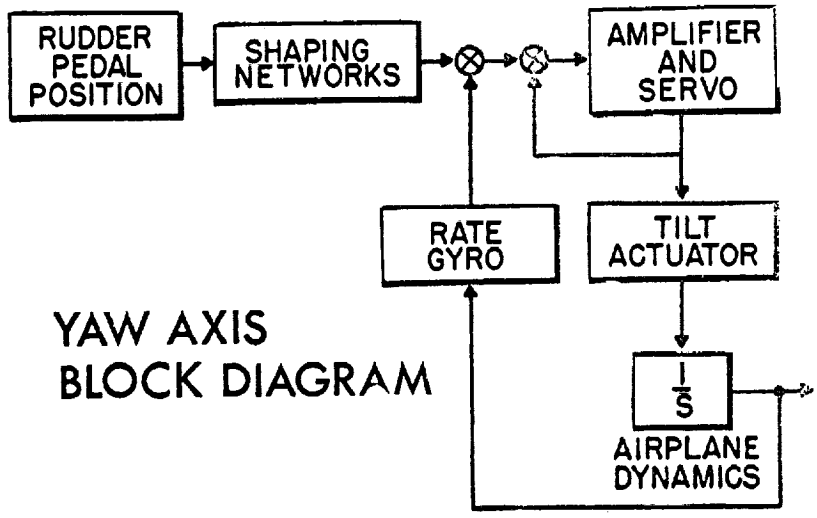
Viggen Pitch Outer Loops



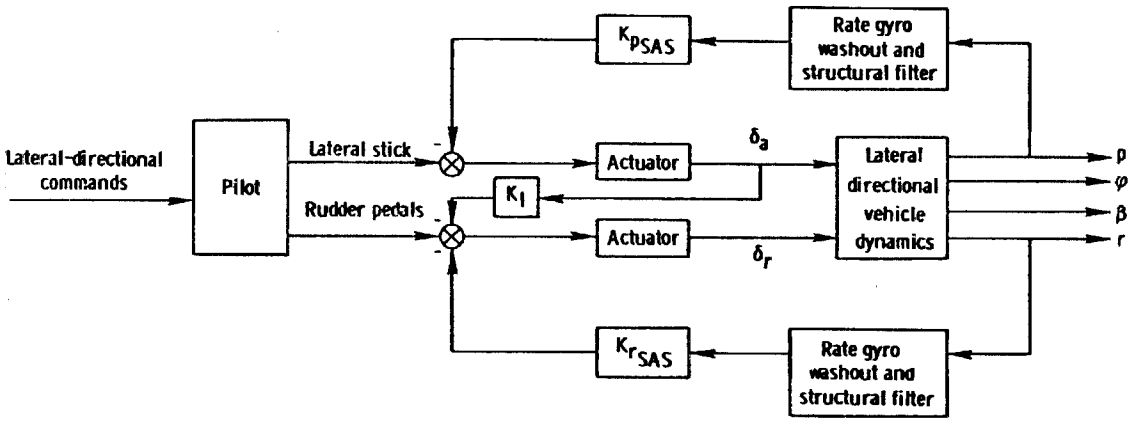
Viggen Lateral Outer Loops

GENERAL BLOCK DIAGRAM FOR ROLL AND PITCH AXES

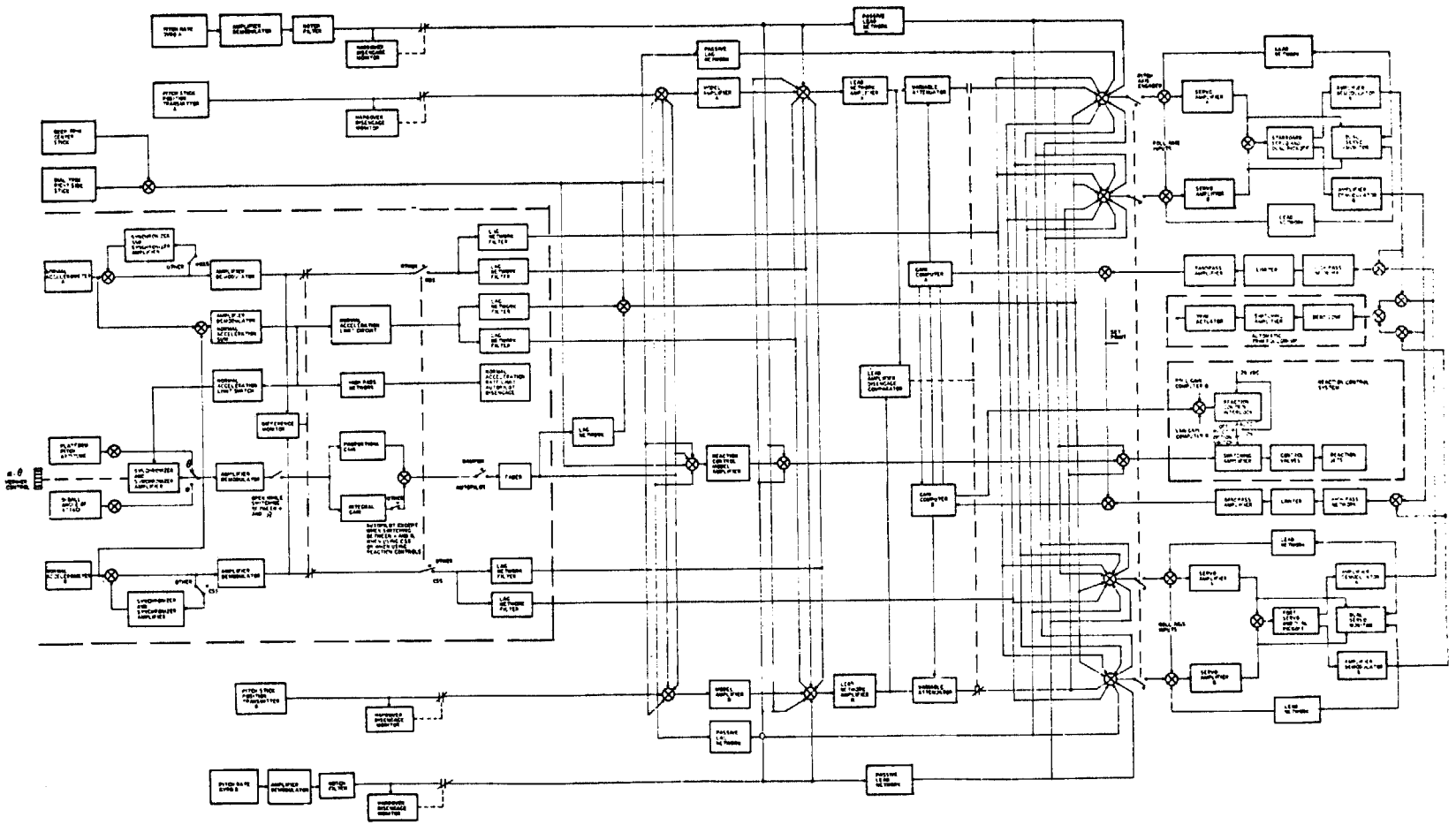




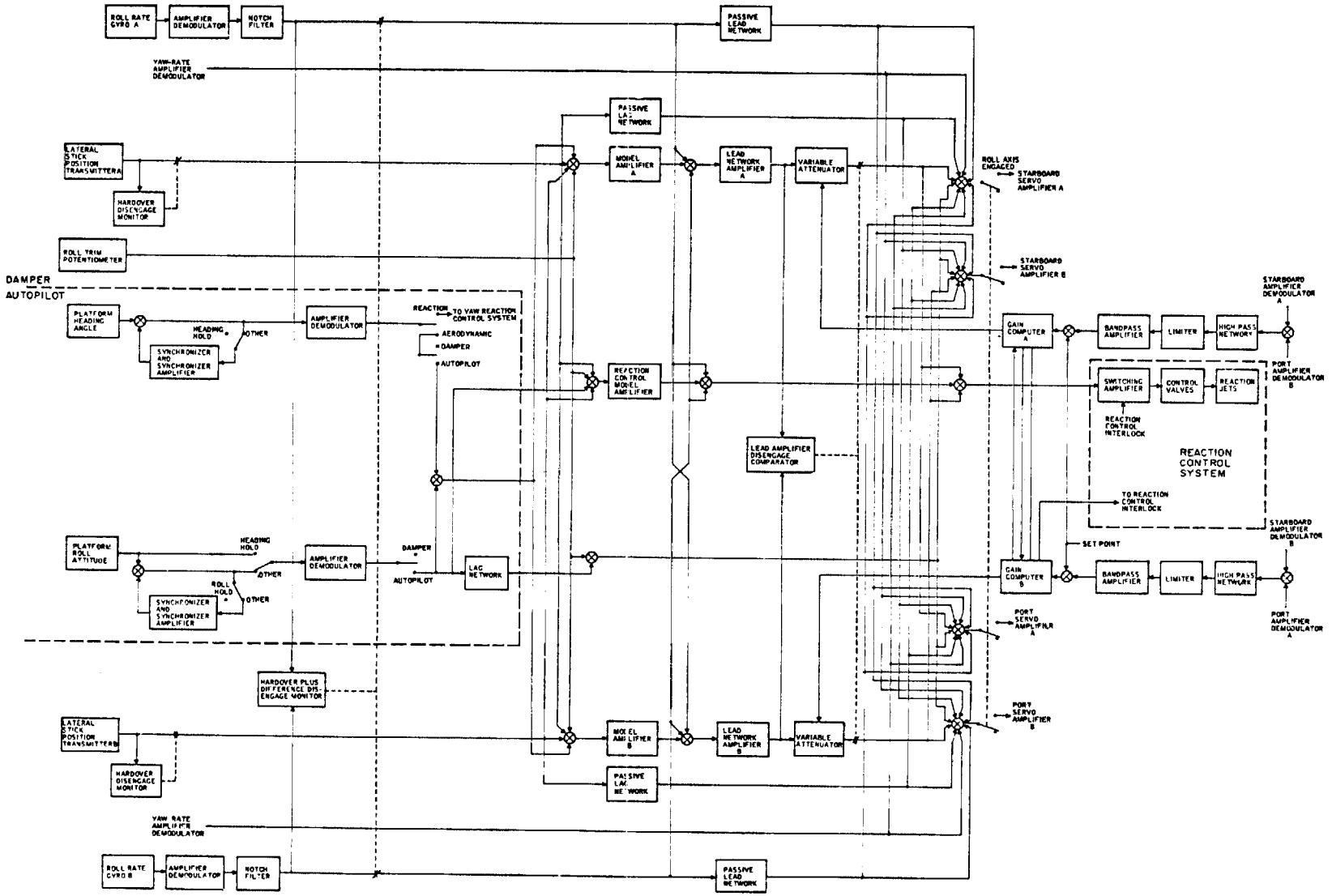
YAW AXIS BLOCK DIAGRAM



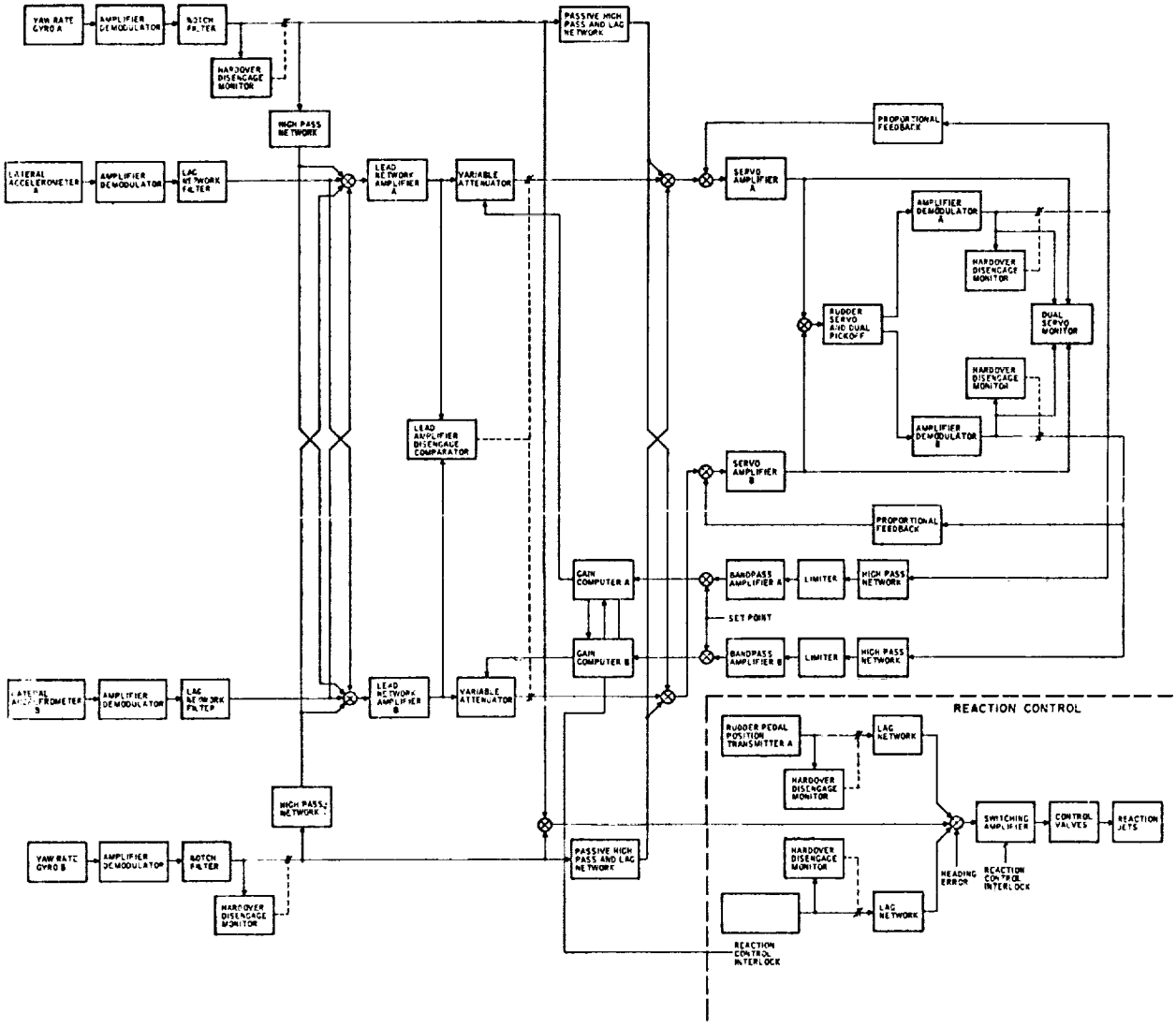
M2-F2 Lateral-Directional Flight Control System



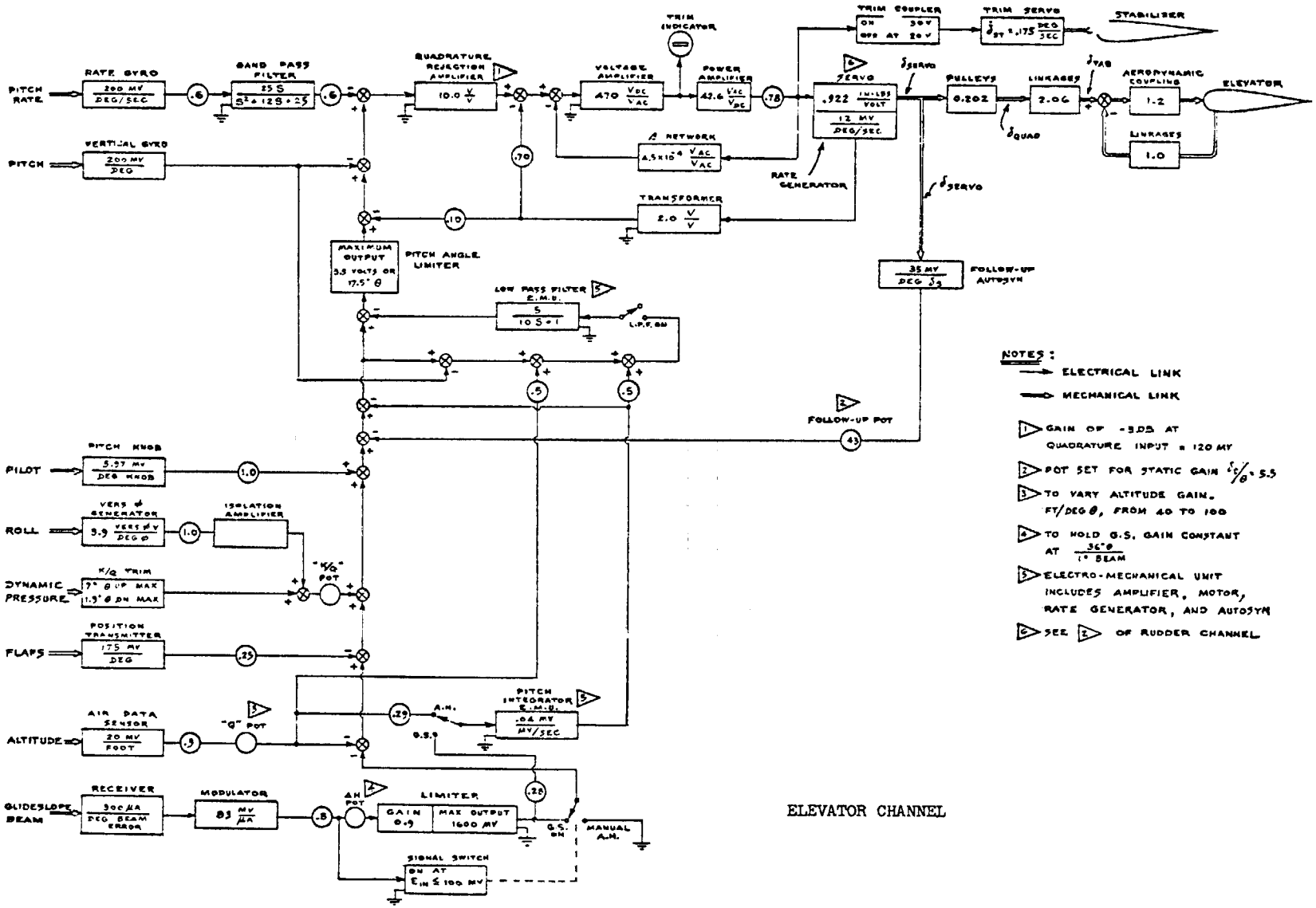
X-15 Pitch Axis Configuration Block Diagram



X-15 Roll Axis Configuration

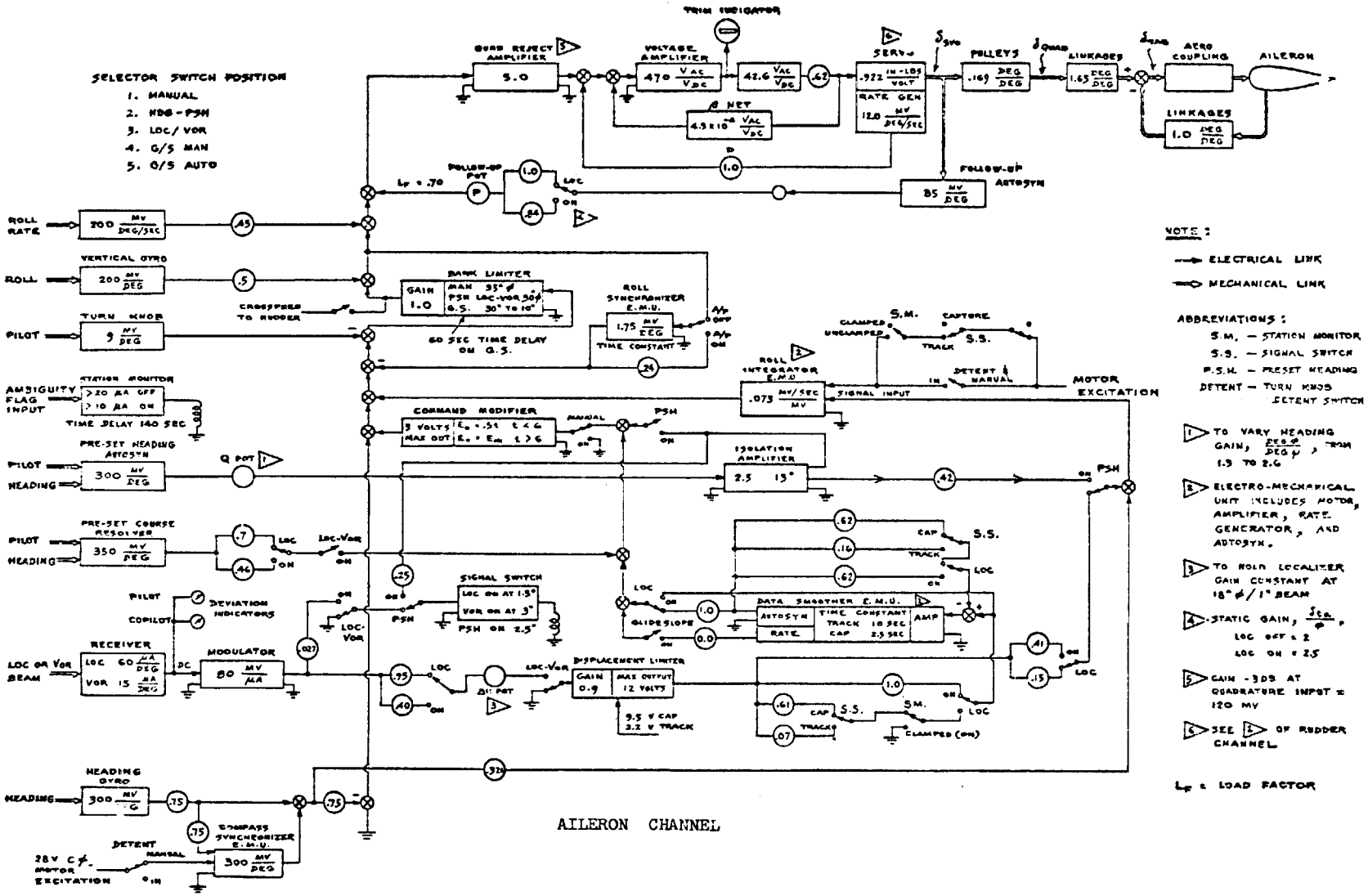


X-15 Yaw Axis Configuration

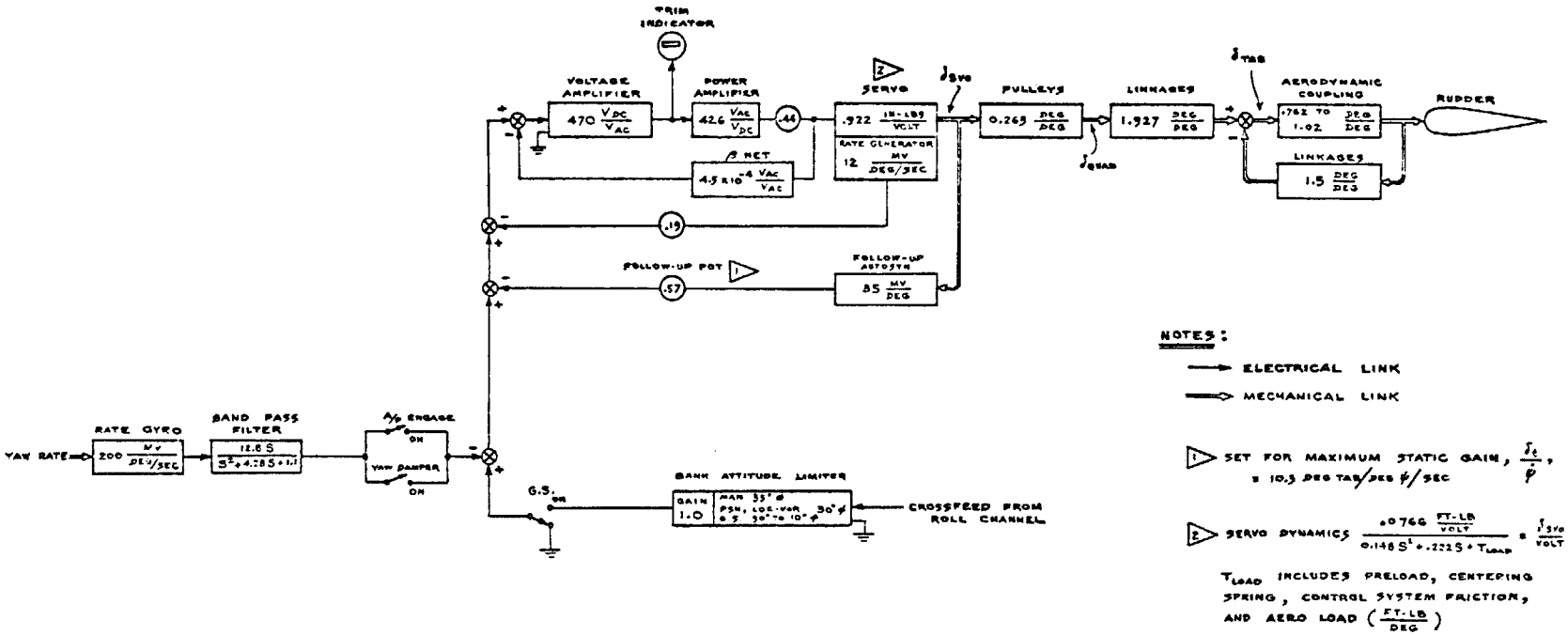


ELEVATOR CHANNEL

B-707 Autopilot



AILERON CHANNEL



NOTES:

ELECTRICAL LINK

MECHANICAL LINK

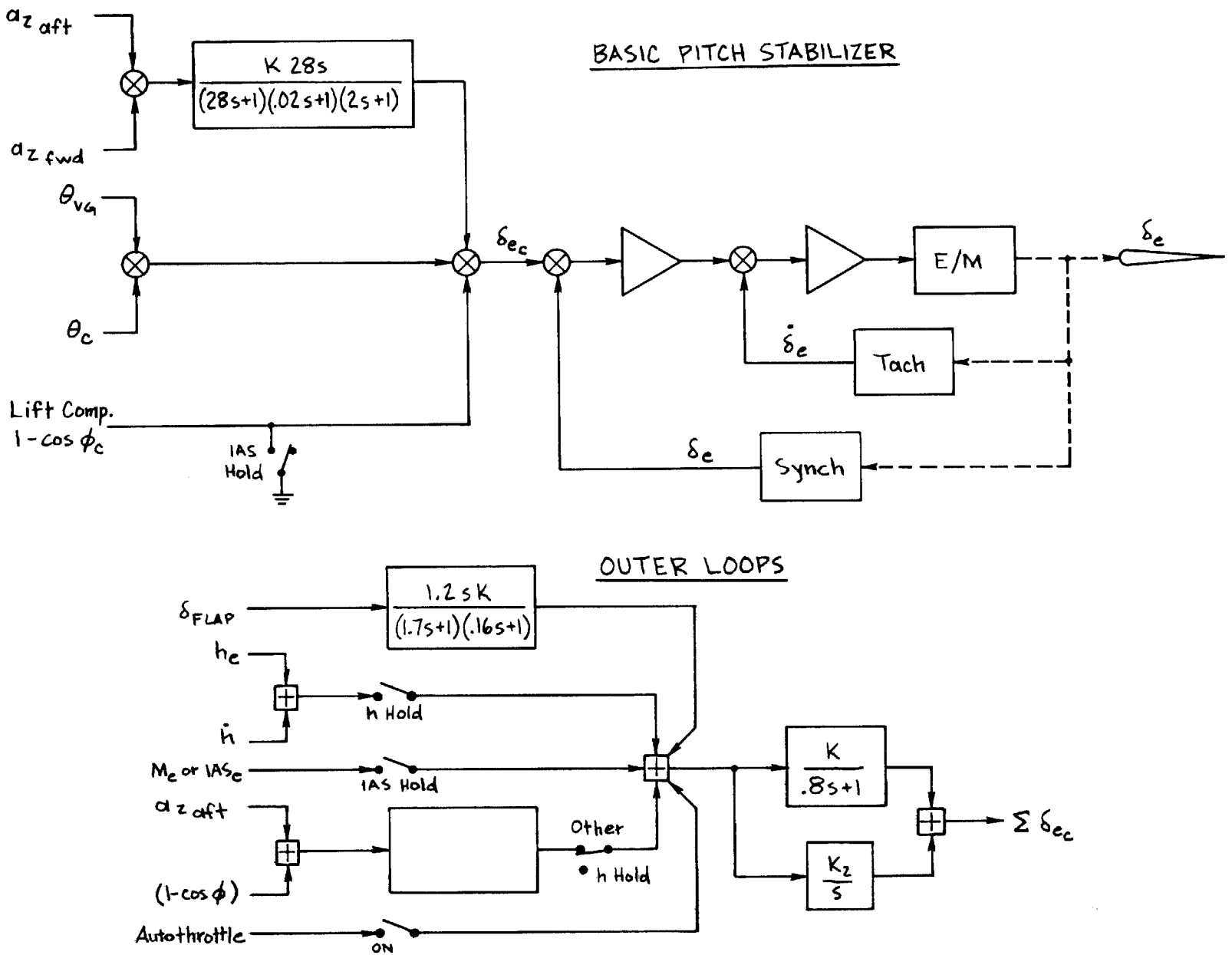
1 SET FOR MAXIMUM STATIC GAIN, $\frac{\delta_r}{\beta}$, = 10.3 DEG TAB/DEG β/SEC

2 SERVO DYNAMICS $\frac{.0766 \text{ FT-LB/VOLT}}{0.148 S^2 + .222 S + T_{LOAD}} = \frac{\delta_{Svo}}{\text{VOLT}}$

T_{LOAD} INCLUDES PRELOAD, CENTERING SPRING, CONTROL SYSTEM FRICTION, AND AERO LOAD $\left(\frac{\text{FT-LB}}{\text{DEG}}\right)$

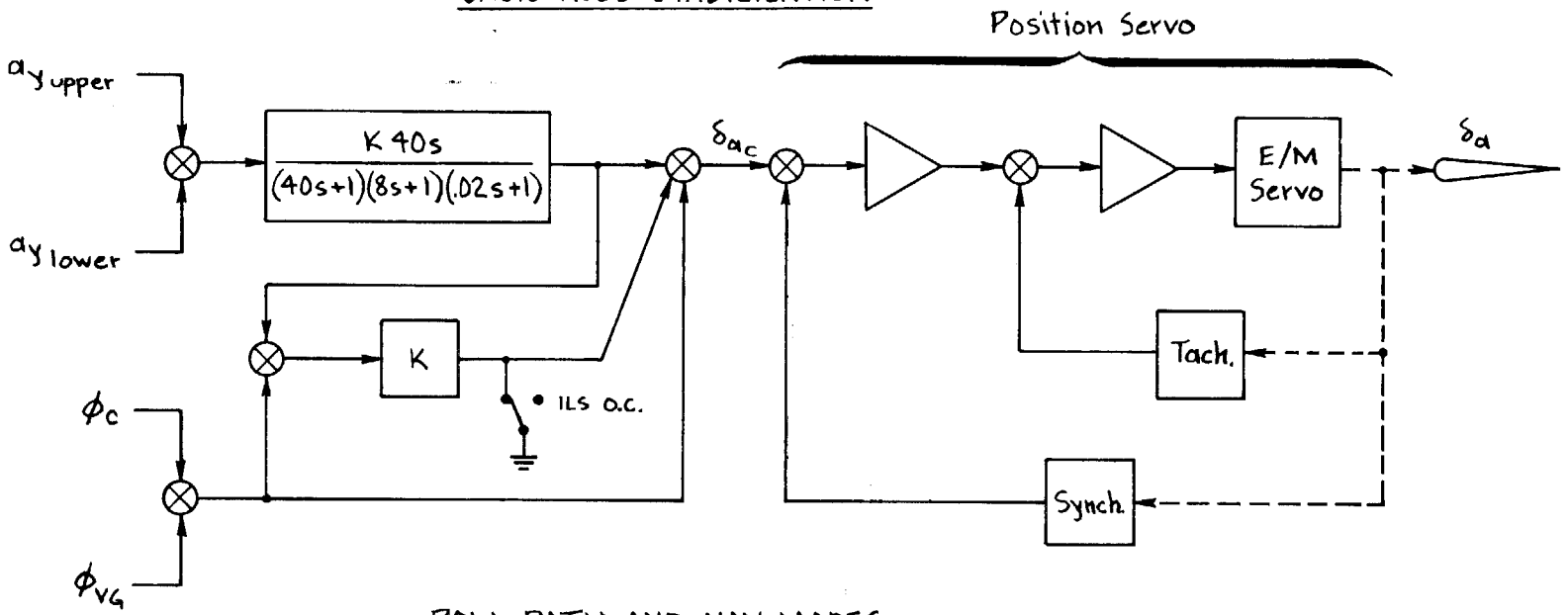
RUDDER CHANNEL

B-707 Autopilot

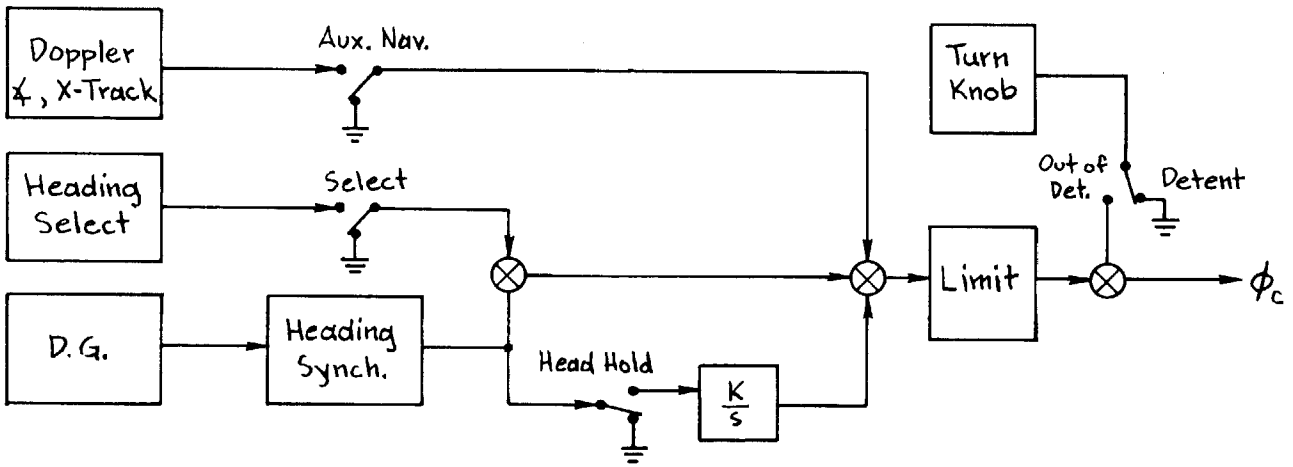


DC-8 Pitch Axis

BASIC ROLL STABILIZATION

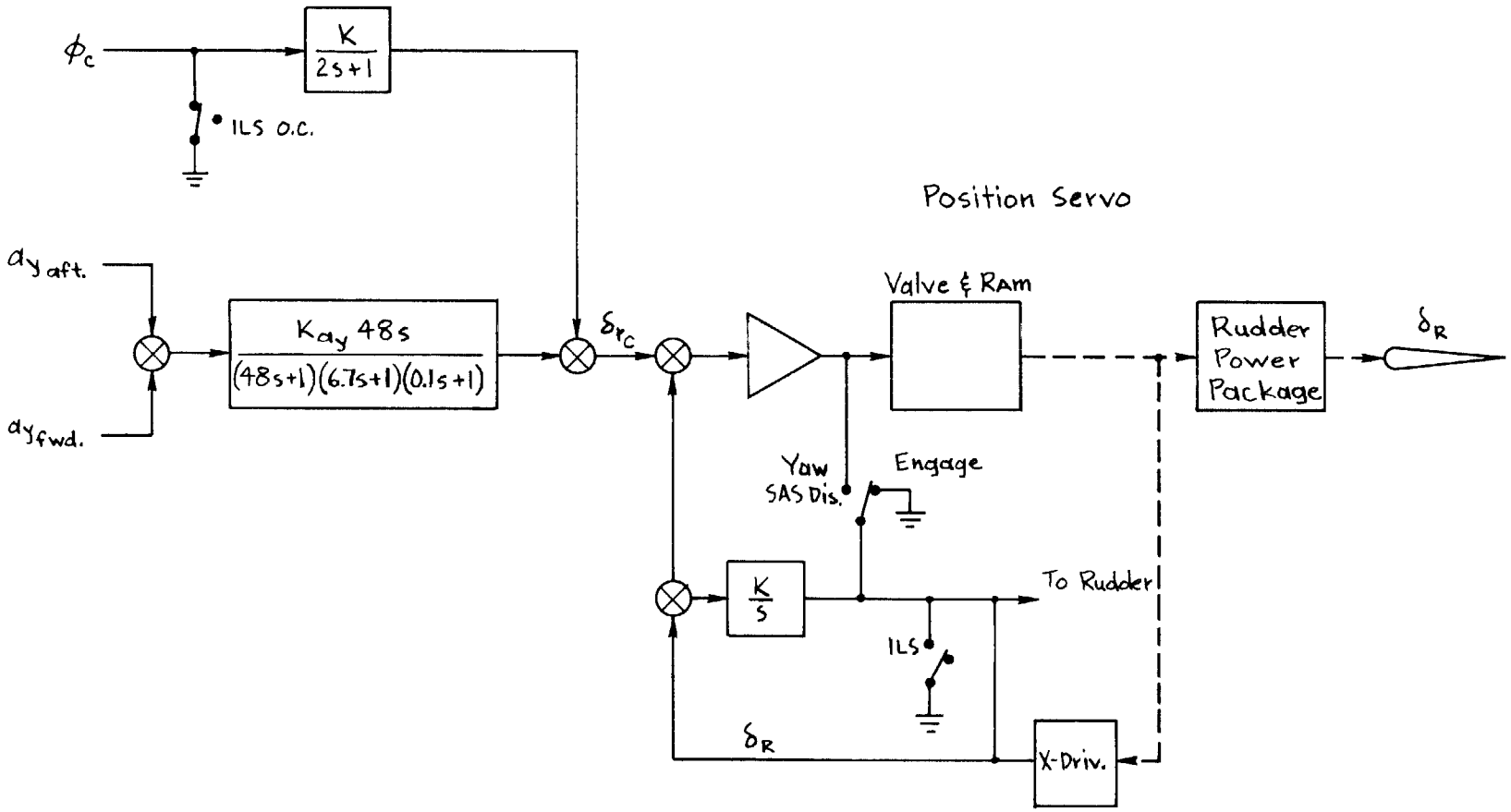


ROLL PATH AND NAV MODES

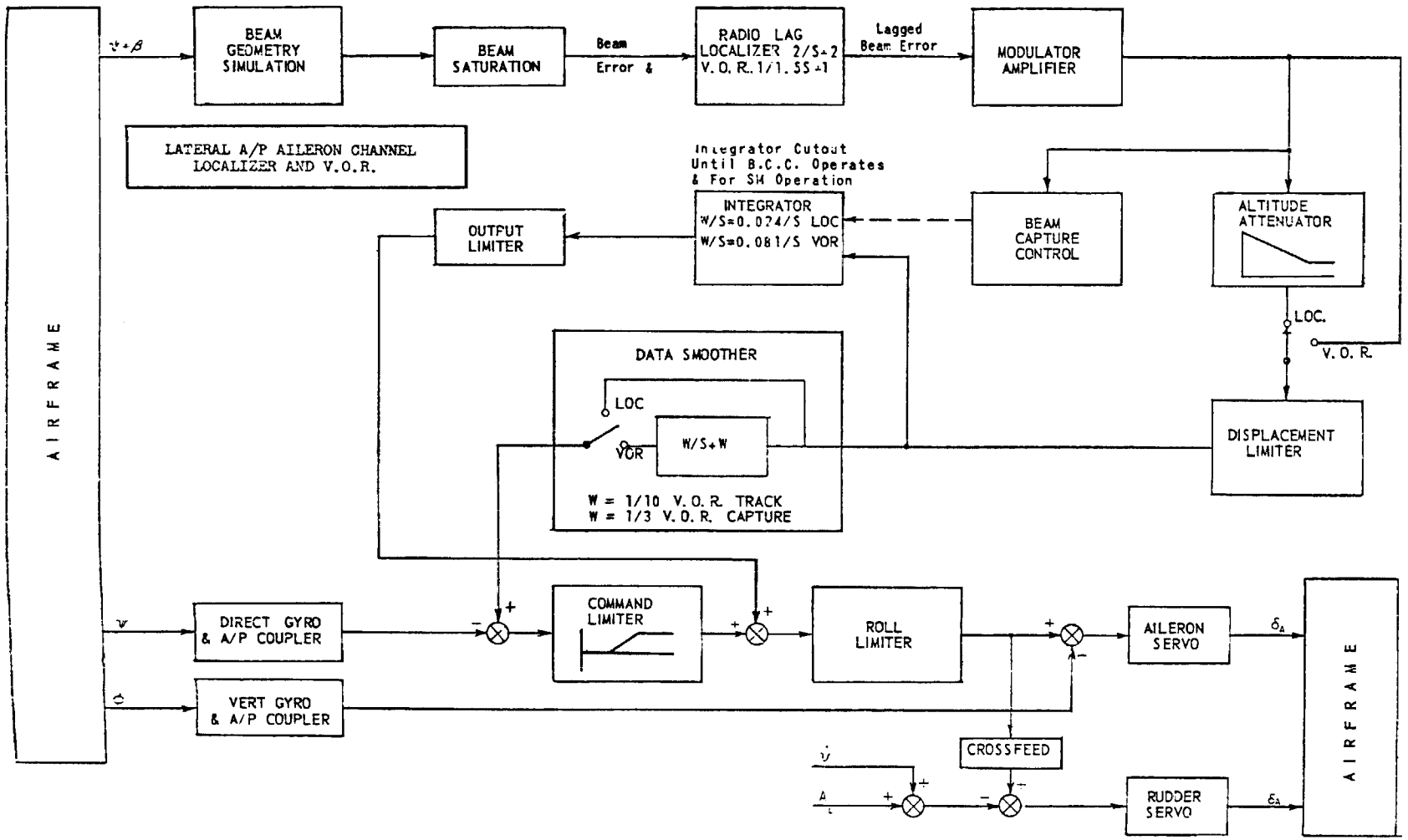


DC-8 Roll Axis

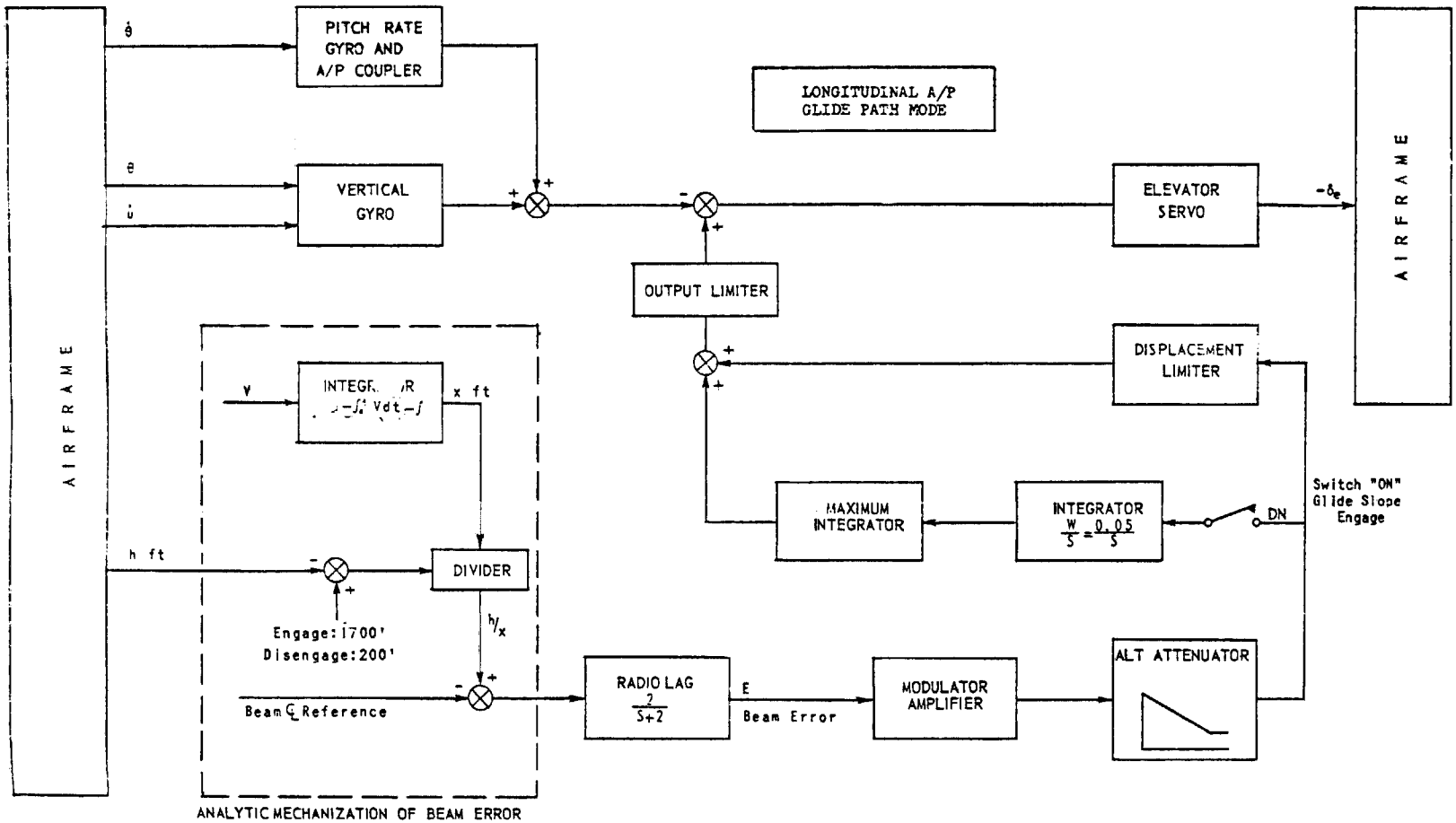
YAW STABILIZATION



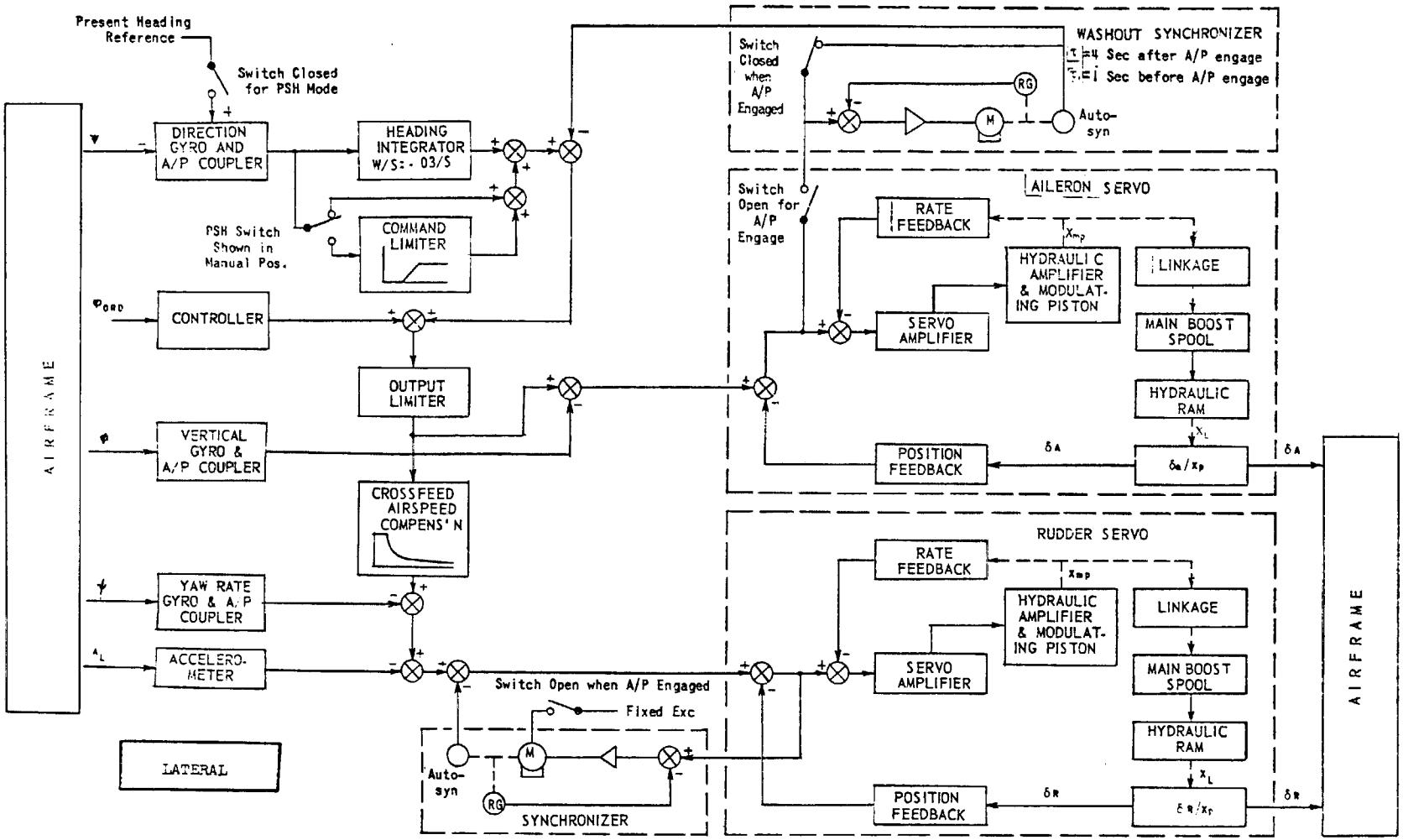
DC-8 Yaw Axis



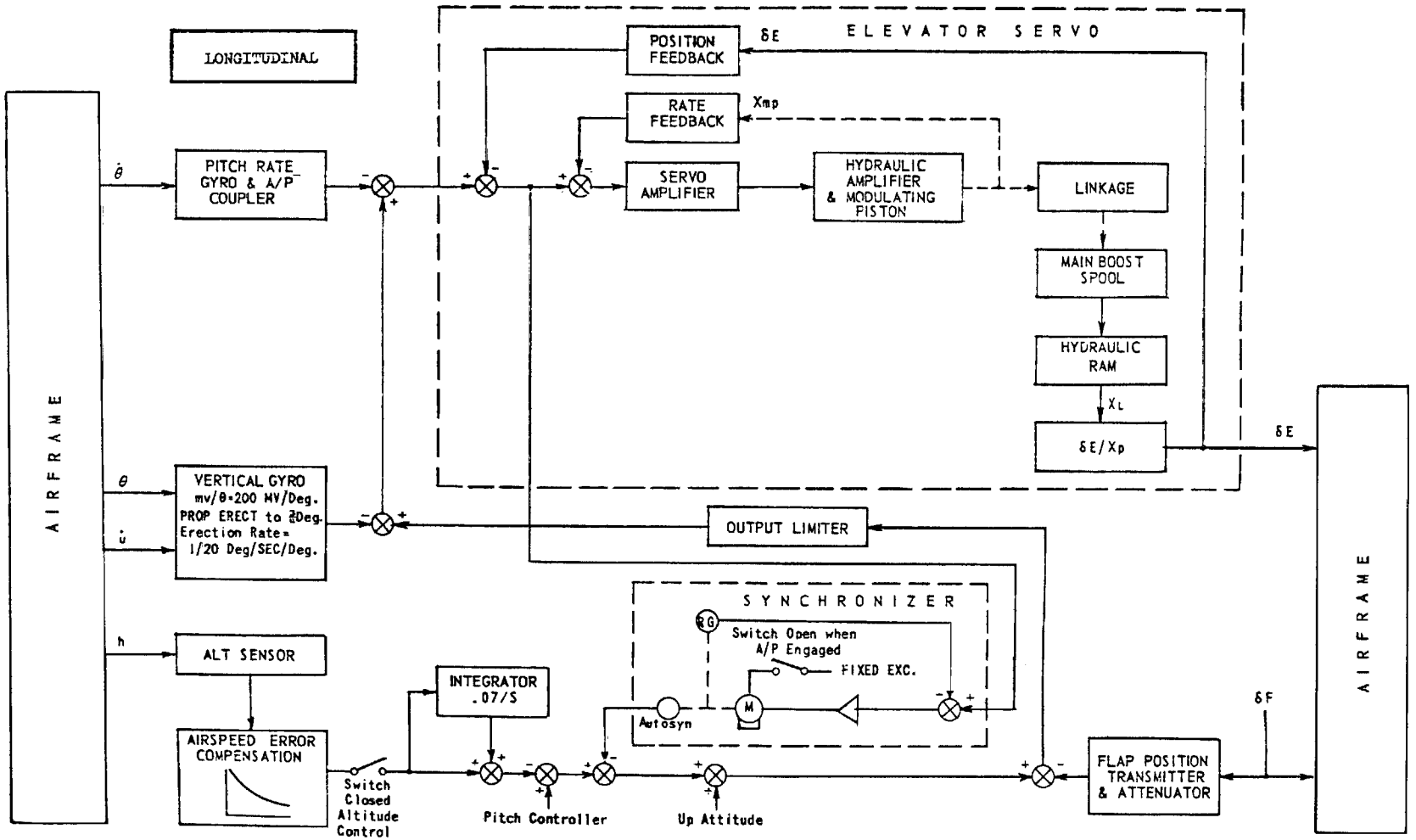
L-188 Autopilot



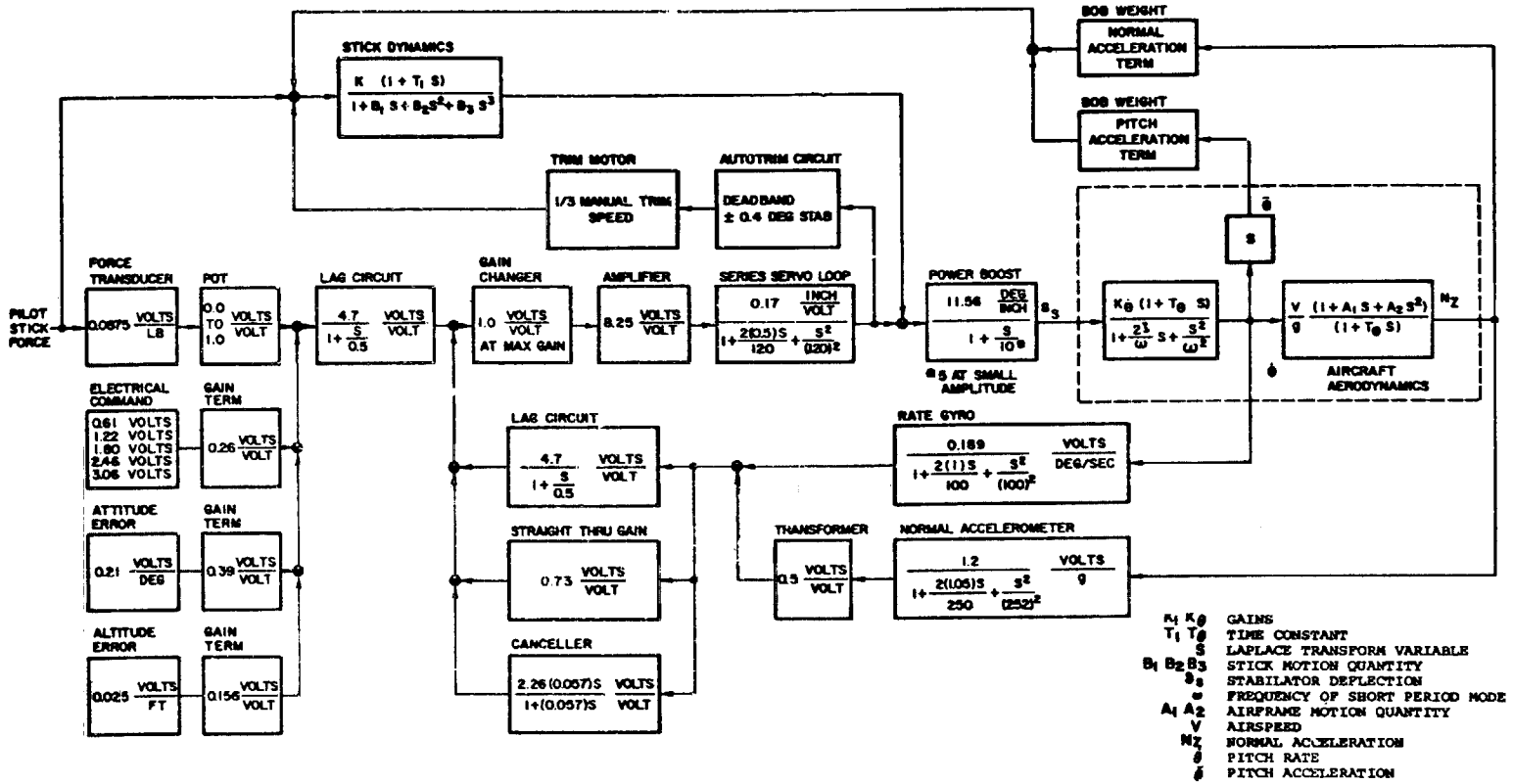
L-188 Autopilot



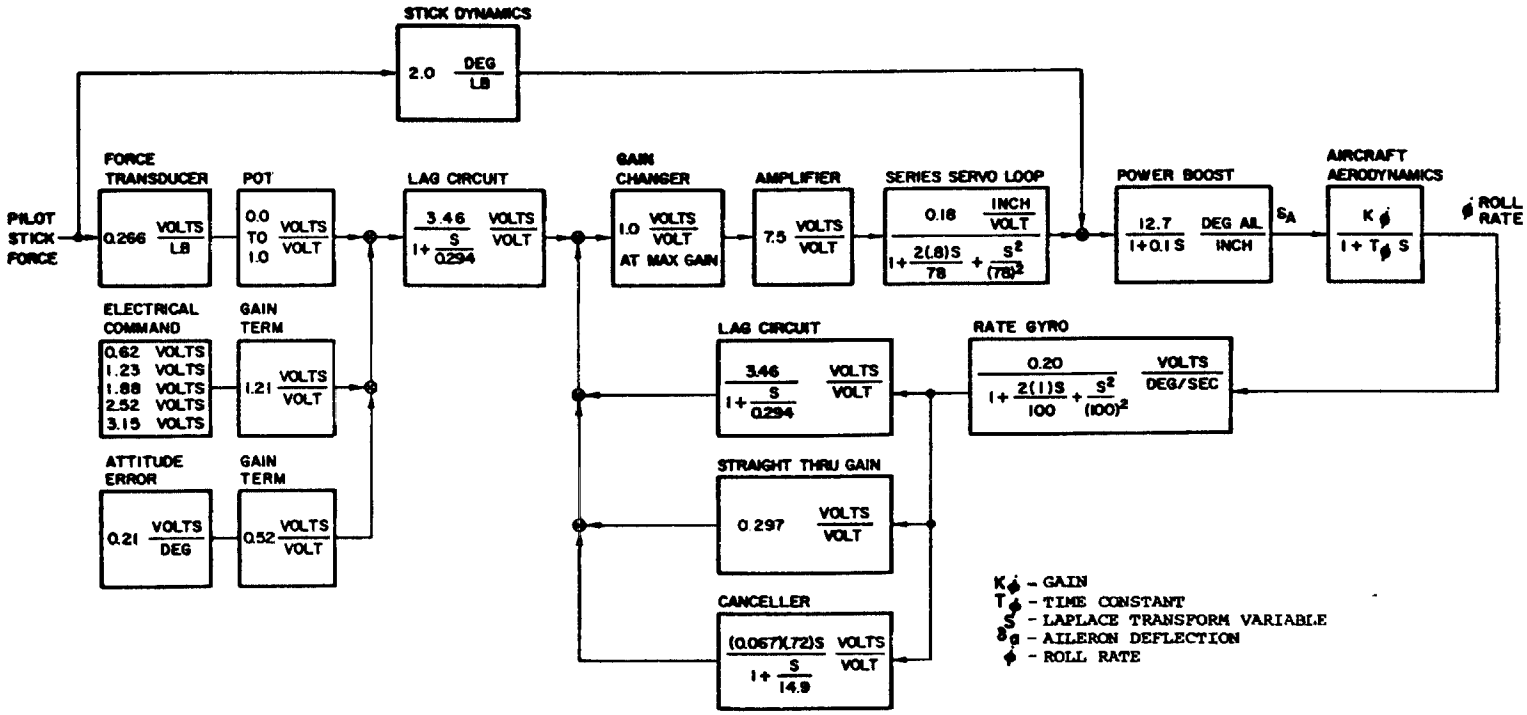
L-188 Autopilot



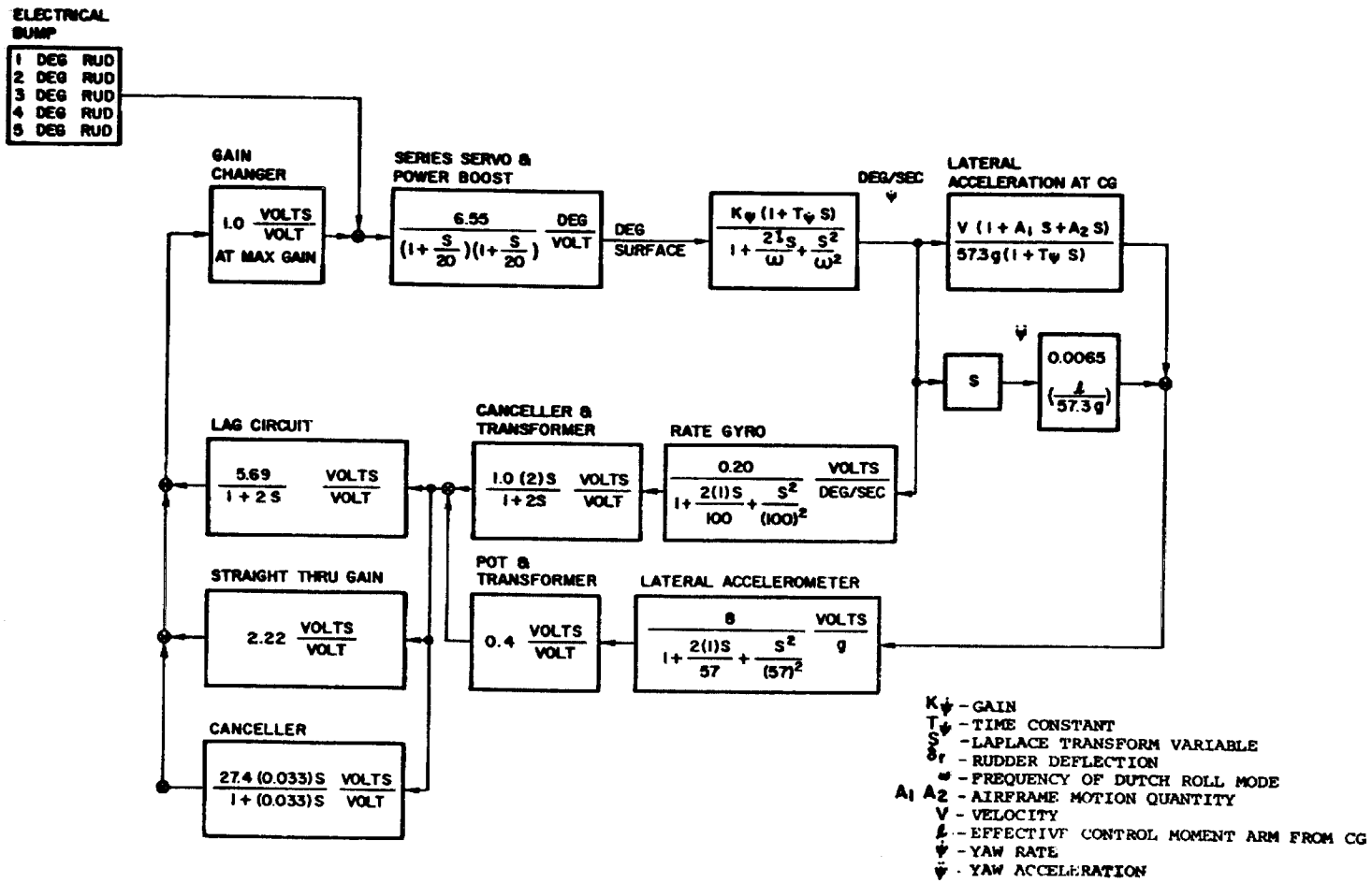
L-188 Autopilot



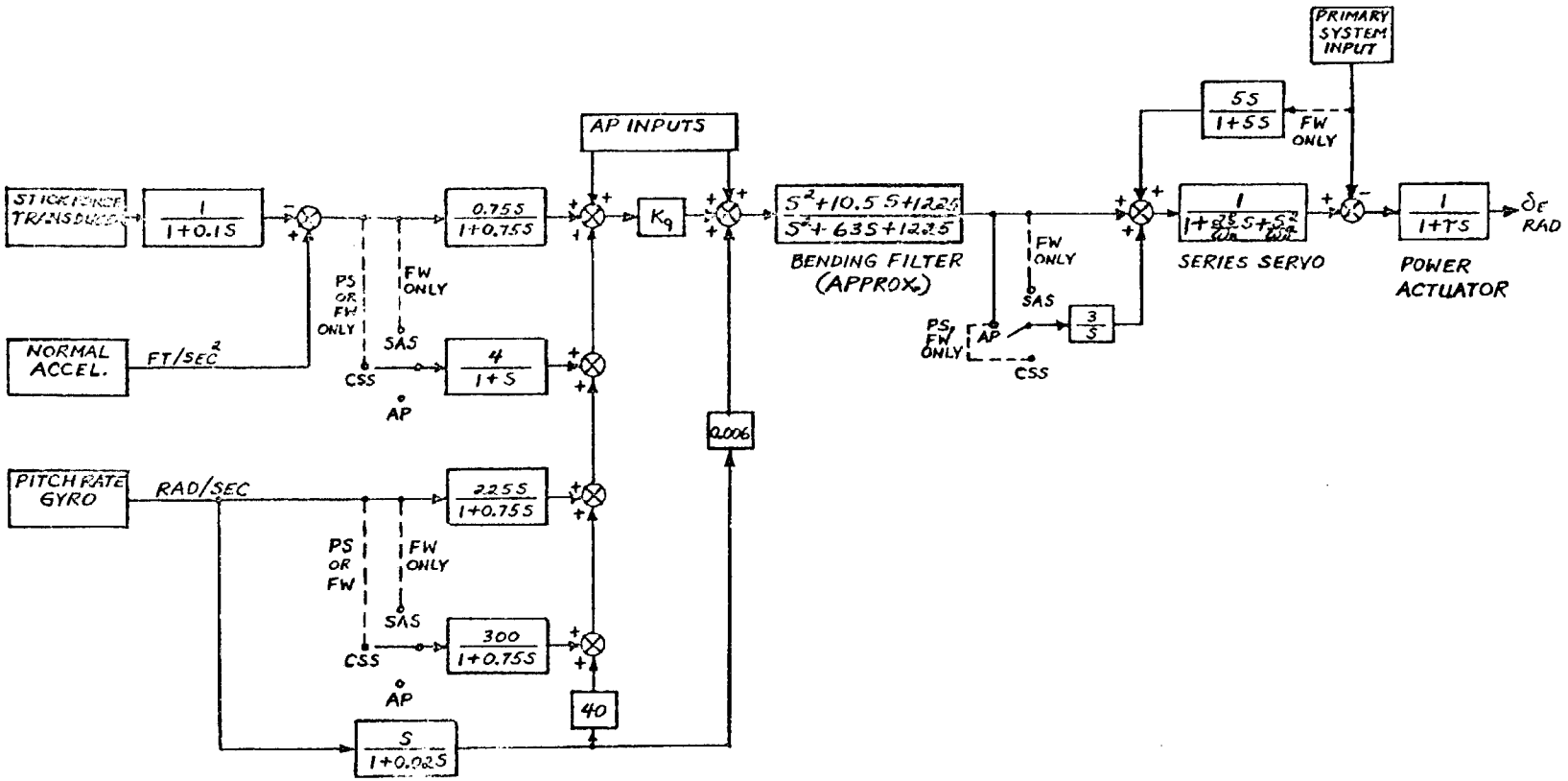
GESAC Pitch Channel (F-4A)



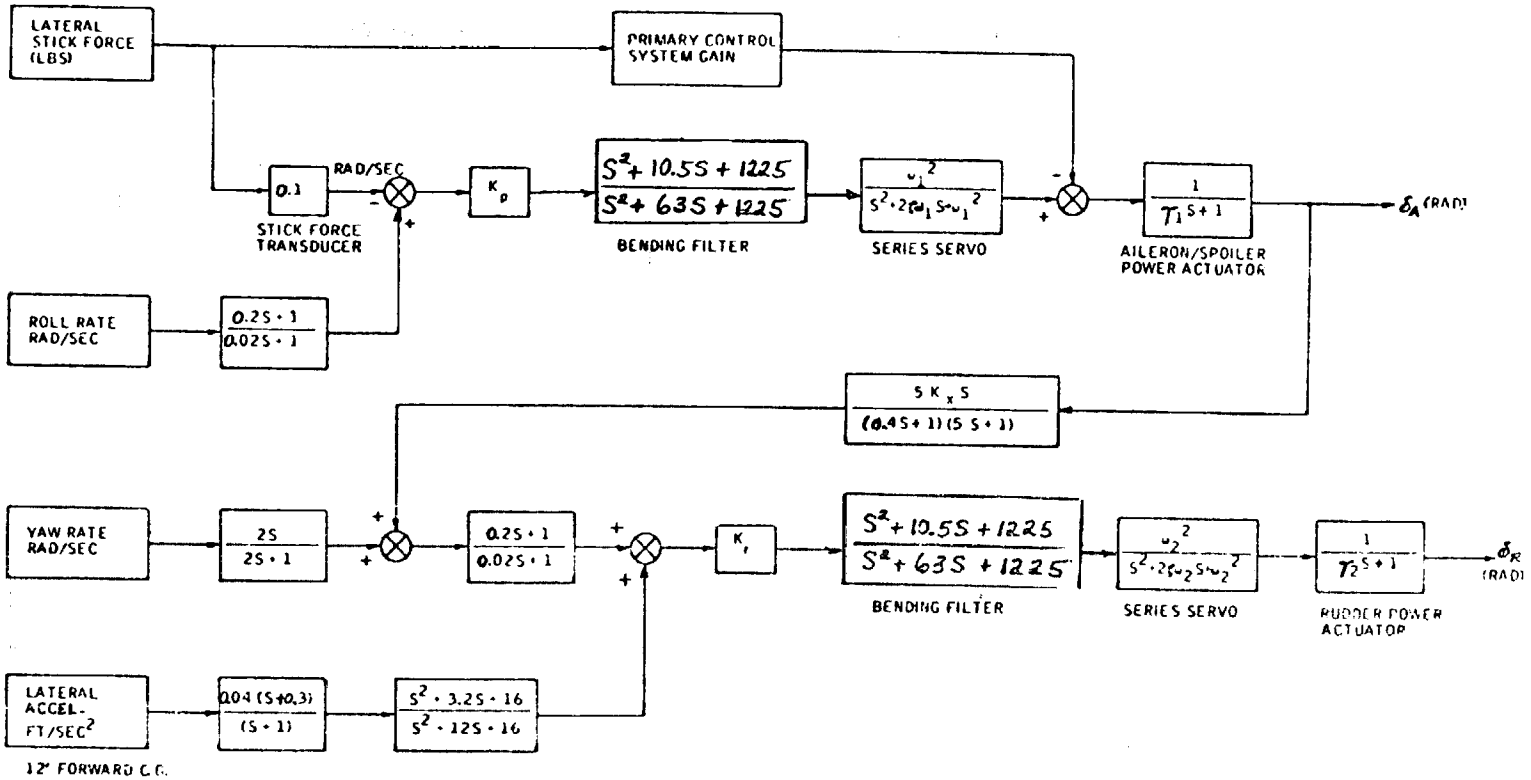
GESAC Roll Channel (F-4A)



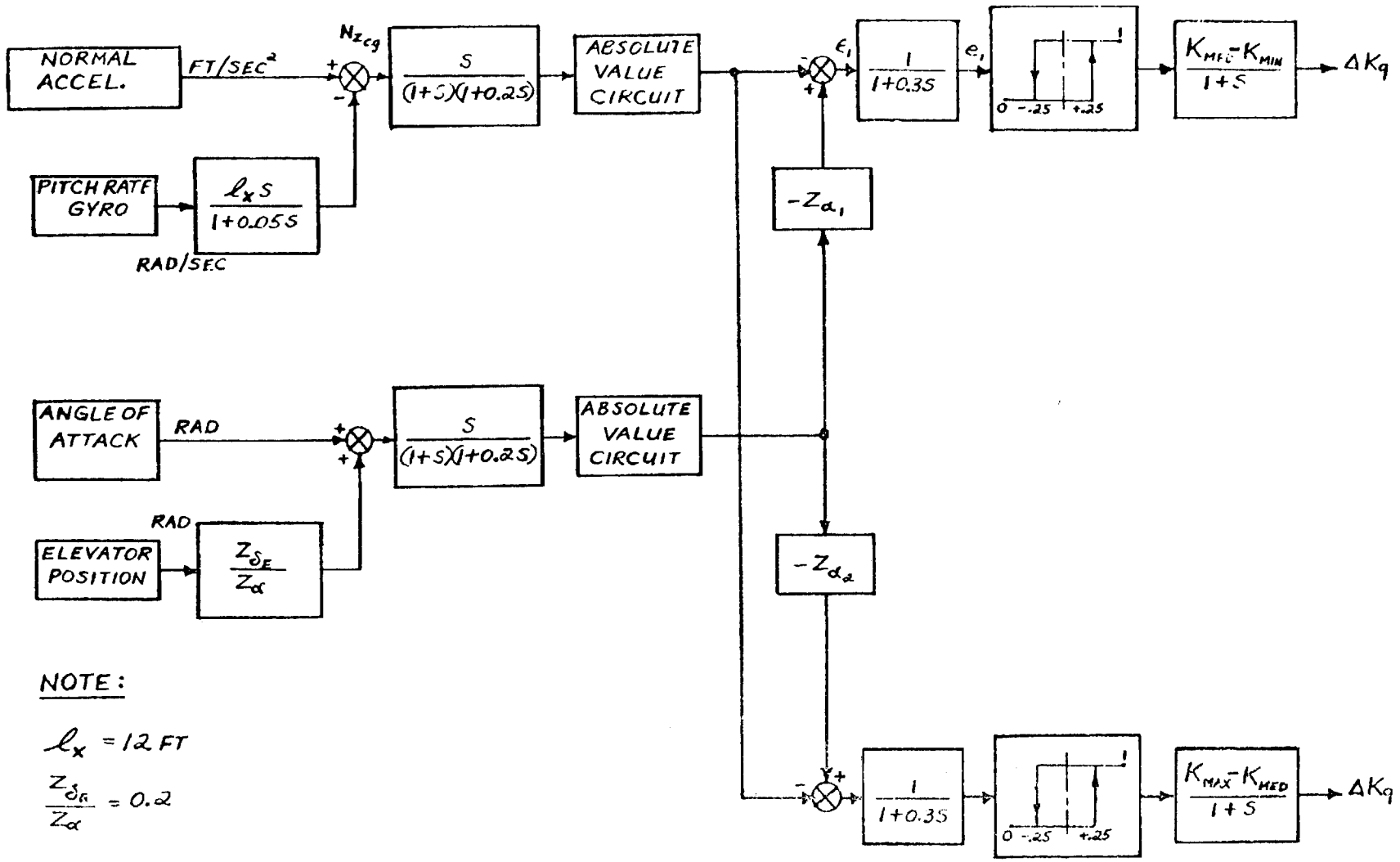
GESAC Yaw Channel (F-4A)



Adaptable FCS Pitch Stability Augmentation System (F-4)



Adaptable FCS Lateral-Directional Stability Augmentation System (F-4)

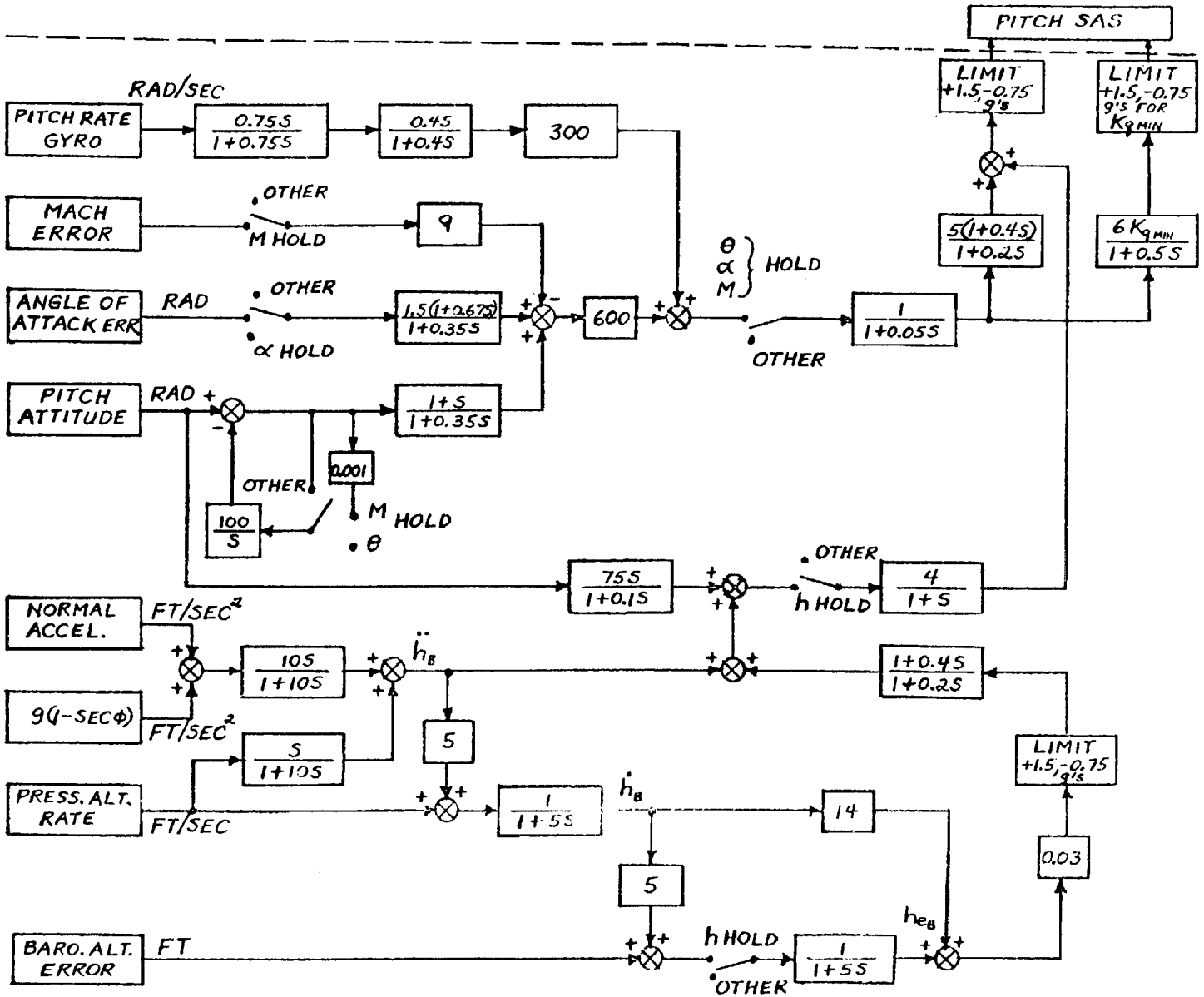


NOTE:

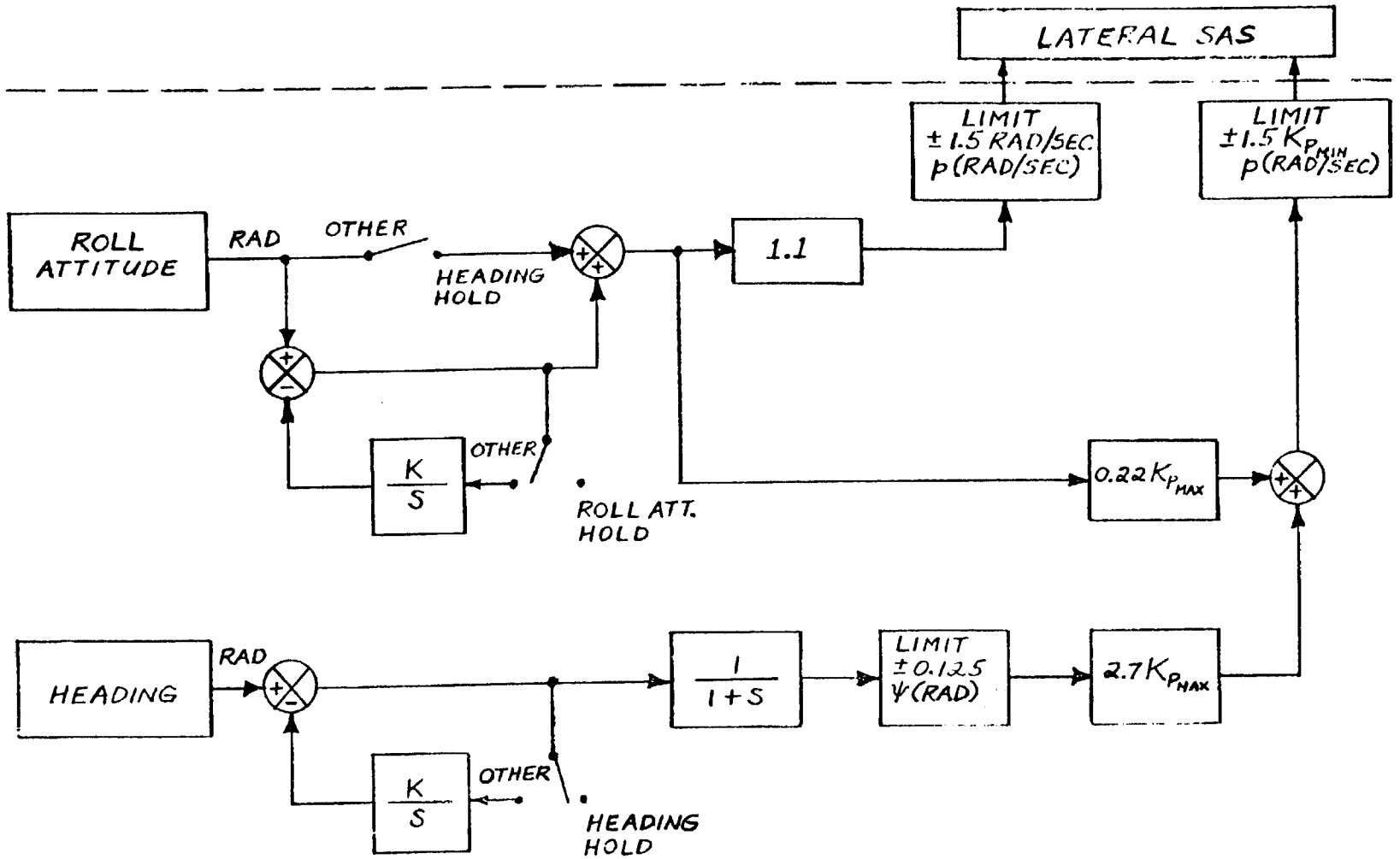
$\ell_x = 12$ FT

$\frac{Z_{\delta_E}}{Z_\alpha} = 0.2$

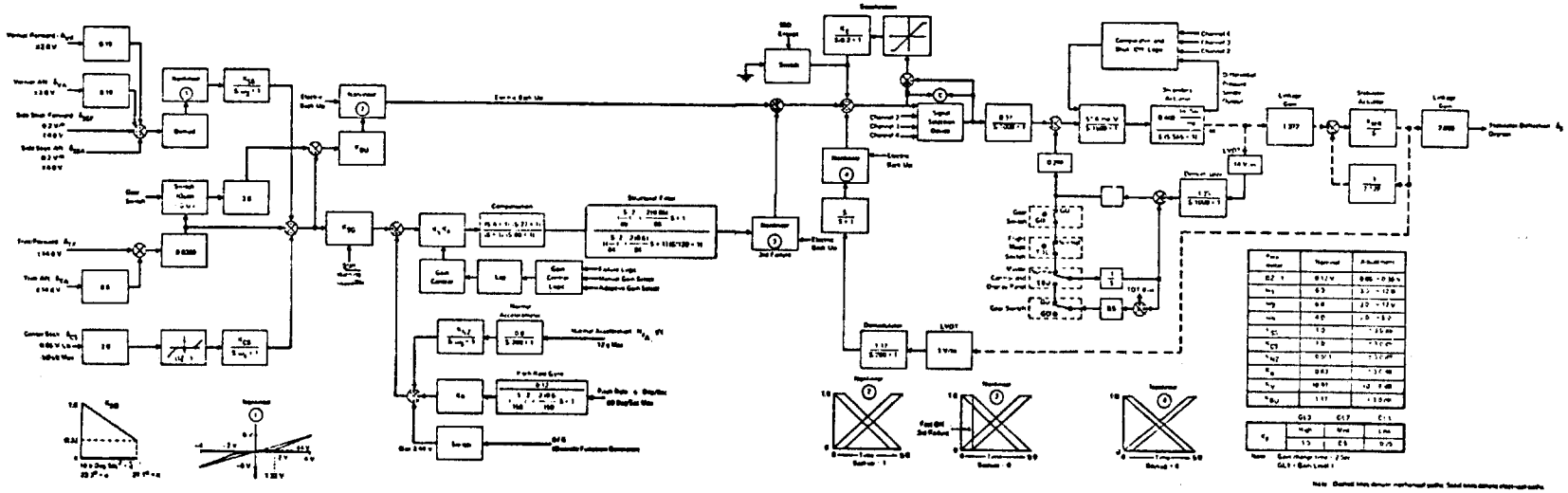
Adaptable FCS Flight Condition Identifier (F-4)



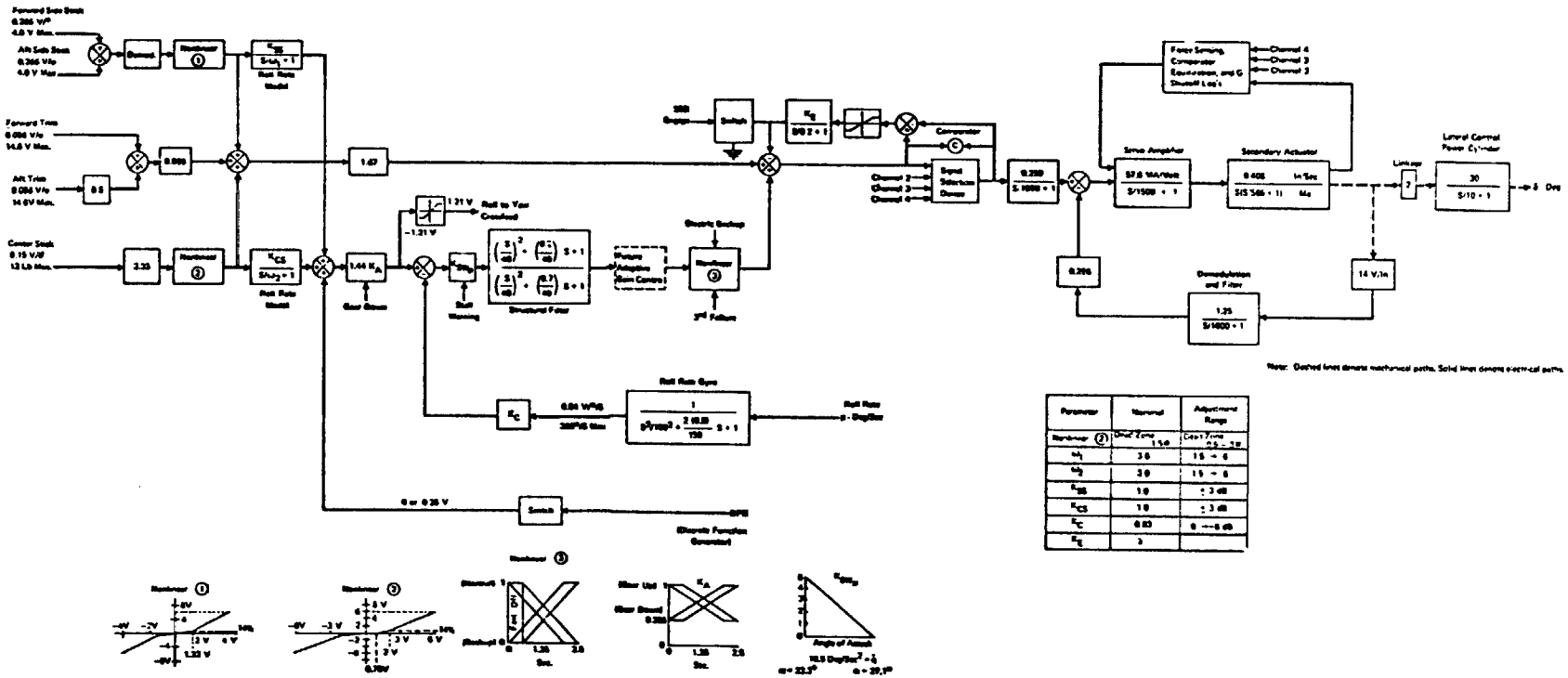
Adaptable FCS Pitch Autopilot Functions (F-4)



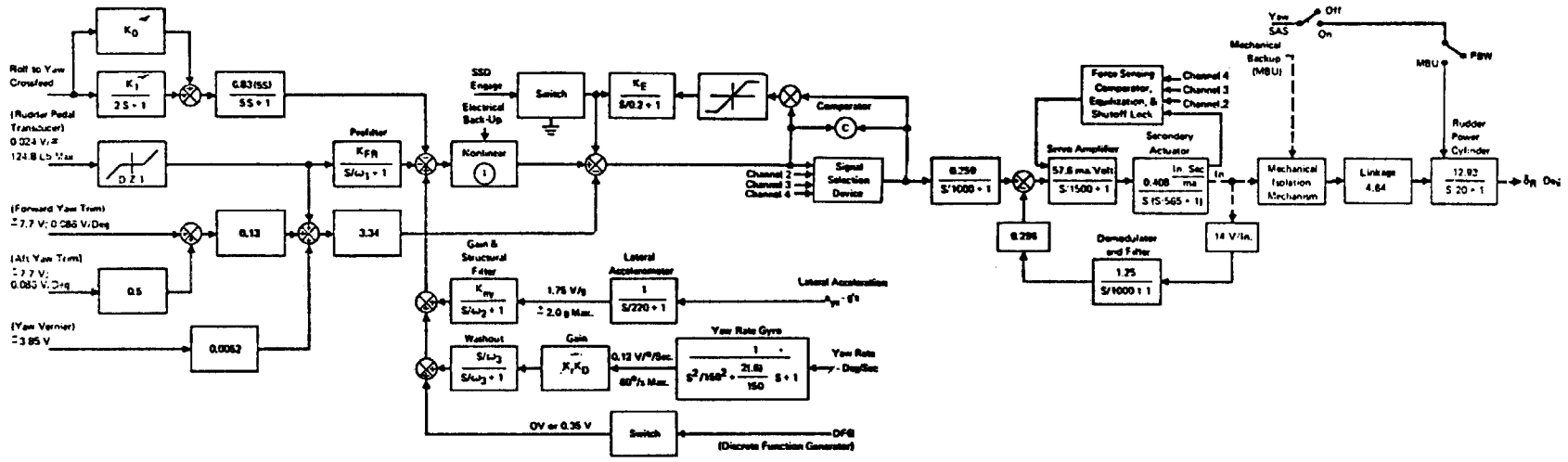
Adaptable FCS Lateral/Directional Autopilot Functions

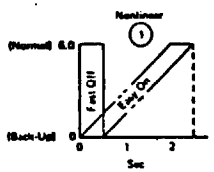


F-4 SFCS Pitch Axis



F-4 SFCS Lateral Axis



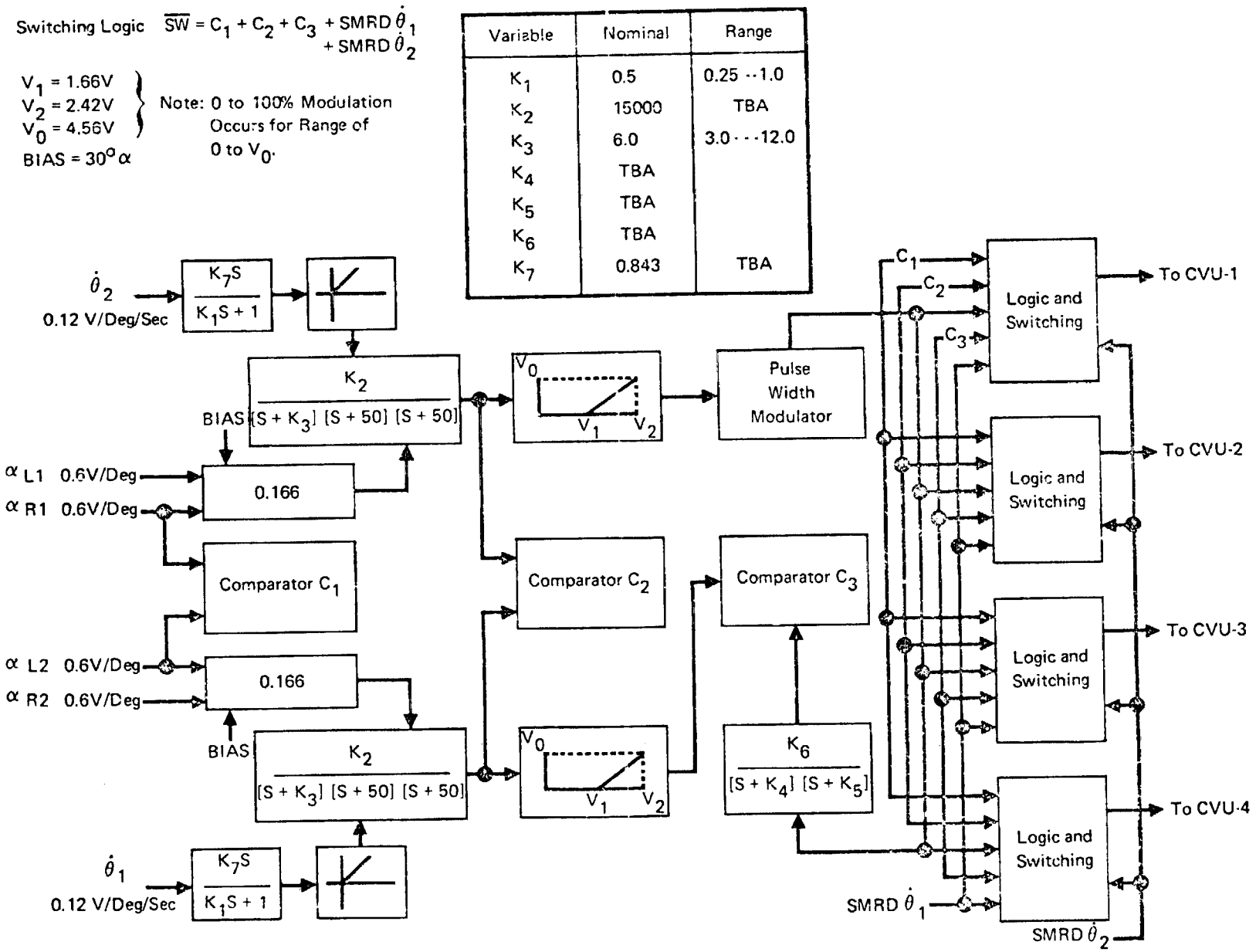


Level / Gain	Gear Up: Adaptive $M_\delta < 6$	Gear Up: Adaptive $6 < M_\delta < 10$	Gear Up: Adaptive $10 < M_\delta < 30$	Gear Up: Adaptive $M_\delta > 30$	Gear Up: Manual Switch Position High	Gear Up: Manual Switch Position Med	Gear Up: Manual Switch Position Low	Gear Down
K_0	0.325	0.15	0.0	0.0	0.325	0.0	0.0	0.35
K_1	0.0	0.05	0.2	0.0	0.0	0.2	0.0	0.2
K_2	0.83	1.67	1.67	3.33	0.83	1.67	3.33	0.83

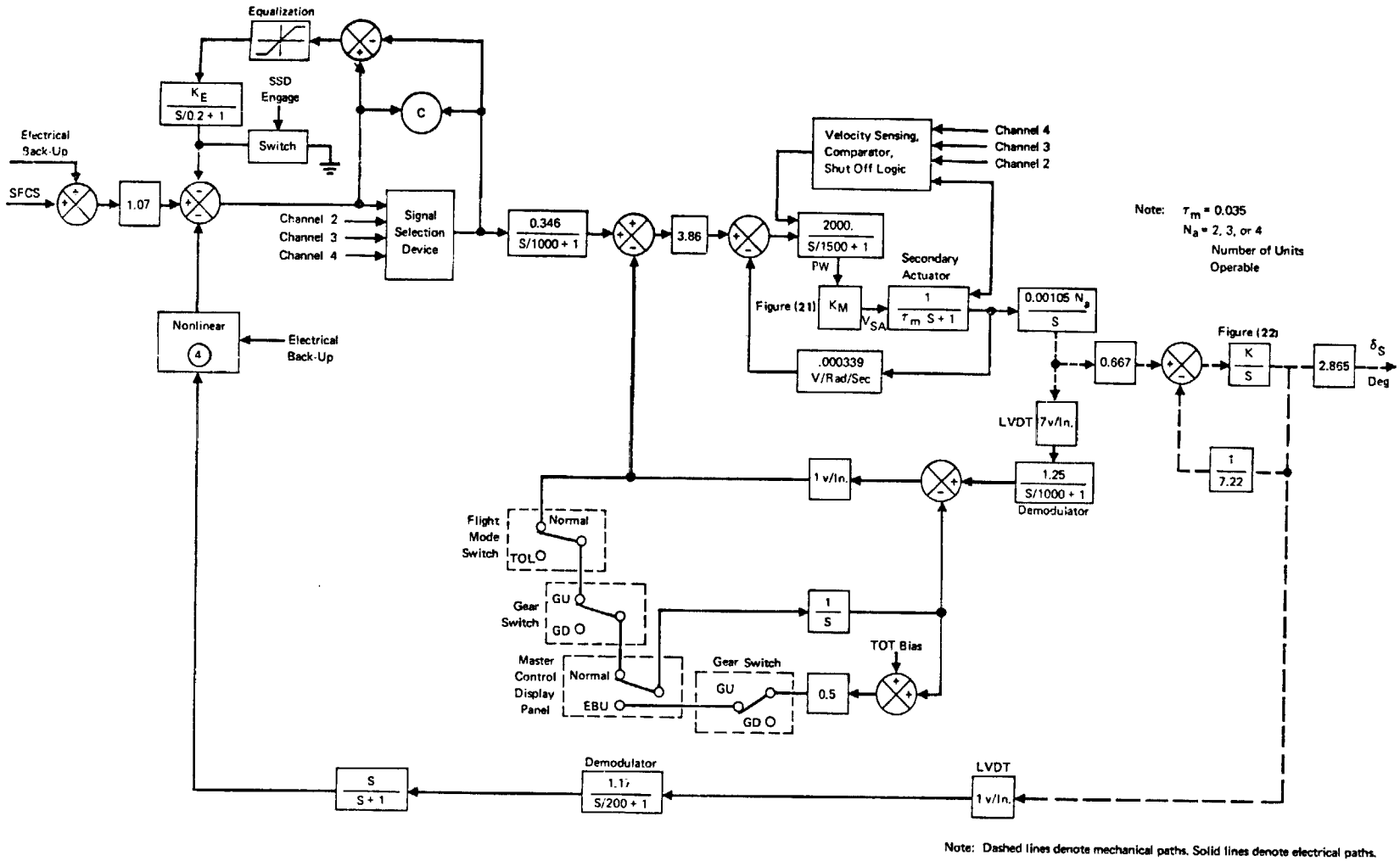
Note: Gain Change Time = 2 Sec.

Parameter	Nominal	Adjust Range
K_{FR}	0.278	
ω_1	3.0	1.5 – 6.0
ω_2	40.0	
ω_3	0.5	0.25 – 1.0
K_{ny}	0.815	±3.0 dB
K_0	0.42	±3.0 dB
K_E	20.0	
DZ-1	5.0 ±	2.4 – 5.5 #

F-4 SFCS Directional Axis

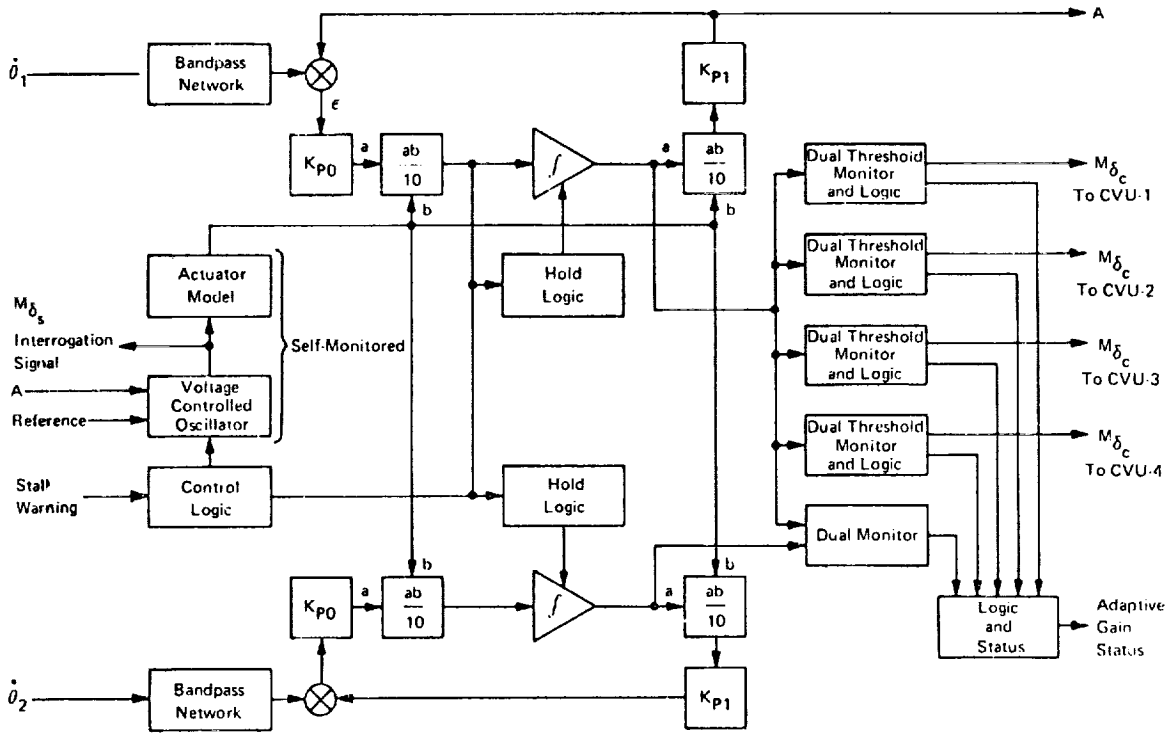


F-4 SFCS Stall Warning

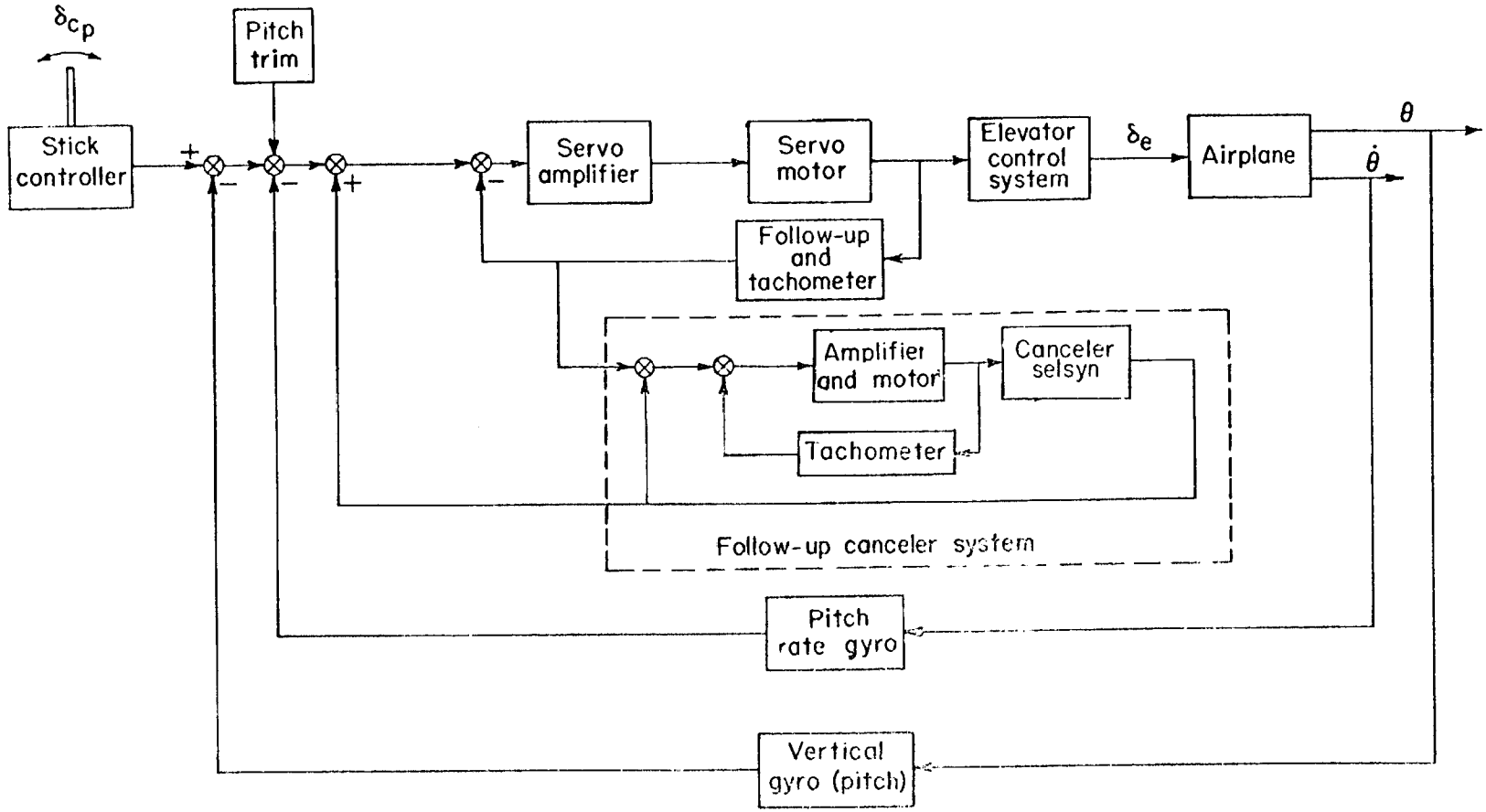


Note: Dashed lines denote mechanical paths. Solid lines denote electrical paths.

F-4 Survivable Stabilator Actuator Package

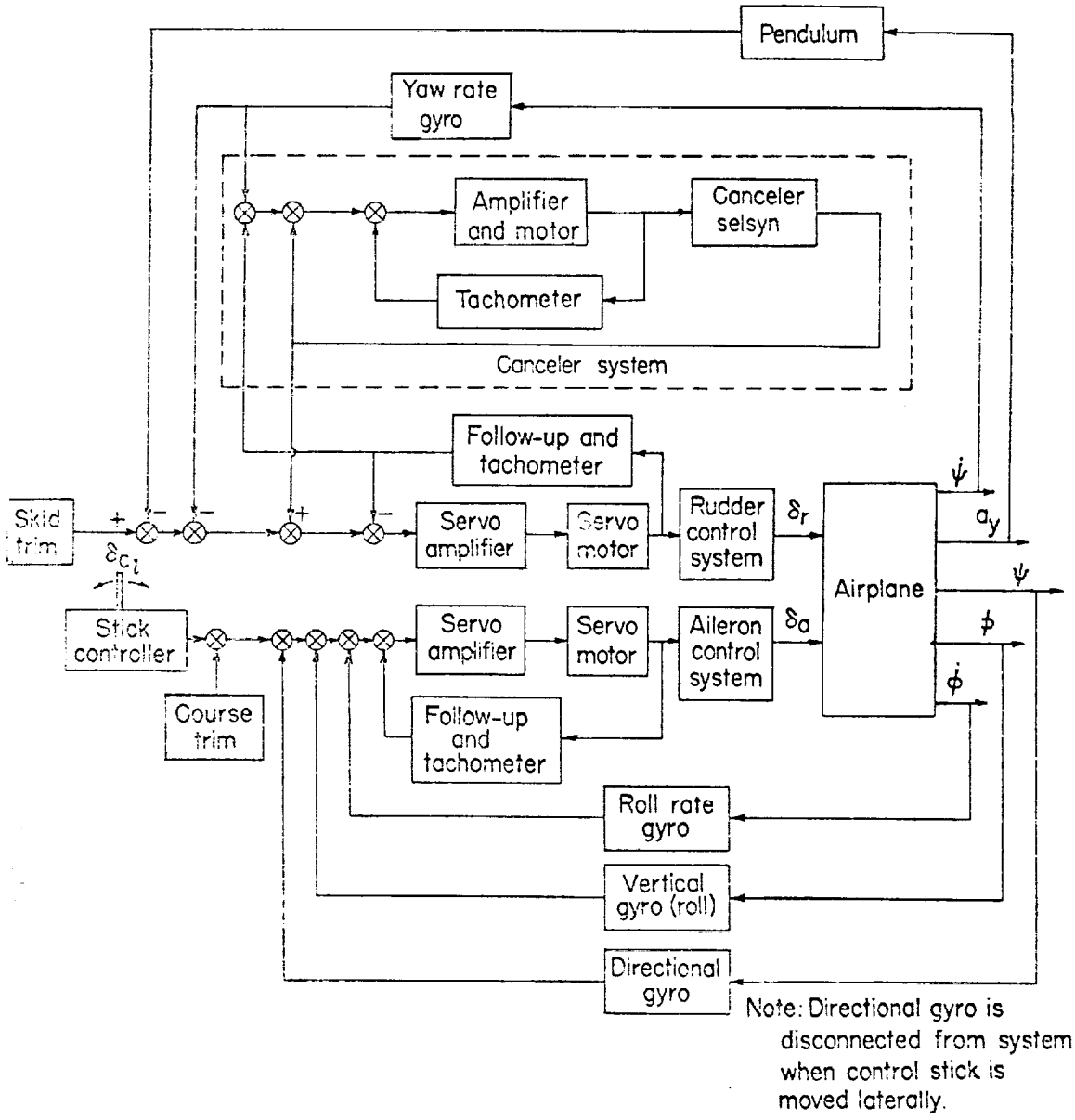


F-4 SFCS Adaptive Gain Changer



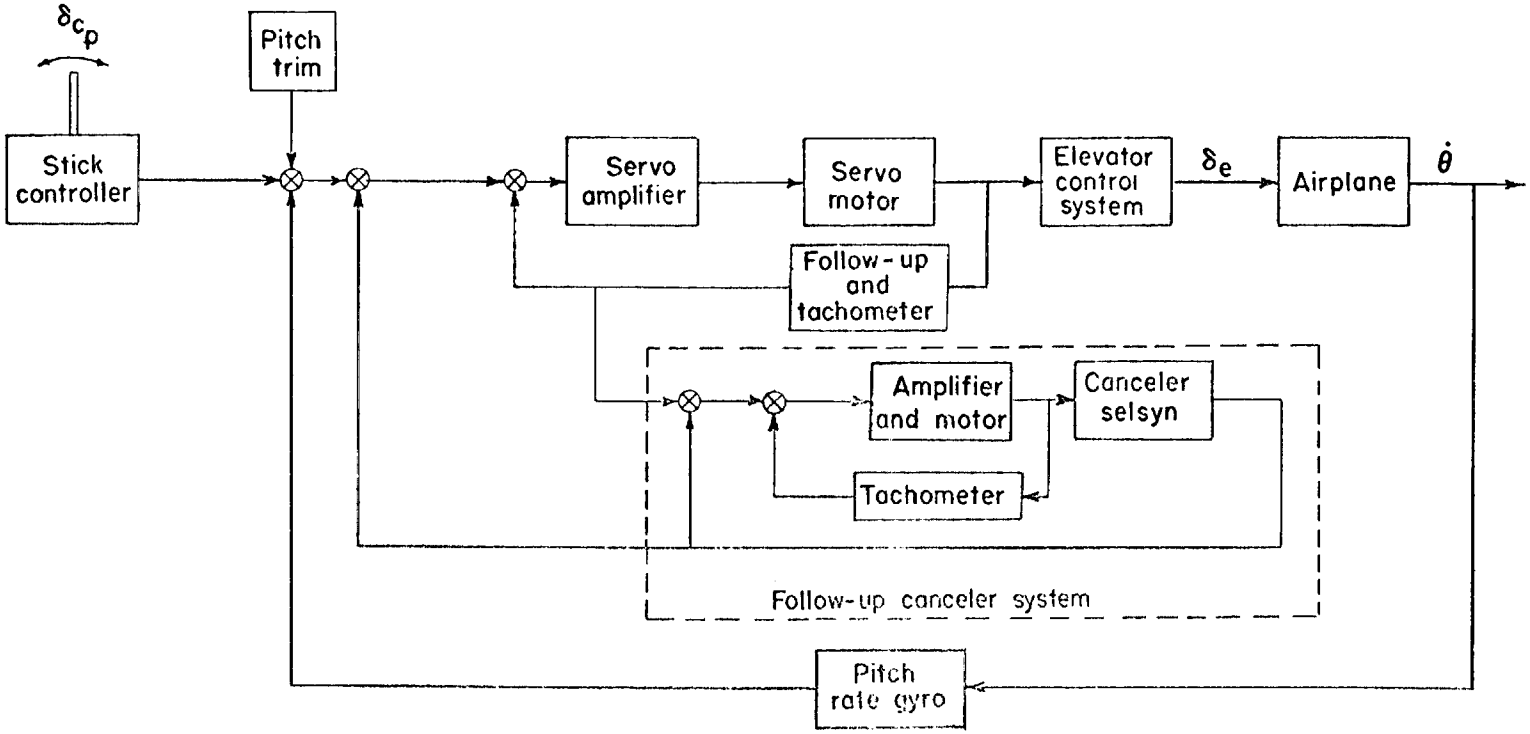
(a) Pitch channel.

Grumman F9F-2 Attitude Command FBW



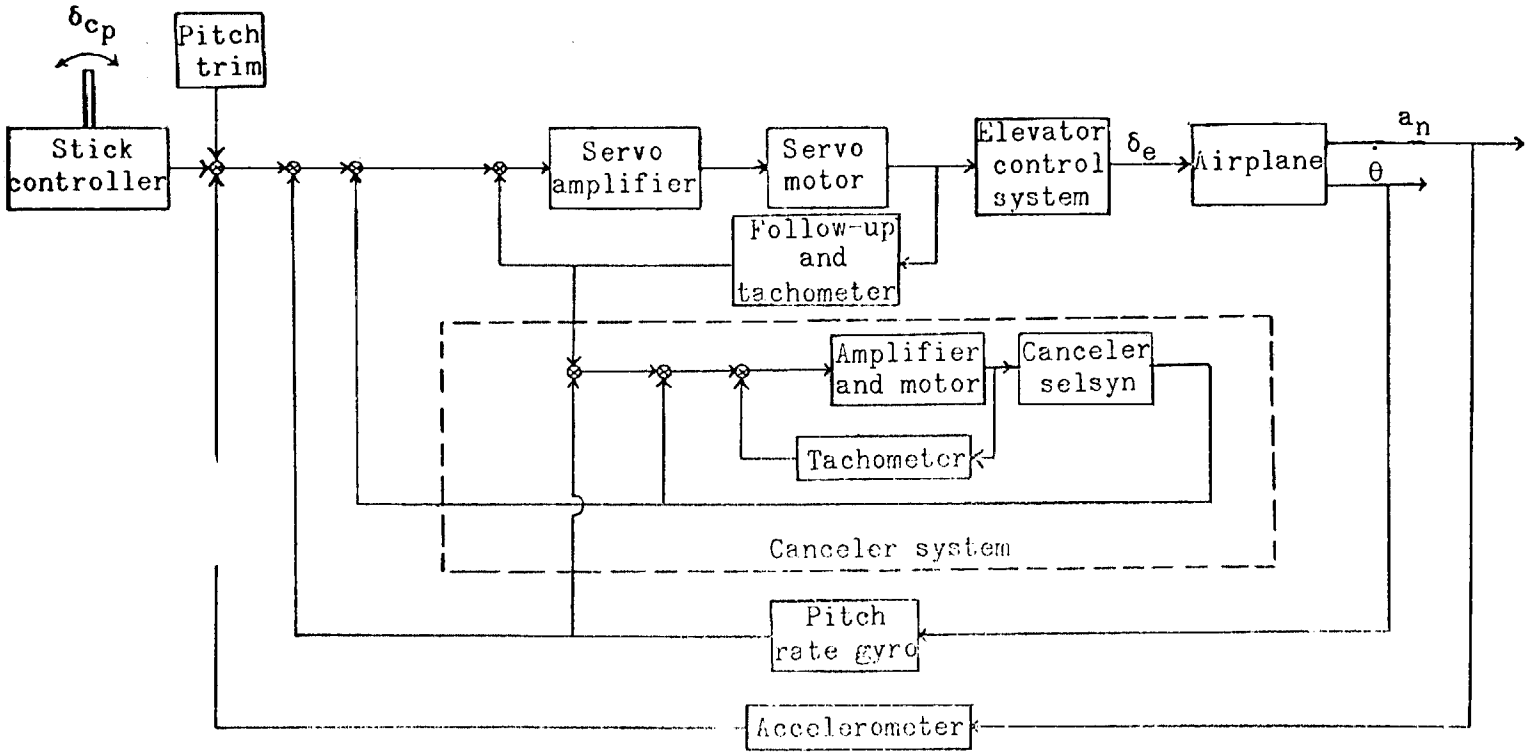
(b) Roll and yaw channels.

Grumman F9F-2 Attitude Command BFW

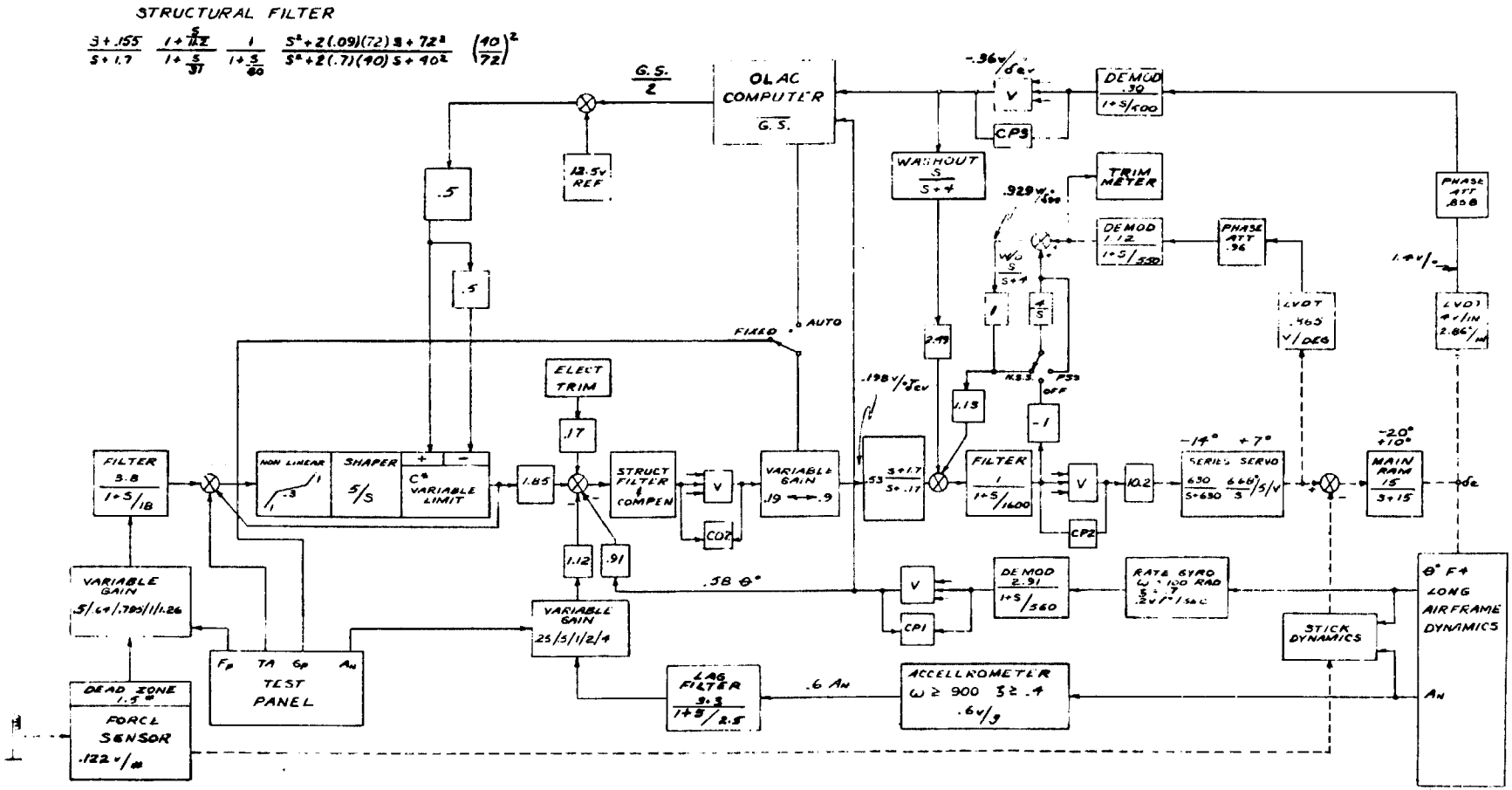


(a) Pitch channel.

Grumman F9F-2 Rate Command FBW



Grumman F9F-2 Normal-Acceleration Control System

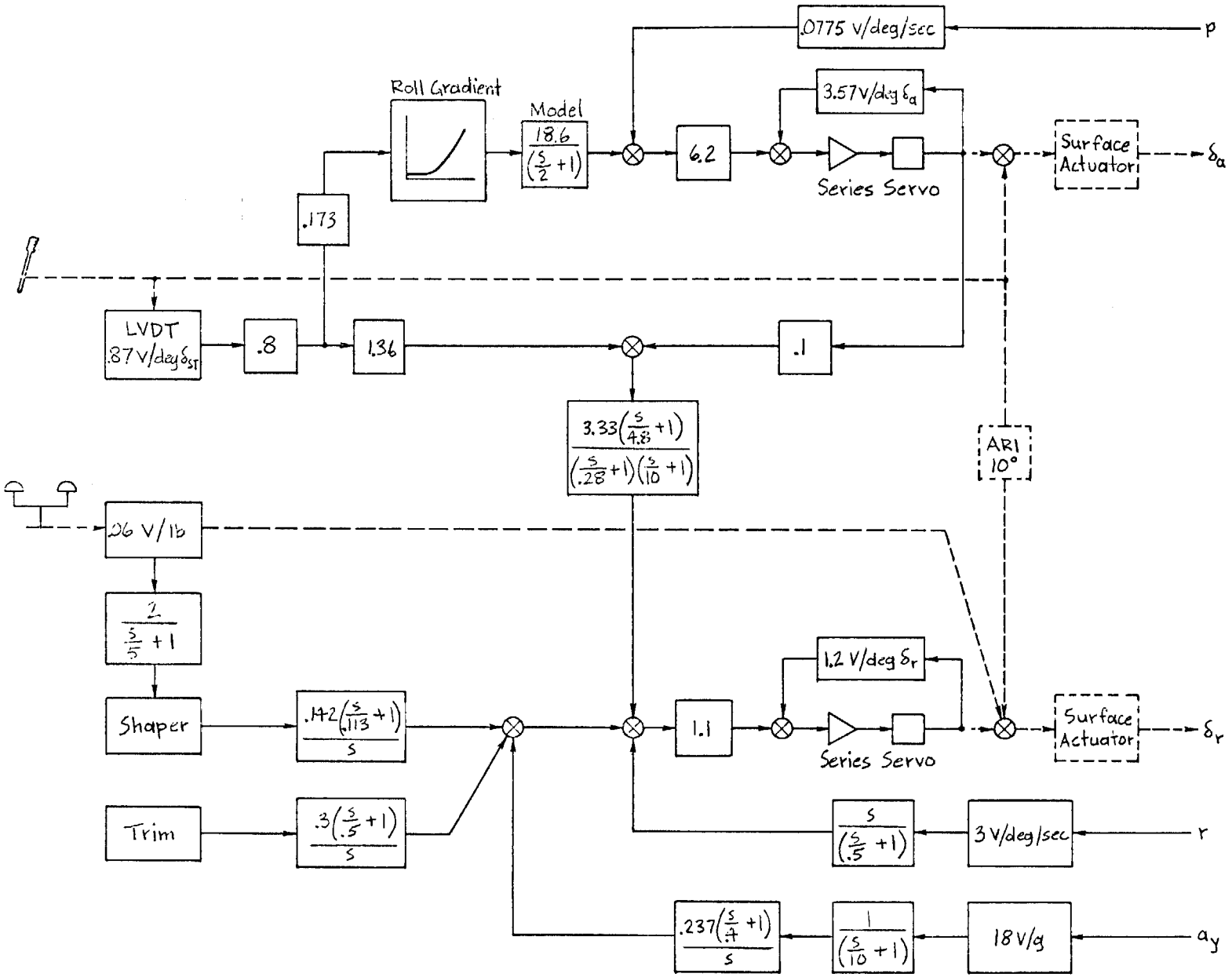


SYSTEM BLOCK OF PITCH C.A.S.

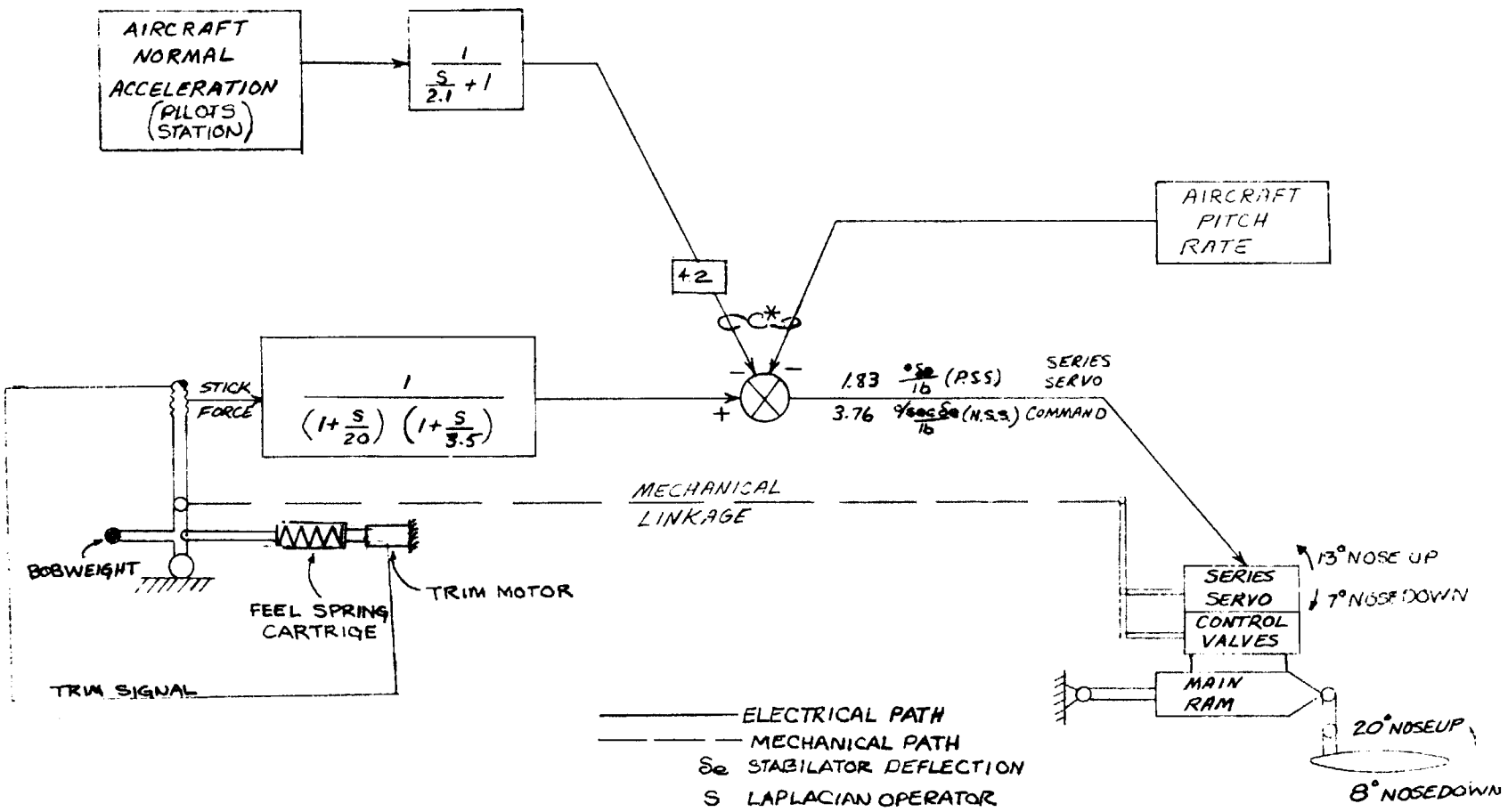
ONE CHANNEL

FLT "39 ⟶

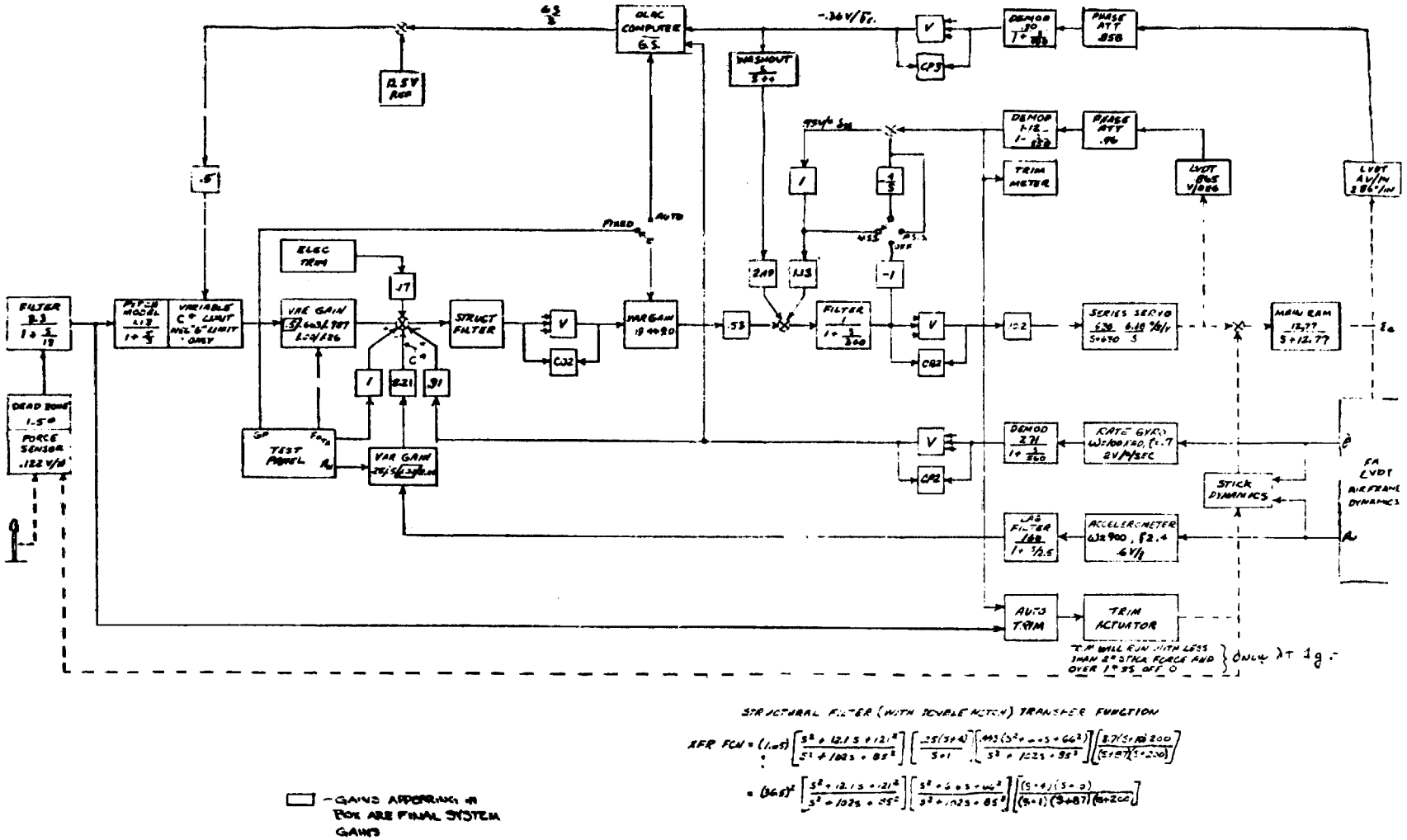
TWEAD I Pitch Axis



TWEAD I Lateral-Directional



TWEAD II Longitudinal Functional CAS Block Diagram

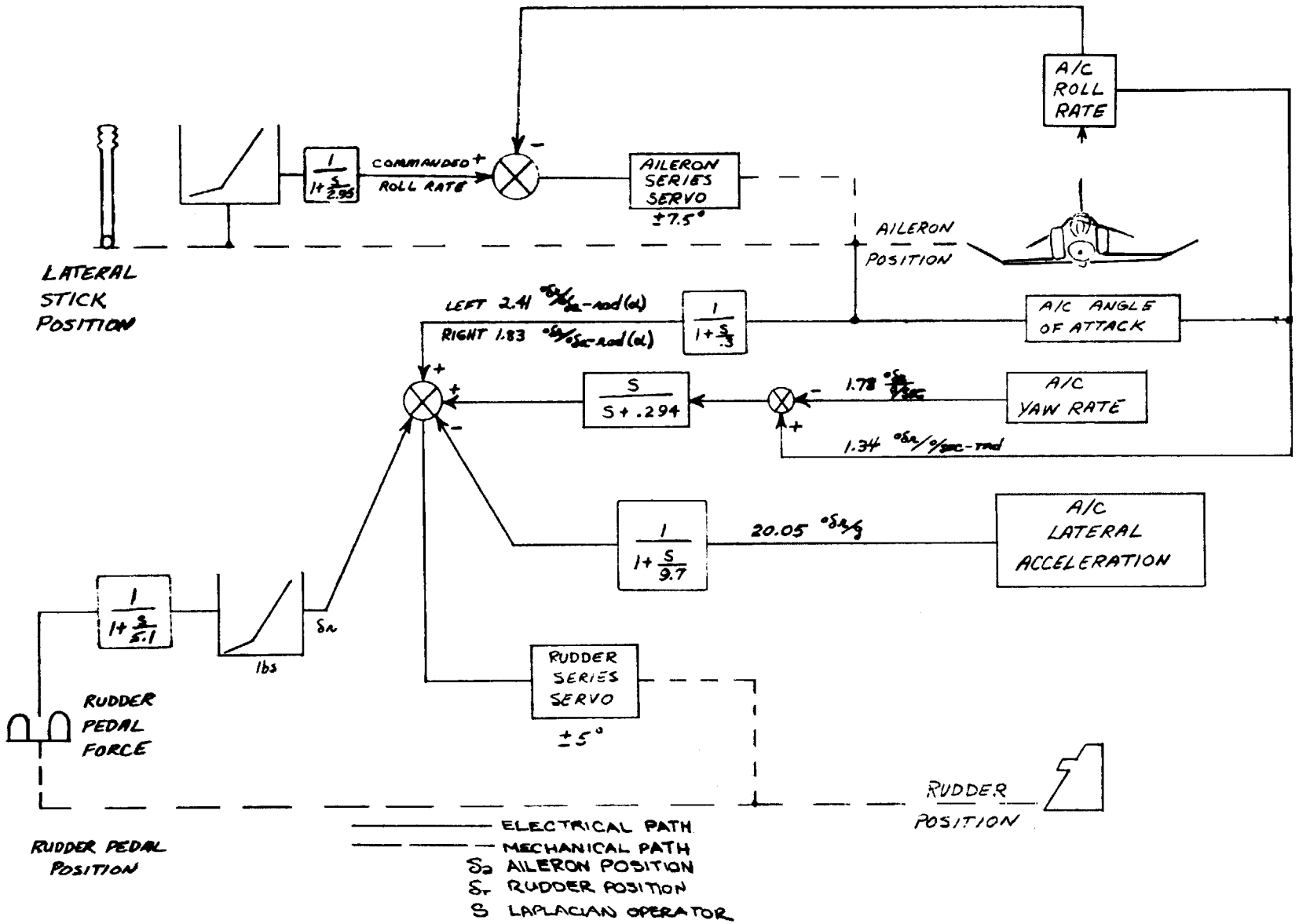


STRUCTURAL FILTER (WITH DOUBLE NOTCH) TRANSFER FUNCTION

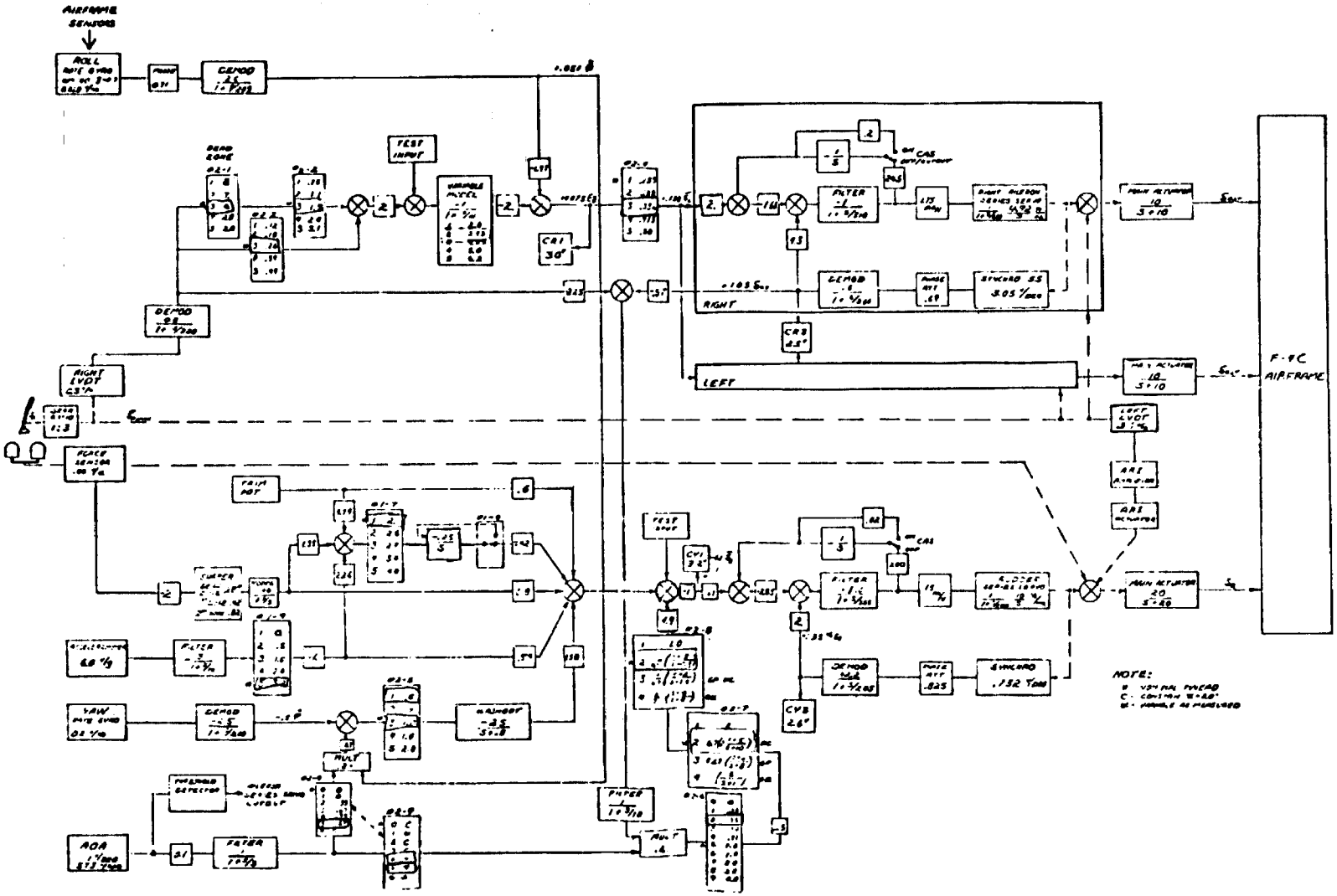
$$\text{XFER FCN} = (1.05)\left[\frac{s^2+12.1s+121^2}{s^2+102s+85^2}\right]\left[\frac{.25(3+4)}{s+1}\right]\left[\frac{.445(s^2+.4s+66^2)}{s^2+102s+85^2}\right]\left[\frac{8.7(s+100)^2}{(s+87)(s+200)}\right]$$

$$= (66)^2\left[\frac{s^2+12.1s+121^2}{s^2+102s+85^2}\right]\left[\frac{s^2+6s+66^2}{s^2+102s+85^2}\right]\left[\frac{(s+4)(s+9)}{(s+1)(s+87)(s+200)}\right]$$

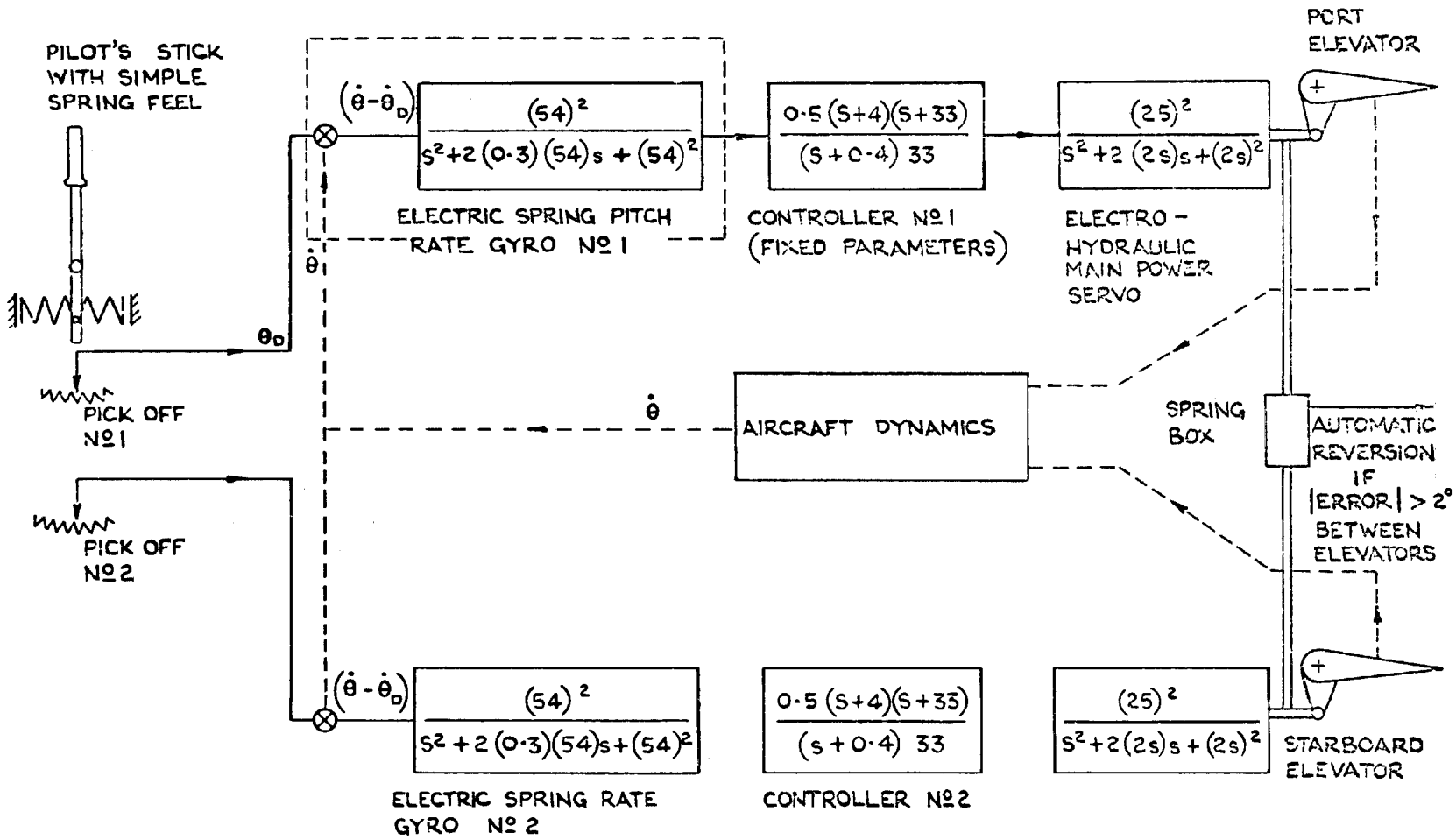
F-4C TWEAD II CAS Longitudinal Block Diagram



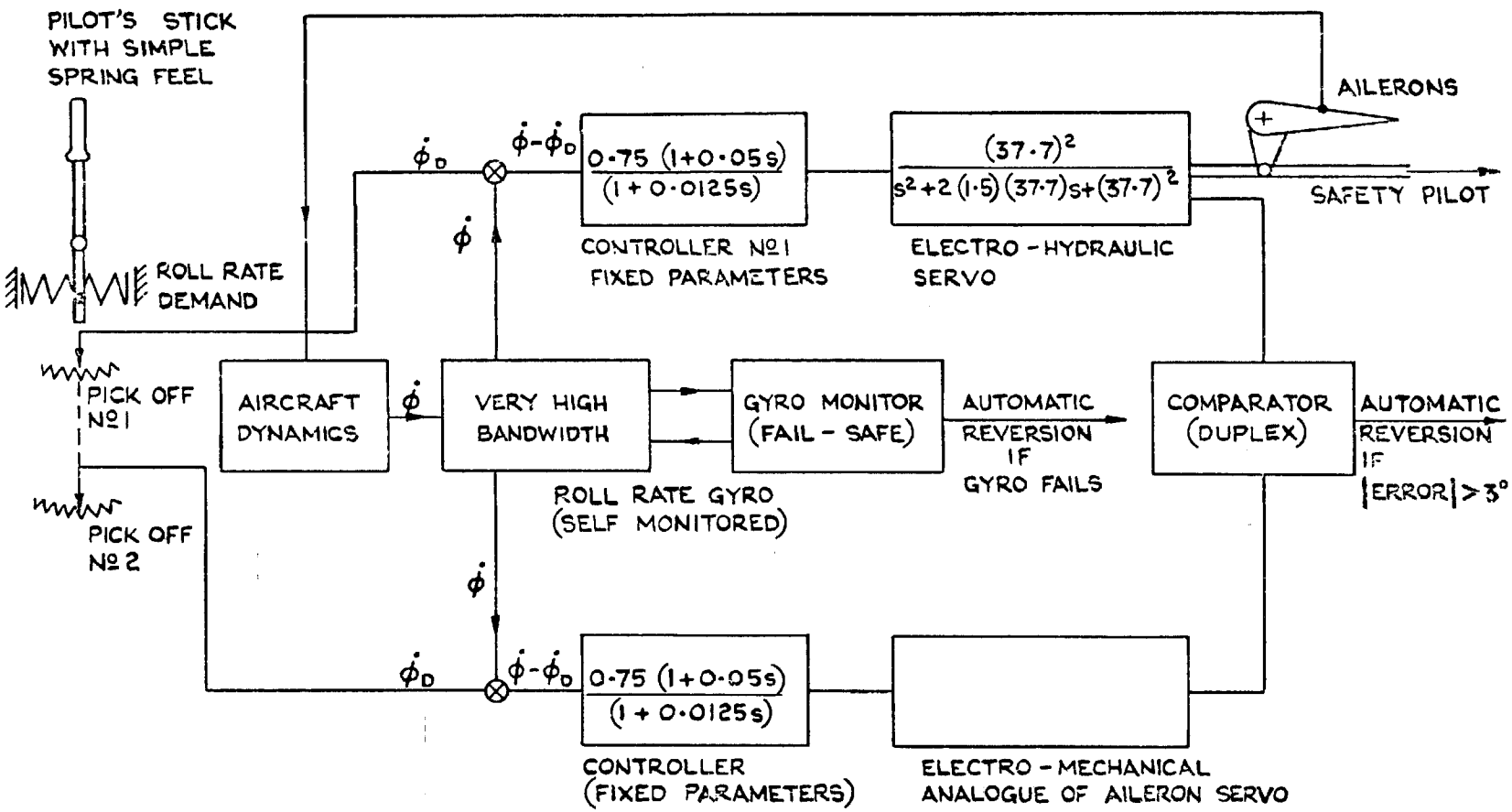
TWEAD II Lateral-Directional Functional CAS Block Diagram



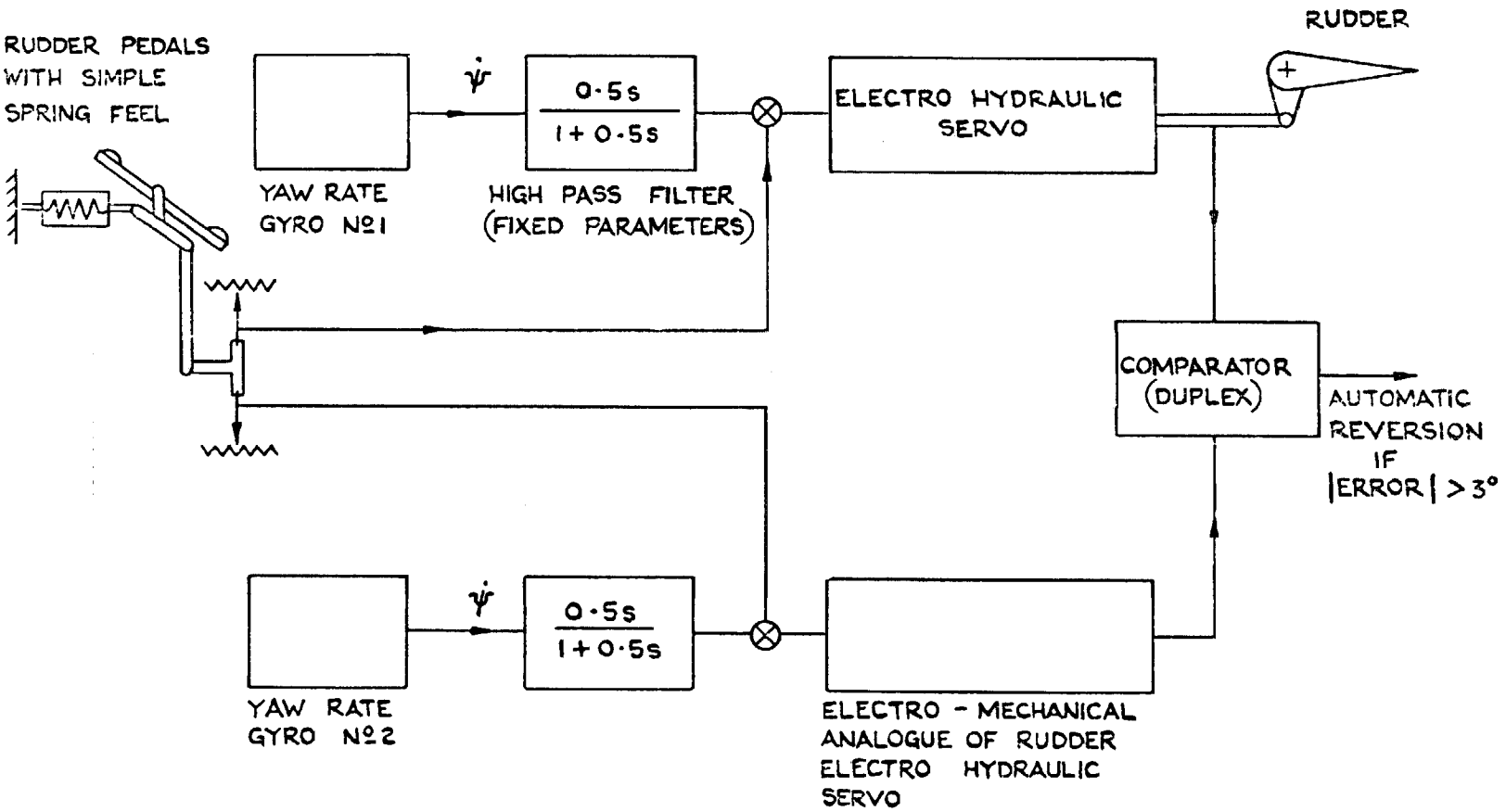
F-4C TWEAD II Lateral Block Diagram



AVRO Pitch Rate Demand Control System (Duplex)

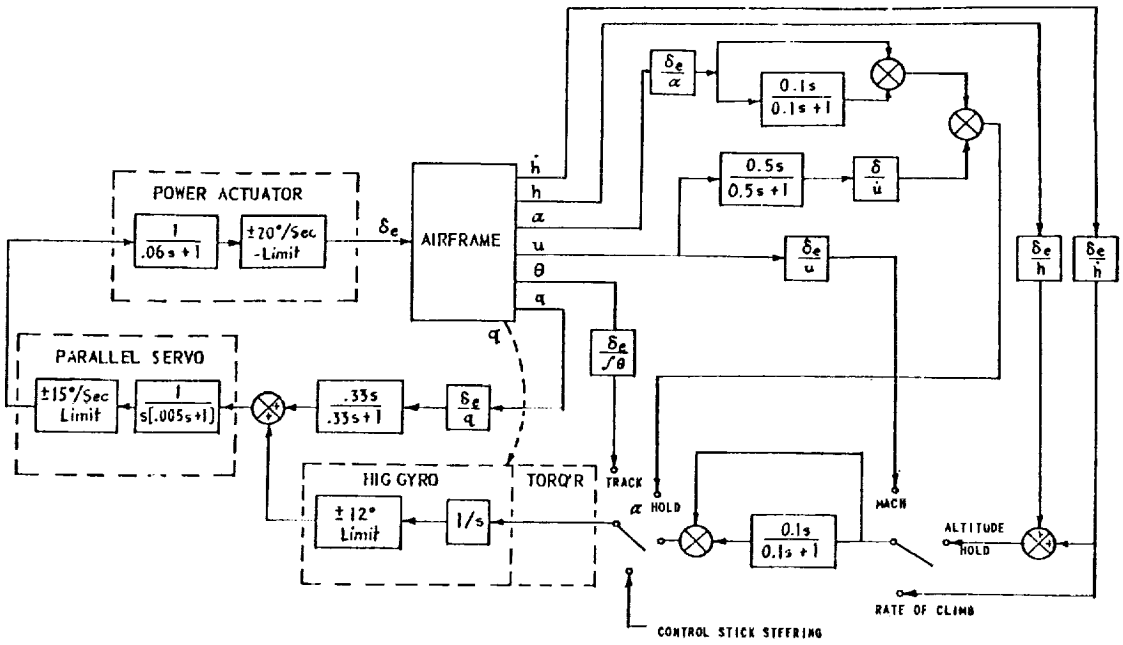


AVRO Roll Rate Demand Control System (Simplex with Comparison Monitor)

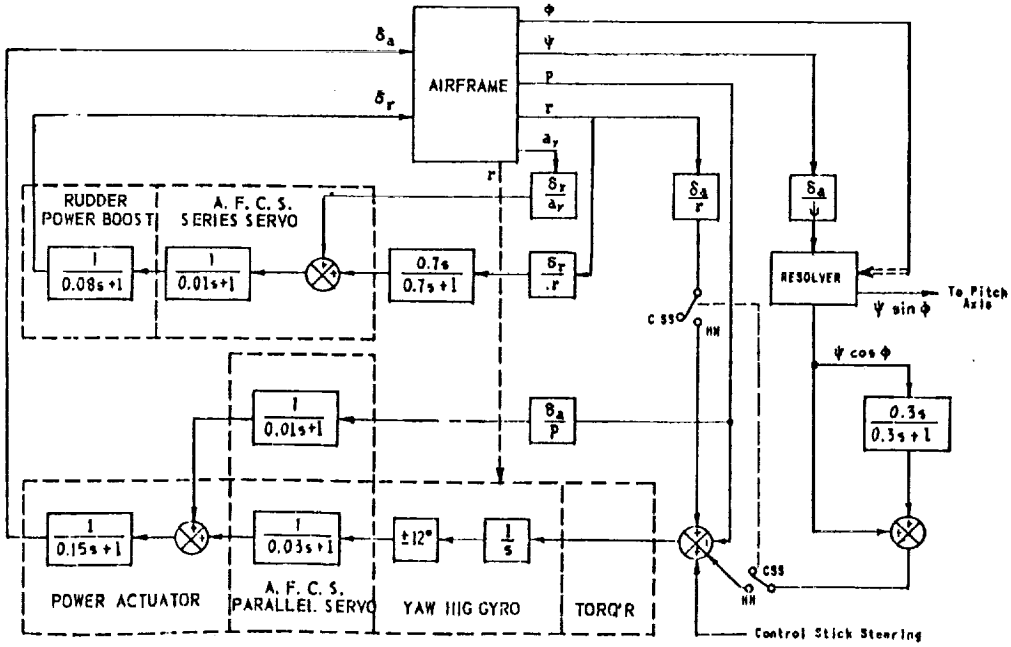


AVRO Rudder Control System Including Yaw Damper
(Simplex with Comparison Monitor)

LONGITUDINAL DIAGRAM



LATERAL DIAGRAM



F-100 Lear Rate Integrating Autopilot

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