NASA Technical Memorandum 88267

AFTI/F-111 MAW Flight Control System and Redundancy Management Description

Richard R. Larson

(NASA-TM-88267) AFTI/F-111 MAW FLIGHT CONTROL SYSTEM AND REDUNDANCY MANAGEMENT DESCRIPTION (NASA) 72 p CSCL 01C

N87-16819

Unclas

G3/05 44001

February 1987

National Aeronautics and
Space Administration

NASA Technical Memorandum 88267

AFTI/F-111 MAW Flight Control System and Redundancy Management Description

Richard R. Larson
Ames Research Center, Dryden Flight Research Facility, Edwards, California

1987

NASA
National Aeronautics and
Space Administration
Ames Research Center
Dryden Flight Research Facility
Edwards, California 93523-5000

TABLE OF CONTENTS

ALPHABETIZED MNEMONIC LIST

MNEMONIC	DESCRIPTION	PG. NO.
A/B	A - left mid & right outboard backup driven flaps B - left out & right mid backup driven flaps	32
AFTI	Advanced Fighter Technology Integration	8
ANFAIR	inboard flap position annunciator discrete (sweep 26 deg)	8
ANIBRK	inboard flap braked annunciator discrete	8
AYC	adverse yaw compensation	2
BU	backup	37
$\overline{\mathrm{BU}}$	not backup	37
BUPWR	backup system power supply fault	33
BUTEST	backup lamp driver	13
C & D	control and display	1
CCC	cruise camber control, auto mode	Fig. 8
CDGT26	wing sweep command greater than 26 deg discrete	9
ΔP	differential pressure across the PDU	3
DETIHB	fail inhibit flag	14
DL/GA	direct lift/gust alleviation, auto mode	Fig. 8
FAIROK	fairing path discrete in sweep logic position	9
FCEU	flight control electronics units	2
FCLIN	left inboard command channel miscompare fault	23
FCLLE	left leading edge command channel miscompare fault	23
FCLOUT	left outboard command channel miscompare fault	23
FCLMID	left midspan command channel miscompare fault	23
FCRIN	right inboard command channel miscompare fault	23
FCRLE	right leading edge command channel miscompare fault	23
FCRMID	right midspan command channel miscompare fault	23
FCROUT	right outboard command channel miscompare fault	23
FCS	flight control system	1
FDPLIN	left inboard delta pressure fault	24
FDPLLE	left leading edge delta pressure fault	24

FDPLMI	left midspan delta pressure fault	24
FDPLOU	left outboard delta pressure fault	24
FDPRIN	right inboard delta pressure fault	24
FDPRLE	right leading edge delta pressure fault	24
FDPRMI	right midspan delta pressure fault	24
FDPROU	right outboard delta pressure fault	24
FIDENT	identity discrete fault	29
FINBRAK	inboard brake command fault from wing sweep lock	24
FLEDIF	Δ LE 73 deg fault	26
FPLIN	left inboard model fault primary	25
FPLLE	left leading edge model fault primary	25
FPLMID	left midspan model fault primary	25
FPLOUT	left outboard model fault primary	25
FPRIN	right inboard model fault primary	25
FPRLE	right leading edge model fault primary	25
FPRMID	right midspan model fault primary	25
FPROUT	right outboard model fault primary	25
FRSTIK	primary system roll stick miscompare fault	24
GND ROLL	ground roll flap position annunciator discrete	10
GO/NO-GO	MAW preflight test initiate switch/light	12
IC	initial condition	Fig. 6
IDENT	identity discrete to differentiate channel 1 from channel 2	3
INB	inboard	(Figs. only)
INBD BRAKE	manual inboard flap brake switch	20
INBD FAIR	command discrete for inboard flap fairing	9
INBD STATUS	inboard flap failure monitor light	20
INBKSW	inboard brake input discrete	16,17
INBRK	inboard flap brake command discrete	7
INLIVE	inboard aliveness fault	31
INMODL	inboard model faults	32
INPOSL	inboard position fault	33
INTMID	integrator output, midspan	5
INTOUT	integrator output, outboard	5
INVMON	inboard valve monitor fault	30
KRSTICK	roll stick gearing gain	4
LE, TE	leading edge, trailing edge	3
LEBRAK	leading edge brake discrete	13
LIM	limiter	Fig. 6
LINB	left inboard position	Fig. 14
LVDT	linear variable differential transducer	& Fig. 2 & 3
LWD	left wing down	Fig. 6
MAN	manual	Fig. 8
MAW	Mission Adaptive Wing	1

MAW CAUTION	MAW warning annunciator	12
MCC	maneuver camber control, auto mode	Fig. 8
MCP	manual command program	4
MID	midspan	3
MIDMRF	mid model fault, raw	32
MLC	maneuver load control, auto mode	Fig. 8
NOGO	MAW preflight test fail annunciator	14
OMLIVE	out/mid aliveness fault	31
OMMODL	out/mid model faults	32
OMPOSL	out/mid position fault	33
OMVMON	out/mid valve monitor fault	30
ONGEAR	weight on wheels	12
OUT	outboard	3
OUTMRF	out model fault, raw	32
P	primary hydraulics	3
PDU	power drive unit	3
PHYDOF	primary hydraulics fault	34
pri hydr press	primary hydraulic pressure	34
PRGMR	programmer	7
PRIPWR	primary system power supply fault	33
PTBRAK	software signal preflight test LE brake command	13
PTFAIL	software signal preflight test primary fail discrete	13
PTISTP	preflight test index step counter	12
PTSTEP	final preflight test step counter	14
Q	impact pressure, lb/ft^2	4
QCAVE	average QC signal	11
QCFAIL	QC probe miscompare fault	31
RGAIN	roll gain	Fig. 6
RINB	right inboard position	Fig. 14
ROLCOM	roll command, deg	4
RWD	right wing down	Fig. 6
S	stabilon	6
STKMON	backup system roll stick miscompare fault	31
SWGT26	wing sweep position greater than 26 deg discrete	9
SWP ENABLE	26 deg wing sweep lockout release command discrete	8
TACT	Transonic Aircraft Technology	1
T.O.	take off	2
TED	trailing edge down	25
U	utility hydraulics	3
UHYDOF	utility hydraulics fault	34
utl hydr press	utility hydraulics pressure	34

WDOGTO	watchdog timer fault	34
3XFLEL	Δ LE 3 deg fault from other processor	26

1.0 INTRODUCTION

A joint Advanced Fighter Technology Integration (AFTI) program was created with the National Aeronautics and Space Administration (NASA) and the United States Air Force to demonstrate a mission adaptive wing (MAW) concept. Flexible leading and trailing edge flaps and a flight control system for the MAW surfaces were incorporated in the NASA F-111 research aircraft.

The manual wing-camber control system provides position and rate commands for two leading edge and six trailing edge wing surfaces. Each of these surfaces is controlled by dual hydraulic servos. These servos receive commands from a dual digital control system when under primary control, or from a dual analog control system when under backup control.

The pilot's interface to the MAW surfaces is provided from the stick, flap selector switch, and MAW control panel. The stick provides roll control to the midspan and outboard MAW flaps, and to the differential stabilon surfaces. The flap selector switch commands three symmetric flap positions. Finally, the MAW control and display (C&D) panel allows for symmetric flap slewing throughout the flap deflection range.

The system design is limited fail-operational, whereby for most primary system failures the FCS downmodes to the backup system, which lacks some of the functions of the primary system. Failures within the backup system will cause a MAW flap pair(s) to be braked. This is because of the partitioning of the surfaces in the backup system.

This document describes the MAW manual flight control system including the modifications that were made to the basic TACT flight control system. In addition, the redundancy management of the MAW primary and backup FCS is described.

2.0 MODIFIED TACT/F-111 FLIGHT CONTROL SYSTEM

The primary function of the MAW FCS is to drive only the wing surfaces, while the F-111 system drives the rudder and stabilon, though there is some interfacing between the two systems (ref. 1). Briefly, the functions are as follows:

2.1 Pitch Channel

The TACT flight control system switch should generally remain in the NORMAL position. The function of this switch is replaced by the added MAW flap switch, which causes the following TACT functions to occur:

TACT Functions	MAW Flap Switch	
	HALF or FULL	RETRACT
pitch channel gain	fixed at 30 %	adaptive
pitch acceleration feedback	off	on
auxiliary pitch trim	enabled	disabled
series pitch trim actuator	locked	unlocked

If the TACT flight control system switch is put in TAKEOFF or LAND, the effect on the F-111 FCS would be the same as placing the flap switch in the HALF or FULL position even if it were to remain in RETRACT.

2.2 Roll Channel

When the flap switch is put in either the HALF or FULL position, or the TACT flight control system switch is placed in T.O. or LAND, the roll adaptive gain will be fixed at 100 percent. This is the same logic that applied for the pitch channel concerning the TACT flight control system switch.

2.3 Yaw Channel

The flap switch which was used to reconfigure the TACT FCS for the pitch and roll modes is also used in the yaw axis. The following logic occurs:

TACT Functions	MAW Flap Switch	
	HALF or FULL	RETRACT
rudder authority	$\pm 30^\circ$	$\pm 11.25^\circ$
adverse yaw compensation	on	off

A roll rate feedback switch has been added to the left side panel to disable the roll rate component portion of the adverse yaw compensation (AYC) logic. Normally, this switch is off.

3.0 MAW SYSTEM ARCHITECTURE

The MAW flaps are controlled by dual flight control electronics units (FCEU). Each FCEU is wired identically, therefore channel 1 is distinguished from channel 2 by grounding a discrete (IDENT) in the connector attached to the FCEU which is in position "one."

The basic MAW flap actuation system consists of a hydraulic motor, gear reduction box, electric brake, rotary actuator, control module, and torque tube. The motor, gear box, servo control valve, and brake are housed in a single module called a power drive unit (PDU), as shown in figure 1. The thin airfoil section of the TACT wing necessitated the use of this compact arrangement. There are 2 PDU's per surface, which make a total of 16 (12 trailing edge and 4 leading edge). The servo control valve and electrical position feedback complete the loop in the servo system. Either PDU can drive any flap with reduced hinge moment capability.

The MAW system architecture for the primary FCS is shown in figure 2. The numbers at each end of the flaps represent a PDU number while the P and U indicate a primary or utility hydraulic system. Each PDU is dedicated to a particular hydraulic system (primary or utility). Note that each flap is driven by both processors. Both primary computers receive a dedicated differential pressure (ΔP) and flap position LVDT.

The backup FCS architecture is shown in figure 3. The backup FCS has no control of the leading edge flaps. Also, the trailing edge flaps are partitioned differently. Backup system A drives both PDU's of the left midspan, right outboard, and the inner PDU's of the inboard flaps. Backup system B drives both PDU's of the left outboard, right midspan, and the outer PDU's of the inboard flaps. The backup system has its own dedicated LVDT's. Note that the roll flaps have only one backup LVDT per surface.

The roll stick partitioning is shown in figure 4. There are six MAW roll stick transducers (two for primary and four for backup). Each backup system receives two stick inputs.

The flap switch redundancy is shown in figure 5. There are four contacts for the FULL and HALF positions. Two of these discretes go to the primary system, while a different set goes to each backup system.

4.0 MAW FLIGHT CONTROL SYSTEM

The MAW FCS is a redundant fly-by-wire control system. It has a dual digital primary system architecture that provides roll and symmetric commands to the MAW control surfaces. A segregated analog backup system is provided in the event of a primary system failure. The MAW FCS was designed to be isolated from the basic F-111 FCS as much as possible so that any problem which developed from the MAW system would not affect the basic systems.

4.1 Manual Flight Control System - Primary

The primary system is designed to manually slew the leading edge and trailing edge flaps symmetrically and to provide roll control that was lost by the removal of the spoilers from the TACT wing. Control of the MAW flap surfaces is accomplished by the use of a flap switch, roll stick, the C&D panel, wing sweep handle, and gun trigger switch. Reference 2 gives details of the primary system specification. Simplified block diagrams of the MAW flight control system follow.

A block diagram of the MAW control system showing the roll and symmetric commands is shown in figure 6. The nose and side QC probes are filtered to reduce the noise and then averaged for use in scheduling the roll stick gearing gain (KRSTICK). A lead-lag filter used in the stick input path quickens the roll response for the takeoff and landing configuration. The roll gain of 1.95 provides 18.5° of roll authority based on 9.5 V of stick command which is at the 2.5 in soft stop detent. If a QC fail occurs, the KRSTICK is fixed depending on the flap switch position. This is discussed in section 4.1.14.3.

The roll command (ROLCOM) is formed by summing the roll stick with the MAW roll trim. The MAW trim has a ±2° limit. Trim commands are faded out either by pressing the trim reset switch or for backup mode reversion.

Symmetric commands are formed by integrating the various ways of commanding symmetric flap motion. The priority is shown left to right at the bottom of the figure. The manual command program (MCP) has the lowest priority, with the inboard flap fairing having the highest.

A block diagram of the servo commands is shown in figure 7. The roll flap servo commands are formed by summing ROLCOM with integrator inputs (INTMID and INTOUT). The trailing edge flap deflection limits are scheduled with QC. Each flap is rate limited. The primary commands track the positions whenever the system is in backup. For a transfer to the primary system the commands are faded from the present flap position to the new, updated primary commands in 2 sec.

The MAW C&D panel is shown in figure 8. The panel is used in conjunction with the roll stick to control the various functions of the MAW flaps. The status and MAW flap positions are also displayed. A description of the manual MAW control functions follows.

4.1.1 PRIMARY/BACKUP switch.

The primary/backup switch is located on the upper left side of the MAW panel. This is a four-pole switch which provides a positive switch to the backup system OR gate. When the switch is in the primary position, the switching logic is armed to return to the primary system.

4.1.2 FLAP switch.

The flap switch located on the front panel of the cockpit is used to command the flaps to three camber configurations: HALF - 15° LE, 10° TE; FULL - 20° LE, 18° TE; and RETRACT - 5° LE, 2° TE. Two discretes are issued when the switch is placed in the FULL position and a second discrete set is generated in the HALF position. A single discrete signal goes to each primary channel. The absence of any signal from the flap switch indicates that the flap switch is in the RETRACT position.

To compensate for lags between the discretes to the primary FCEU's, a 1 sec delay is used before recognizing a change in the flap switch position.

This allows both FCEU's to respond at the same time before issuing a flap command which could otherwise result in a command difference and downmode to backup. The discretes are passed regardless of their values after 1 sec.

4.1.2.1 RETRACT:

1. The flaps move to LE/TE of 5/2° at a rate of 2 deg/sec.
2. The position accuracy is ± 0.5°.
3. No flap annunciator lights illuminate for the RETRACT position.

4.1.2.2 HALF:

1. The flaps move to LE/TE of 15/10° at a rate of 2 deg/sec.
2. The position accuracy is ± 0.5°.
3. The HALF flap annunciator illuminates when the inboard and LE position LVDT's indicate that the surfaces are within 1° of the symmetric command.
4. The roll stick command goes through a lead-lag filter, (S + 3)/(S + 8).

4.1.2.3 FULL:

1. The flaps move to LE/TE of 20/18° at a rate of 2 deg/sec.
2. The position accuracy is ± 0.5°.
3. The FULL flap annunciator illuminates when the inboard and LE position LVDT's indicate that the surfaces are within 1° of the symmetric command.
4. The roll stick command goes through a lead-lag filter, (S + 3)/(S + 8).

<u>4.1.3 Slew switches.</u>

There are five sets of three-position, spring-loaded symmetric command slew switches. The following pairs of surfaces can be slewed: LE, INBD, MID, OUT, and ALL. The flaps can be slewed to the full deflection limit allowed by the QC limiter.

<u>4.1.4 Rate select.</u>

The slew rate switch allows symmetric slewing at three different rates: FAST = 5 deg/sec, NORM = 1 deg/sec, SLOW = 0.33 deg/sec. This slew rate switch affects only the slew switches and the manual command program (MCP).

4.1.5 Roll trim.

The roll trim switch is used to command asymmetric trim for the MAW roll surfaces (midspan and outboard) at a slew rate of 0.3 deg/sec. It has a limited authority of ± 2° about the symmetric command.

4.1.6 Trim reset.

The TRIM RESET light illuminates when the absolute value of the roll trim command is greater than or equal to 0.01°. Pressing the TRIM RESET button will cause the roll trim command to fade out in 4 sec. The light goes out when the roll trim command is reduced below 0.01°.

4.1.7 Manual command program.

The manual command program (MCP) function is used in combination with a 12-position selector to automatically slew the leading edge and trailing edge flaps to 11 predefined settings at a rate indicated by the RATE SELECT switch. Position zero is an off position. The flap switch must be in the RETRACT position for the MCP to function. When the MCP button is pressed, the TRANST light will illuminate to indicate that the flaps are in the process of being commanded to an MCP flap position. When all the flaps are within the command accuracy (dictated by the slew rate), the TRANST light goes out and the VALID light illuminates. Command accuracy = slew rate/100.

PRGMR STEP	LE	INBOARD	MIDSPAN	OUTBOARD
0	NA	NA	NA	NA
1	2	2	2	2
2	0	6	6	6
3	0	10	10	10
4	5	6	6	6
5	5	10	10	10

6	5	17.8	18	18
7	10	2	2	2
8	10	10	10	10
9	10	17.8	18	18
10	15	6	6	6
11	15	10	10	10

4.1.8 Wing sweep inboard flap fairing.

The sweep range for the AFTI/F-111 is from 10 to 58°. At approximately 35° of sweep the inboard flaps begin to enter the wing seal on the fuselage. Before this entry, the inboard flaps must be guaranteed to be in the correct "faired" position. The primary wing sweep logic (ref. 3) description follows.

The basic F-111 has a 26° detent on the sweep lever that prevents further aft sweeps unless certain logic is satisfied, as shown in figure 9.

1. Put the wing sweep lever at the 26° detent.

The wing sweep position must be greater than 24.5° to initiate the fairing logic.

2. The flap switch must be in RETRACT.

Flap fairing logic cannot be activated if the flap switch is in the HALF or FULL position. Once the sweep is aft of 26°, the flap switch can be put in HALF or FULL and the inboard brake logic will still remain set.

3. Press the INBD FAIR button on the C&D panel and release in less than 2 sec.

This generates a "fair" command to slew the inboard flaps to 1.8° trailing edge down at a rate of 10 deg/sec. The INBD FAIR switch illuminates while the inboard flaps are being driven to the "faired" position and then goes out. Both inboard flaps are tested for 3 sec to be within a 0.2° tolerance of the 1.8° faired command position. If the flaps are not within 0.2° during the first 3 sec, the tolerance is opened to 0.6°. After all four primary inboard LVDT's show that these flaps are within the tolerance, the following output discretes are generated: ANFAIR, ANIBRK, INBRK, and SWP ENABLE. The discrete (INBRK) is issued to the backup hardware. When both computers send out this discrete, the inboard flaps are braked. The SWP ENABLE discrete releases the sweep lever solenoid to allow sweeps beyond the detent. The FAIRED light indicates that the fairing logic has been requested and that all four primary inboard LVDT's indicate that the flaps are within the specified tolerance.

4. Pull the sweep lever aft and through the detent.

When the sweep position reaches about 26.5° to 27°, a command and sweep position greater than 26° discretes are set (CDGT26 and SWGT26, respectively). These discretes serve to latch the sweep logic in case the INBD FAIR should be pressed. The FAIROK flag stops a failure path in fairing the flaps in case the CDGT26 and SWGT26 discretes were to be set.

5. The inboard brakes can be released by two methods: (1) sweep the wing forward of 24.5°, or (2) sweep the wing back to the 26° detent and press the INBD FAIR button.

CAUTION - There is one known problem with the sweep logic. The lever lockout can be defeated by sweeping the wing forward and stopping just aft of the detent so that CDGT26 and SWGT26 discretes become false without the lever lockout becoming engaged. At this point the lever can be pulled aft again and there will be no fairing command for the inboard flaps. To reestablish the fairing command, the INBD FAIR button must be pressed. This again sets the required FAIROK logic.

The proper procedure for sweeping the wing forward is to bring the lever back into the detent or forward of the detent.

4.1.9 Flap rate limits.

Rate limiters are used to help prevent overspeeding the power drive units (PDU's). The maximum rate of change in the servo commands for each flap pair is shown below. A 3 deg/sec overspeed for the roll flaps is allowed for aiding wind loads.

CONTROL SURFACE	RATE, deg/sec
LEADING EDGE	10
INBOARD	30
MIDSPAN	40
OUTBOARD	40

4.1.10 Surface position accuracy.

The total error from the command source to the actual surface position (as measured by a protractor), which includes all error sources from the analog and digital components, is less than 0.5°.

4.1.11 HOME command.

The gun trigger switch from either stick can be pressed to command the LE and TE flaps to a HOME position of 0° and 2°, respectively. The flap rate is 5 deg/sec. The flaps selector switch must be in RETRACT for this function.

4.1.12 Ground roll brake.

The MAW flaps can be used for ground roll braking for landings. The following conditions must be established for the ground roll braking to occur:

1. Ground roll brake enable switch in the cockpit is set.
2. The flaps are in the FULL position.
3. Weight is detected on the main gear.
4. Both thrust levers are in their idle positions.

A 0.1 sec time delay is provided after the above conditions are satisfied. The table below shows the flap requirements.

	POSITION	RATE
LEADING EDGE	20.0°	10 d/s
TRAILING EDGE	-0.5°	40 d/s

A GND ROLL light will illuminate on the MAW panel to indicate that the LE and TE flaps are within 1° of the symmetric commands. When the ground roll brake is released the LE and TE flaps will return to the flap selector commanded value at a rate of 10 and 20 deg/sec, respectively, for the first second. After the first second the flap rates return to the normal 2 deg/sec rate.

4.1.13 Flap position limits.

There is danger of damage to the flap mechanism if the mechanical stops are contacted three or more times during flap cycles. Therefore, the system has software limits which further reduce the flap limits from the mechanical stops.

		LEADING EDGE	INBOARD	MIDSPAN	OUTBOARD
Mechanical	up	-2.10	-2.60	-2.35	-2.53
stop, deg	dn	21.30	19.00	21.00	20.83
Software	up	-1.07	-1.08	-0.69	-0.71
limit, deg	dn	20.63	17.87	19.74	19.59

4.1.14 QC scheduling.

There are two impact pressure (QC) probes on the airplane that are filtered in hardware 2/(S + 2), and then again in software 20/(S + 20) to suppress the noise. This averaged signal (QCAVE) is used to limit the downward deflection for the MAW TE flaps and to schedule the roll stick gain (fig. 10).

4.1.14.1 QC TE limiter:

For a QCAVE less than 830 lb/ft^2, there is no QC TE limiting. If QCAVE is between 830 and 1360 lb/ft^2 the TE is QC limited linearly from 21° to 4°. For a QCAVE greater than 1360 lb/ft^2 the TE limit is fixed at 4°.

4.1.14.2 Roll stick gain:

If the QCAVE signal is less than 150 lb/ft^2, the gain stays at 100 percent. If the QCAVE is between 150 and 250 lb/ft^2, the gain decreases linearly from 100 percent to 27 percent. For a QCAVE greater than 250 lb/ft^2 the gain remains at 27 percent.

4.1.14.3 QC fail scheduling:

A failure will be declared if the two impact pressure probes differ by more than 100 lb/ft^2. The TE limiter and roll stick gain are set at fixed values depending on the flap switch position (fig. 11). If the flaps are in HALF or FULL, the TE limiter will be at full authority and the roll stick gain at 100 percent. If the flaps are in RETRACT, the TE limiter and roll stick gain will both be set at the minimum values of 4° and 27 percent, respectively.

4.1.15 Preflight test program.

A pilot-activated ground preflight test is provided to test the following functions of the MAW FCS:

1. The delta pressure monitors for the eight flap surfaces
2. The leading edge brake hardware latch
3. The backup system hardware latch

Entry into the preflight test program is possible only on the ground. The following conditions must be satisfied in order to activate the preflight test program:

1. No failures are detected and the system is in primary.
2. The leading edges are not braked.
3. The preflight test switch is in the "on" position. (This action causes the MAW CAUTION annunciator to flash.)
4. The preflight selector switch is in position "one."
5. The weight on wheels switch is set (ONGEAR).
6. Both throttles are in "idle."
7. Wing sweep is less than 26°.
8. Flap switch is in RETRACT.
9. All surfaces are within 1° of their HOME position (press the gun trigger).
10. Press the GO/NO-GO button to start the preflight test.

A counter (PTISTP) within the preflight test program is incremented from 0 to 120 in steps of 10 as each test is completed (fig. 12).

PTISTP	PREFLIGHT TEST ACTION
10	Slew the flap commands down to 18° from FCEU 1 while keeping the commands from FCEU 2 at 2°. Test for all eight delta pressure fail monitors from both FCEU's. When these are set, go to the next step.
20	Fade out the flap command offset from FCEU 1. Test that all eight delta pressure fail monitors from both FCEU's have reset.
30	Slew the flap commands down to 18° from FCEU 2 while keeping the commands from FCEU 1 at 2°. Test for all eight delta pressure fail monitors from both FCEU's . When these are set, go to the next step.
40	Fade out the flap command offset from FCEU 2. Test that all eight delta pressure fail monitors from both FCEU's have reset.
50	Set a software signal (PTBRAK) to brake the leading edge flap. After six minor cycles, examine the hardware latch circuit of LEBRAK. If LEBRAK is "true" proceed to the next step.
60	Reset PTBRAK; after nine minor cycles, examine LEBRAK to determine if it is still latched. If LEBRAK is "true" proceed to the next step.
70	Set a software signal (PTFAIL) from FCEU 1 that commands the system to backup. After nine minor cycles, examine the hardware latch circuit of the backup lamp driver (BUTEST). If it is "true" proceed to the next step.
80	Reset PTFAIL and after nine minor cycles, examine BUTEST to determine if it is still latched. If BUTEST is "true" proceed to the next step.
90	This portion of the automated sequencing of the preflight test program is with the system in backup. The PRI FAILED RESET button must now be pressed to continue the preflight test.

100 Set a software signal (PTFAIL) from FCEU 2 that commands the system to backup. After nine minor cycles, examine the hardware latch circuit of the backup lamp driver (BUTEST). If it is "true" proceed to the next step.

110 Reset PTFAIL; after nine minor cycles, examine BUTEST to determine if it is still latched. If BUTEST is true proceed to the next step.

120 All the preflight steps have successfully passed. Set the GO light and reset the fail inhibit flag (DETIHB).

If not all the steps are passed, PTISTP will show the last successful test and PTSTEP will go to 120 with the NOGO light being set. When the preflight test switch is placed in the off position, PTSTEP will reset to zero, the GO/NOGO light will go out, and the latched error flags will reset.

4.2 Manual Flight Control System - Backup

The backup system is designed as a "get home" mode. It basically consists of two single-string and independent A and B analog controllers. The A backup system drives both power drive units (PDU) of the left midspan and right outboard flaps, and the inner PDU'S of the left and right inboard flaps. The B backup system drives both PDU'S of the left outboard and right midspan flaps, and the outer PDU's of the left and right inboard flaps. There is no backup control for the leading edge flaps. The leading edge stays braked in whatever position it was in when the backup mode was first entered. Details of the design are described in reference 4.

An easy-on system is designed to suppress the flap command switching transients when the control is transferred from primary to backup. This is accomplished by driving first order filters with the current flap positions. An example for a single surface is shown in figure 13. When control is transferred to the backup system, the outputs of these filters are switched so that they are connected to the summing junctions to provide the initial flap command. The initial roll and symmetric commands are zeroed immediately after switching to the backup control. They are then faded to their requested values by 4 sec time constant easy-on filters.

Backup control functions are the flap switch, roll stick, and wing sweep. The backup system does not utilize pressure equalization between the primary and utility systems.

4.2.1 PRIMARY/BACKUP switch.

The primary/backup switch is located on the upper left side of the MAW panel. This is a 4-pole switch which provides a positive switch to the backup system OR gate. When the switch is in the primary position, the switching logic is armed to return to the primary system.

4.2.2 Flap switch.

The flap switch is used to command the trailing edge flaps to one of three positions: HALF - 10°, FULL - 18°, and RETRACT - 2°. (The inboard flaps go to the "faired" position of 1.8°.)

The backup system has a dedicated set of contacts to indicate the switch position. Two discretes are used for the HALF, and another two discretes for the FULL position. For example, if the switch is in the FULL position, a FULL discrete is input to the A backup and another FULL discrete is input to the B backup system.

4.2.2.1 RETRACT:

1. The flaps move to a trailing edge position of 2° at a flap rate according to the filter 1/(4S + 1).
2. The position accuracy is ± 0.5°.
3. There is no annunciator light.
4. The roll stick goes through a .625(S + 3)/(S + 8) lead-lag filter.

4.2.2.2 HALF:

1. The flaps go to a trailing edge position of 10° at a flap rate according to the filter 1/(4S + 1).
2. The position accuracy is ± 0.5°.

3. The HALF annunciator light will not illuminate unless the leading edge flaps are at 15° and the primary system is working.
4. The roll stick goes through a .625(S + 3)/(S + 8) lead-lag filter.

4.2.2.3 FULL:

1. The flaps go to a trailing edge position of 18° at a flap rate according to the filter 1/(4S + 1).
2. The position accuracy is ± 0.5°.
3. The FULL annunciator light will not illuminate unless the leading edge flaps are at 20° and the primary system is working.
4. The roll stick goes through a .625(S + 3)/(S + 8), lead-lag filter.

4.2.3 Slew switches.

Not available in the backup system.

4.2.4 Rate select.

Not available in the backup system.

4.2.5 Roll trim.

Not available in the backup system.

4.2.6 Trim reset.

Not available in the backup system.

4.2.7 Manual command program.

Not available in the backup system.

4.2.8 Wing sweep inboard flap fairing.

Wing sweeps aft of the 26° detent are also available from the backup system. The sweep logic is shown in figure 14. To generate a SWP ENABLE discrete, the following procedure must be done:

1. Put the flap switch in RETRACT.

The RETRACT position in the backup mode positions the inboard flaps at the faired value of 1.8°.

2. Set the inboard brake.

The INBKSW is OR'd with the CDGT26 in hardware to artificially set this discrete. This allows the path on the left side of the figure to be followed. If all four backup LVDT's are at 1.8° ±0.5°, then the INBRK and SWP ENABLE discretes will be set.

3. Pull the sweep lever through the 26° detent.

When the wing sweep moves beyond 27°, the SWGT26 and actual CDGT26 discretes are set. At this point, the INBRK would be latched even if the inboard brake switch (INBKSW) were released because of the other two discretes. However, the INBKSW should never be released for backup wing sweep aft of 26° because the brake would be released if both SWGT26 and CDGT26 were to fail to false states. The flap switch can be placed in either HALF or FULL if desired at this point. The FAIRED light will not illuminate for backup sweeps because the fairing request discrete which comes from the primary system is not set during this procedure.

4. To release the fairing logic, set the sweep lever forward to the 26° detent and reset the inboard brake. The INBRK and SWP ENABLE discretes are reset to "false" at this point.

4.2.9 Flap rate limits.

Rate limiters are used to help prevent overspeeding the power drive units (PDU's). The maximum rate of change in the servo commands for each flap pair is shown below.

CONTROL SURFACE	RATE LIMIT
LEADING EDGE	NOT DRIVEN IN BACKUP
INBOARD	30 deg/sec
MIDSPAN	40 deg/sec
OUTBOARD	40 deg/sec

4.2.10 Surface position accuracy.

The total error from the command source to the actual surface position (as measured by a protractor), which includes all error sources from the analog and digital components, is less than 0.5°.

4.2.11 HOME command.

Not available in the backup system.

4.2.12 Ground roll brake.

Not available in the backup system.

4.2.13 Flap position limits.

The backup system has the same protection to reduce the possibility of a mechanical stop strike as the primary system. The backup system has slightly different electrical limits than the primary software limits. They are also a function of the flap position. Position limits do not apply for the leading edge flaps since they cannot be driven by the backup system.

		MECH	RETRACT	HALF	FULL
INBOARD	- up	-2.60	-0.63	-0.63	-0.63
	- dn	19.00	17.48	17.48	17.48
MIDSPAN	- up	-2.35	-0.17	-0.17	1.19
	- dn	21.00	19.15	19.15	19.15
OUTBOARD	- up	-2.53	-0.12	-0.12	1.06
	- dn	20.83	19.18	19.18	19.18

4.2.14 QC scheduling.

There are two impact pressure (QC) probes on the airplane which are filtered, $2/(S + 2)$ to suppress the noise and averaged (QCAVE). This signal is used to limit the downward deflection for the MAW TE flaps and to schedule the roll stick gain (fig. 10).

4.2.14.1 QC TE limiter:

For a QCAVE that is less than 830 lb/ft^2 , there is no QC TE limiting. If QCAVE is between 830 and 1360 lb/ft^2, the TE is QC-limited linearly from 21 to 4°. For a QCAVE greater than 1360 lb/ft^2, the TE limit is fixed at 4°.

4.2.14.2 Roll stick gain:

If the QCAVE signal is less than 150 lb/ft^2, the gain stays at 100 percent. If the QCAVE is between 150 and 250 lb/ft^2, the gain decreases linearly from 100 percent to 27 percent. For a QCAVE greater than 250 lb/ft^2, the gain remains at 27 percent.

4.2.15 LE RESET/ENGAGE/BRAKE switch.

The leading edge flaps may be manually braked by setting the switch to the BRAKE position. This causes the brakes to be engaged and the LE BRAKE light illuminated. The system stays in primary, but all leading edge flap commands are ignored. The brakes can be released in two ways:

1. Put the switch to RESET and then back to ENGAGE, or
2. Put the switch to ENGAGE and press the PRI FAILED RESET button.

The leading edge flaps are also braked whenever the system is in the backup mode or a leading edge failure is detected. Failures related to the leading edge are discussed in section 5.

4.2.16 A ENGAGE/BRAKE switch.

The left midspan and right outboard flaps may be manually braked by setting the A switch to the BRAKE position. This will illuminate the A BRAKE light and also cause the system to downmode to the backup system. The primary mode cannot be engaged with the switch in the BRAKE position. To release the brakes, put the switch in the ENGAGE position.

The brakes automatically set if the system is in the backup mode and a failure is detected in either the left midspan or right outboard flaps, or in the A stick transducers or the A backup power supply. In this case the A STATUS light is also illuminated, and a latch is set to hold the brakes. To release the brakes in this situation the following must be true:

1. The A BRAKE switch is in the ENGAGE position.
2. There are no A backup failures.
3. The A STATUS button is pressed.

4.2.17 B ENGAGE/BRAKE switch.

The left outboard and right midspan flaps may be manually braked by setting the switch to the BRAKE position. This illuminates the B BRAKE light and also causes the system to downmode to the backup mode. The primary mode cannot be engaged with the switch in the BRAKE position. To release the brakes put the switch in the ENGAGE position.

The brakes will be set automatically if the system is in the backup mode and a failure is detected in either the left outboard or right midspan flaps or the B backup power supply. In this case the B STATUS light will also be illuminated. A latch to hold the brakes has occurred. To release the brakes in this situation the following must be true:

1. The B BRAKE switch must be in the ENGAGE position.
2. There are no B backup failures.
3. Press the B STATUS button.

4.2.18 INBD ENGAGE/BRAKE switch.

The left and right inboard flaps may be manually braked by setting the switch to the BRAKE position. This will illuminate the INBD BRAKE light and also cause the system to downmode to backup mode. The primary mode cannot be engaged with the switch in the BRAKE position. To release the brakes, put the switch in the ENGAGE position.

The brakes will be automatically set and latched if the system is in the backup mode and a failure is detected with either inboard flap. In this case the INBD STATUS light will also be illuminated. To release the brakes in this situation the following must be true:

1. The INBD BRAKE switch is in the ENGAGE position.
2. There are no inboard flap backup failures.
3. The INBD STATUS button is pressed.

The inboard flaps are also automatically braked, as previously mentioned in the wing sweep description, whenever the sweep is aft of 26°. This braking command comes from either the primary or the backup system, depending on which mode is active. The brake command cannot be released until the wing is positioned further forward than 26°.

5.0 FAILURE MONITORING AND REDUNDANCY MANAGEMENT

Failure monitoring is described in ref. 5. The monitoring can be divided into those failure discretes set by the primary system and those set by the backup system. Primary system failures can be grouped into two categories: (1) system stays in primary and, (2) system downmodes to backup. Backup system failures can also be grouped into two categories: (1) do not set brakes and, (2) set any combination of A, B, or INBD brakes.

PRIMARY FAILURES

STAY IN PRIMARY	DOWNMODE TO BACKUP
1. Any LE failure - set LE brakes	1. Command - except LE
2. QC - fixed roll gain and TE limit	2. Selected output discretes
3. Ideal model - LE and roll flaps	3. Ideal model - inboard flaps only
4. IDENT discrete	4. Delta pressure (force fight)
	5. Roll stick
	6. Power supply
	7. Hydraulic pressure < 1200 lb/in^2
	8. Computer executive error
	9. Watchdog timer

BACKUP FAILURES

DO NOT SET BRAKES	SET A, B, AND/OR INBD BRAKES
1. Aliveness monitor	1. Valve current
2. QC - fixed roll gain & TE limit	2. Position limit

3. Single hydraulics
4. Ideal model (flaps HALF/FULL)
5. IDENT discrete

3. Power supply
4. Roll stick
5. Ideal model (flaps RETRACT)

For the situation of a backup failure while the system is in the backup mode, the affected backup channel will set the brakes to the flap pair driven by that system, while the other channel will continue to function normally. The inboard flaps will continue to function with only one backup channel because the failed channel will open the bypass valves to allow the functioning channel to move the flaps.

There is no failure testing done on any input discretes. For example, assume the flap switch has a faulty primary contact at the FULL position. When the switch is put in FULL, one primary channel will try to drive the flaps to the FULL position while the other primary channel will not receive the FULL input discrete and the flap command will be in the RETRACT position. This will cause a command difference between the two primary computers which will result in a downmode to the backup system. For details on the MAW failure annunciators and the possible implications on the flight control system, refer to the Appendix.

5.1 Failure Monitors - Primary System

A fail flag is set only after the fail condition has exceeded a time delay threshold. There are two types of fail flags: latched and unlatched. Once a latched fail flag is set, it stays in memory until the power switch is cycled or the preflight test has been run. A monitor can be connected to the FCEU in order to read the latched fail discretes since they are not available on the cross channel data bus.

The unlatched fail flags are set only as long as the failure exists. Some unlatched flags are reset if the system downmodes to backup. This allows the system a chance to reengage the primary without preexisting failures ready to trigger another downmode. The unlatched fail flags are available for monitoring on the cross channel data bus.

Failure monitors are provided for the following signals:

1. All analog outputs
2. Selected discrete outputs
3. Differential motor pressures for each surface
4. Selected analog input signals
5. Wing surface position model
6. Leading edge left and right differential position
7. Other modules within the processor
8. Flags set from the other processor

5.1.1 Analog output commands.

The commands between the FCEU's are compared. If they differ by more than 1.5° for 0.2 sec or longer, a fail flag is set and the system downmodes to backup.

MNEMONIC	THRESHOLD, DEG	TIME DELAY, SEC
FCLLE*	1.5	0.2
FCRLE*	1.5	0.2
FCLOUT	1.5	0.2
FCLMID	1.5	0.2
FCLIN	1.5	0.2
FCRIN	1.5	0.2
FCRMID	1.5	0.2
FCROUT	1.5	0.2

* LE brakes only - no downmode

5.1.2 Output discretes.

A test of common output discretes of the FCEU's is made. If these discretes differ for 0.3 sec or longer, a fail flag is set and a downmode to backup is generated.

MNEMONIC	TIME DELAY, SEC	MNEMONIC	TIME DELAY,SEC
FEXDOG	0.3	FGO†	0.3
FANGROL†	0.3	FANFAIR†	0.3
FMASTER*	0.3	FTRANST	0.3

FFALHLD	0.3	FVALID†	0.3
FTRMNUL*	0.3	FBRKHLD	0.3
FNOGO	0.3	FONTEST	0.3
FANTOFF†	0.3	FANLAND†	0.3
FANQC*	0.3	FANSW45*	0.3
FMLC*	0.3	FMAN*	0.3
FCCC*	0.3	FDL*	0.3
FMCC*	0.3	FDLGA*	0.3
FSPAN2*	0.3	FSPAN1*	0.3
FAUTVAL*	0.3	FAUTENT*	0.3
FINBRAK†	0.3		

* DISABLED † NULL TEST

5.1.3 Differential pressures.

Differential pressure transducers are provided for each of the 16 wing surface drive motors. The absolute value of the difference between the two FCEU's is compared to a 3600 lb/in^2 threshold. If the delta pressure exceeds this threshold for 0.06 sec or more, a differential pressure fail flag is set and a downmode to backup is generated. Once in the backup mode, the delta pressure fail flags are reset after a time delay of 200 msec. These monitors are not activated until after 200 msec, once the primary mode is reengaged.

MNEMONIC	THRESHOLD, PSI	TIME DELAY, SEC
FDPROU	3600	0.063
FDPRMI	3600	0.063
FDPRLE*	3600	0.063
FDPRIN	3600	0.063
FDPLOU	3600	0.063
FDPLMI	3600	0.063
FDPLLE*	3600	0.063
FDPLIN	3600	0.063

* LE brakes only - no downmode

5.1.4 Roll stick.

The roll stick input for the primary system is dual. Each FCEU gets its own roll stick command. The failure detection logic compares these inputs, and if the absolute value of the difference exceeds a threshold for more than the time delay, a downmode to backup will result. A failure flag will be set to indicate the reason for the downmode.

MNEMONIC	THRESHOLD	TIME DELAY
FRSTIK	0.8 VOLTS	0.2 SEC

5.1.5 Impact pressure.

The impact pressure input for the primary system is dual. Each FCEU gets its own impact pressure signal. The failure detection logic compares these inputs, and if the absolute value of the difference exceeds a threshold for more than the time delay, an impact pressure fail annunciator will illuminate and the corresponding fail flag will be set. The system, however, will stay in primary.

For an impact pressure failure, the TE down-deflection limit and roll gain schedules (fig. 11) are determined as follows:

RETRACT - The symmetric command will drive to 2° at 2 deg/sec. If symmetric slewing had been applied at the time of the failure, the trailing edge flaps will drive to 4° at 4 deg/sec and then to 2° at 2 deg/sec. The trailing edge flaps will be limited to 4° TED. The roll stick gain will be fixed at 27 percent.

HALF/FULL - The flaps will remain at the commanded flap switch position and full roll authority will be allowed. The roll stick gain will be fixed at 100 percent.

An impact pressure failure also locks out the manual command program slewing.

MNEMONIC	THRESHOLD	TIME DELAY
FQIMPF*	100 lb/ft^2	0.5 sec

* no downmode

5.1.6 Ideal position model.

The actual flap position for each MAW surface is compared with an ideal model to determine if the flap is at the expected position. The leading edge and inboard flaps are handled differently than the midspan and outboard flaps.

The LE and INBOARD MAW flap positions from the primary LVDT's are compared with a 22 rad/sec first order model in order to predict the positions. If the predicted position disagrees with the actual position by 5° or more for at least 0.2 sec, a position error flag discrete is generated which causes a downmode to backup. The model fail flags are reset in the backup mode after a delay of 200 msec. These monitors are not activated until 0.2 sec once the primary mode is reengaged.

The MIDSPAN and OUTBOARD flap positions from the primary LVDT's are compared with a second order model (f_n = 27 rad/sec; damping = 0.60; and 20 msec time delay). If the predicted positions disagree with the actual positions by 5° or more for at least 0.2 sec, a position error flag discrete is generated. This does not cause a downmode to backup. These model fail flags cause the MAW CAUTION light to flash only during the time the failure is being declared.

MNEMONIC	THRESHOLD, DEG	TIME DELAY, SEC
FPROUT*	5.0	0.2
FPRMID*	5.0	0.2
FPRLE†	5.0	0.2
FPRIN	5.0	0.2
FPLOUT*	5.0	0.2
FPLMID*	5.0	0.2
FPLLE†	5.0	0.2
FPLIN	5.0	0.2

* no BACKUP downmode (MAW CAUTION light)
† LE brakes only

5.1.7 Leading edge differential position.

The absolute value of the difference between the left and right leading edge positions is compared. If this difference exceeds 3.0° for 0.06 sec or more, a fail discrete (FLEDIF) is set. This will result in the leading edges being braked for the remainder of the flight. The system will not go to backup for this failure. This failure can only be reset on the ground. The latched error fail (XFLEL) on the cross channel is set.

5.1.8 Other modules within the processor.

The following is a description of executive type fails.

MNEMONIC	DESCRIPTION
FROLLF	Set by the ROLL MODULE to indicate a lead-lag filter overflow condition.
FCDACT*	Set by the SERVO ACTUATOR MODULE.
FCDINT	Set by the INTEGRATOR MODULE to indicate initialization overflow of position (mid or outboard) + ROLCOM for midspan or outboard surfaces.
FCOMMD*	Set by the COMMAND MODULE.
FOUTPT*	Set by the OUTPUT MODULE.
FINPUT*	Set by the INPUT MODULE if any of the following three synchro inputs have overflowed into the high order word: WSPOS, THETA, ROLPOS.
FEWDOG*	External watchdog failure.
FIWDOG*	Internal watchdog failure.
FSYNCR*	Synchronization failure.
FCOMUN*	Communication failure.
FCKSUM	Set by the EXECUTIVE MODULE in the background during self test in WAITE1 (20 msec wait loop). This discrete

sets FATFAL in the CONTROL FIELD byte.

* DISABLED

5.1.9 Flags set from the other processor.

The following flags are set in the CTLFLD byte:

MNEMONIC	DESCRIPTION
SYNCBT	Sync bit. Always zero in this buffer to distinguish the CTLFLD byte from the sync byte (53H) which replaces it in the sync message.
XFLEL	Leading edge latched (from other processor) flag. The FLEDIF fail flag is set in the other processor.
OVRRUN	Set by the EXECUTIVE MODULE to indicate that a frame overrun has occurred.
FATFAL	Fatal fail set by the EXECUTIVE MODULE from the following tests:

1. MEMTST/RAMTST - in power up self test. Address of defective cell save in MEMADR.

2. CHKSUM - background during self test in WAITE1 (20 msec wait loop) if CHKSUM incorrect

3. RTINT - If TFSYNC is set.

4. RTINT - If MONREQ is set.

5. RTINT - If OVRRUN is set.

6. BADINT - If bad interrupt is detected.

7. BREAK2 - If illegal instruction is detected.

8. NMINT2 - Executive NM1 routine.

9. WHYINT - Set by exec system call routine.

TFSYNC	Synchronization failure. Set by the synchronization module (MDSYNC) if the processors get out of sync by more than 120 micro sec.
OKMON	OK to go to the monitor. Set by the preflight test module (MDPFT). The following discretes are set: IDLE, ONGEAR, and PFT switch is in "on" position.
MONREQ	Monitor request. Set by the executive when FATFAL is set.
TTCON	Terminal connected. Set by the executive routine.

5.1.10 Ident flag.

The two FCEU's are differentiated from each other by the grounding of a pin to a box 1 connector. This provides an input discrete, IDENT, which is set to "1" for box 1, and "0" for box 2. The FCEU's interpret this as channel 1 and channel 2, respectively. The primary system reads an initialization value of the IDENT discrete at power-up. If they are the same, a FIDENT fault is set. The IDENT discrete is also tested real time so that a difference after power up is detected. A flashing IDENT light on the C&D panel will result whenever a FIDENT fault is declared. The MAW CAUTION light will also flash.

The primary system is designed to maintain proper flap phasing after an IDENT fault. However, in the backup system the rolling flaps driven by the faulted IDENT discrete will be in the opposite direction for roll stick inputs. For example, if the IDENT discrete went from "1" to "0" in channel 1 and the backup system was entered, the "A" backup roll flaps (left midspan and right outboard) would be opposite in direction for roll inputs. This would cancel out the normal roll control and cause the MAW roll surfaces to act like a speed brake for roll inputs.

5.2 Failure Monitors - Backup Hardware.

The backup hardware electronics does its own fault testing which is independent of the primary system. A failure in the backup system would not cause a downmode from a good primary system, but if a downmode did occur, brakes would be set automatically in the failed backup system. The following backup tests are being performed while the system is in primary: aliveness monitor, backup power supply, roll stick monitor, surface model, and valve current mismatch test. When the backup mode is entered, the position limit test is added to the above set.

Failure monitors are provided for the following signals:

1. Valve current comparison
2. Aliveness monitor comparison
3. Analog inputs
4. Position model
5. Position limits
6. Power supply monitor
7. Hydraulic pressure monitor
8. Watchdog time out
9. A STATUS light
10. B STATUS light
11. INBD STATUS light
12. MAW CAUTION light

5.2.1 Valve current comparison.

The valve current comparitors check for mismatch of PDU commands coming from the same backup channel. These discretes cycle at a frequency of 8.7 Hz with a pulse width of 60 msec.

For example, an INVMON fail flag in channel 1 would be set if the backup A generated an inboard flap command difference between the left inboard flap PDU number 10 and right inboard flaps PDU number 11 of 5 milliamps or greater for at least 0.115 sec. An INVMON fail will not set the inboard brake or the INBD STATUS light.

MNEMONIC	THRESHOLD	TIME DELAY
INVMON*	5 mamp	0.115 SEC
OMVMON	5 mamp	0.115 SEC

* does not set inboard brakes

5.2.2 Aliveness monitor comparison.

The aliveness monitor is a test of the backup system while flap control is being driven by the primary system. This test checks for a mismatch between the output signals generated by identical electronics in the A and B backup systems of the right outboard and midspan flaps, left outboard and midspan flaps, and the left and right side of each inboard flap. An outboard/midspan aliveness monitor fault will set both A and B STATUS lights. Once the backup system is entered, the aliveness monitor is disabled. These discretes cycle at a frequency of 0.51 Hz with a pulse width of 130 ms.

An OMLIVE fail flag in channels 1 and 2 would be set if the backup A and B commands to the right midspan and right outboard flaps, for example, disagreed by greater than 0.5 volts for at least 1.96 sec.

MNEMONIC	THRESHOLD	TIME DELAY, SEC
INLIVE	0.5 volts	1.96
OMLIVE	0.5 volts	1.96
MIDMRF	0.5 volts	NO DELAY
OUTMRF	0.5 volts	NO DELAY

5.2.3 Roll stick.

Two dedicated roll stick transducers are used by backup A and another two are used by backup B system. If the absolute of the difference of the roll stick inputs within a system exceeds the threshold of 0.8 volts or more, then that backup system will be braked. Flaperon roll control will be driven from the other backup system only.

MNEMONIC	THRESHOLD	TIME DELAY
STKMON	0.8 VOLTS	NO DELAY

5.2.4 Impact pressure.

The nose and side impact pressure probes used for the primary system are also brought into both the A and B backup systems.

MNEMONIC	THRESHOLD	TIME DELAY
QCFAIL (LIGHT)	100 lb/ft^2	1.96 sec

5.2.5 Position model.

The backup system does its own model testing independent of the primary system. However, if the system is in the primary mode, the input to the backup model is the surface position rather than the flap command. The model and logic for the inboard flap is different from the model and logic for the midspan and outboard flaps.

The inboard flap position is compared with a 22 rad/sec first order model in order to predict the positions. If the prediction disagrees with the actual position by 5° or more for 0.13 sec or more, then both inboard flaps will be braked.

The midspan and outboard flaps are compared with a second order model (f_n = 24.9 rad/sec, damp = 0.47). If the predicted position disagrees with the actual LVDT position by 5° or more for 0.13 sec or more, then either the A or B brakes will be set, depending which system is setting the error, if the flaps are in the RETRACT position. If the flap switch is in either HALF or FULL, then the A or B STATUS light will illuminate only while the model fault is being declared. Whenever a brake is being set, the MAW CAUTION light will also flash. The table below shows the brake and STATUS light logic for each flap position.

FLAPS	INBOARD	MIDSPAN	OUTBOARD
RETRACT	INBD BRAKE	A/B BRAKE	A/B BRAKE
HALF	INBD BRAKE	A/B STATUS	A/B STATUS
FULL	INBD BRAKE	A/B STATUS	A/B STATUS

The inboard and out/mid model faults (INMODL and OMMODL) cycle at a frequency of 7.7 Hz with a pulse width of 60 msec.

MNEMONIC	THRESHOLD, DEG	TIME DELAY
INMODL	5	0.13 SEC
OMMODL	5	0.13 SEC
MIDMRF	5	NO DELAY
OUTMRF	5	NO DELAY

5.2.6 Position limits.

The down deflection limit of the trailing edge flaps is scheduled with QC pressure so that the actuator limit load will not be exceeded. The surface position limit test is not computed while the system is in the primary mode so that QC schedule differences (particularly in the 830 to 1360 lb/ft^2 range between the primary and backup systems) will not cause a limit fault to be set. These discretes cycle at a frequency of 8.7 Hz with a pulse width of 60 msec.

If the flap position exceeds the trailing edge limit by 1.9° or more for at least 0.115 sec, then a limit fault will be generated. It is only possible to generate a position limit monitor fault while the TE flaps are being driven with the QC limiter (QC > 830 lb/ft^2). The reason is because the 1.9° threshold is beyond the normal full mechanical limits.

MNEMONIC	THRESHOLD	TIME DELAY
INPOSL	1.9°	0.115 SEC
OMPOSL	1.9°	0.115 SEC

5.2.7 Power supply monitor.

Electrical power to the FCEU's is supplied by four sources. For FCEU 1 the power comes from the right engine MAIN BUS and the ENGINE START BATTERY BUS. For FCEU 2 the power comes from the left engine ESSENTIAL BUS and the MAW FCS BATTERY. A single generator from either engine can supply all the electrical demands, therefore, in the event of a generator failure the circuits will automatically switch-in to the remaining good generator.

The primary (ch 1 and 2) and backup (A and B) systems each have independent power supplies. There is a continuous monitor of each power supply so that if a primary power supply fails, the system will automatically downmode to the backup system. Should the power supply fail in one of the backup systems, the flaps associated with that system will be braked. The other backup system will continue to drive the remaining flap set.

MNEMONIC	THRESHOLD	TIME DELAY
PRIPWR	± 5% of 5 volts	13 msec
	± 5% of ± 15 volts	13 msec
	± 5% of 26 vac/400 Hz	34 msec
BUPWR	± 5% of 5 volts	13 msec
	± 5% of ± 15 volts	13 msec
	± 5% of 26 vac/400 Hz	34 msec

5.2.8 Hydraulic pressure monitor.

The primary and utility hydraulic pressures are monitored. If the pressure drops below 1200 lb/ft^2, that system is declared failed and the FCS downmodes to the backup system. The PDU's driven by the failed hydraulic system are commanded to the bypass position and the flaps are driven by the functioning hydraulic system only.

MNEMONIC	THRESHOLD, lb/in.^{2}	TIME DELAY
PHYDOF	pri hydr press < 1200	0.45 RAD/SEC FILTER
UHYDOF	utl hydr press < 1200	0.45 RAD/SEC FILTER

5.2.9 Watchdog timeout.

A watchdog timer must be reset every frame (20 msec). If this timer is not reset within 30 msec, a watchdog timeout failure will be declared and a downmode will occur.

MNEMONIC	THRESHOLD
WDOGTO	30 msec

5.2.10 A status light.

The A STATUS light is latched to indicate failures associated with the A backup system. If the backup mode is entered while the A STATUS light is lit, the left midspan and right outboard flaps are braked unless the light is set by the aliveness monitor flag (OMLIVE) from channel 1. The logic to set the light is described below.

$$\text{A STATUS LIGHT} = \text{STKMON} + \text{OMVMON} + \text{OMMODL} + \text{BUPWR} + (\text{OMPOSL}\cdot\text{BU}) + (\text{OMLIVE}\cdot\overline{\text{BU}})$$

These fail flags are all associated with channel A of the backup system. The light may be reset if the failure no longer is declared and the status button is pressed.

5.2.11 B status light.

The B STATUS light is latched to indicate failures associated with the B backup system. If the backup mode is entered while the B STATUS light is lit, the left outboard and right midspan flaps are braked unless the light is set by the aliveness monitor flag (OMLIVE) from channel 2. The logic to set the light is described below.

$$\text{B STATUS LIGHT} = \text{STKMON} + \text{OMVMON} + \text{OMMODL} + \text{BUPWR} + (\text{OMPOSL}\cdot\text{BU}) + (\text{OMLIVE}\cdot\overline{\text{BU}})$$

These fail flags are all associated with channel B of the backup system. The light may be reset if the failure no longer is declared and the STATUS button is pressed.

5.2.12 Inboard STATUS light.

The INBD STATUS light is latched to indicate failures associated with the inboard flap. The light may be set from either A or B or both backup systems. If the backup mode is entered while the INBD STATUS light is lit, the left and right inboard flaps will be braked unless the light was set by the aliveness monitor flag (INLIVE) from either backup channel. The logic to set the light is described below.

$$\text{INBD STATUS LIGHT} = \text{INMODL} + \text{BUPWR} + \text{INPOSL} + (\text{INLIVE}\cdot\overline{\text{BU}})$$

5.2.13 MAW CAUTION light.

The MAW CAUTION light is latched to indicate failures which originate from either the primary or the backup systems. The logic to set the light is described below.

MAW CAUTION = A STATUS + B STATUS + INBD STATUS + MASTER + BRAKE TEST PLUG

where MASTER = PFT SW ON + IN MONITOR PRG + FALHLD + BRKHLD + FPLOUT + FPLMID + FPRMID + FPROUT

The MAW CAUTION light can always be reset, even if the failure is still present, unless the preflight test switch is in the "on" position, or the monitor program has been entered, or the brake test plug is installed.

6.0 FLAP DRIVE SYSTEM

The basic MAW flap actuation system consists of a hydraulic motor, gear reduction box, electric brake, rotary actuator, control module, and torque tube. The motor, gear box, servo control valve, and brake are housed in a single module called a power drive unit (PDU). There are two PDU's per surface. The servo control valve and electrical position feedback complete the loop in the servo system.

6.1 Servo Electronics.

The servo electronics (refs. 6 and 7) provide signals to the valve for each PDU. These signals consist of a command, block, bypass, and brake. There are separate electronics for the primary and the backup systems so that a failure in one would not affect the other. The backup servo electronics perform various fault monitoring tests.

6.1.1 Command path.

A simplified block diagram of the servo feedback loop for a roll flap is shown in figure 15. The commands are received from whichever system is controlling the flaps (primary or backup) and generates a signal to the valve at each PDU. Each primary channel drives a single PDU for a given flap. The primary servo command consists of an error signal between the FCEU command and the actual flap position, plus the same error from the other channel for position equalization, plus pressure equalization. The backup servo command receives a single dedicated backup LVDT feedback. It does have the position or pressure equalization loops.

6.1.2 Equalization loops.

Two equalization loops are used in the dual channel system to minimize the inherent force fight that develops between two high pressure gain servos that are driving common output shafts in parallel. One loop provides position error equalization and the other is used for pressure equalization.

The purpose of the position error equalization loop is to reduce force fight by providing identical actuating error signals to both servo amplifiers. Position equalization corrects for the force fight that is introduced by unequal position command and/or unequal position transducer outputs within a 2.6° limit.

The purpose of the pressure equalization networks is to minimize the amount of force fight between the two servo loops due to the inherent servo valve driver amplifier offsets and the bias offset currents of the two servo valves. The command and position equalization will not account for the tolerances of the servo valve driver amplifier and the servo valves, without these pressure equalization networks.

6.1.3 Block, bypass, and brake logic.

Each PDU can receive four types of commands: servo valve, block, bypass, and brake (fig. 1). The servo valve has already been explained. MAW surfaces are braked by first issuing a block command. The block signal is used to slow the hydraulic motor speed to under 500 rpm (2 deg/sec flap rate). The brake command is delayed 120 msec after the block command. This physically locks the motor by meshing gear teeth from the brake.

The bypass command is used to open the PDU valve so that it can be driven by its companion PDU only. An example is a hydraulic failure, where all the TE PDU's would go to the bypass mode for that failed system and the drive would be from one side from a single PDU per flap. Logic for the block, bypass, and brake commands follow:

$$BLOCK_{A/B} = BU \cdot (OMVMON + OMMODL + OMPOSL + STKMON + BUPWR) + A(B)BKSW$$

$$BLOCK_{INB} = BU \cdot (INMODL + INPOSL + BUPWR) + INBKSW + INBRK(wing\ sweep)$$

$$BLOCK_{LE} = BU + FCLLE + FCRLE + FDPLLE + FDPRLE + FPLLE + FPRLE + FLEDIF + LEBKSW$$

$$BRAKE = 120\ msec\ delay\ after\ BLOCK$$

$$BYPASS_{A/B/INB} = PHYDOF + UHYDOF$$

$$BYPASS_{LE} = not\ available$$

6.2 Torque Shaft and Rotary Actuator

The flap drive mechanism is completed by the use of torque shafts and rotary actuators. The rotary actuators are attached to the front of the wing box and to an auxilary spar bolted to the rear of the wing box. A linkage is attached from the rotary actuator to the flexible fiberglass panels. The torque shafts link the rotary actuators and the PDU's for a given flap. This arrangement can allow for considerable wing flexing without jamming any part of the mechanism.

7.0 REFERENCES

1. Hynes, R. J.: AFTI/F-111 MAW Manual Flight Control System Description. D365-10100-1, The Boeing Company, 1983.

2. Logan, D. and Thomasson, R.: Software Requirements Specification for AFTI/F-111 MAW Manual Flight Control System. D365-10062-1, Revision L, The Boeing Company, l985.

3. Suhl, E. and Wagaman, J.: AFTI/F-111 Manual Control System Software Design Description. D365-10072-1, Revision E, The Boeing Company, 1981.

4. Thomasson, R. E.: Requirements Specification for AFTI/F-111 MAW

Backup Flight Control System. D365-10091-1, The Boeing Company, 1982.

5. Thomasson, R. E.: AFTI/F-11 Failure Modes and Effects Analysis. D365-10047-1, Revision D, The Boeing Company, Apr. 1984.

6. Olson, A. G.: Actuator Control Concept Verification Test (Phase 0). D365-10059-1, Revision A, The Boeing Company, Aug. 1981.

7. Rice, J., Thorntron, A., and Nelson, D.: Phase 1 - Structures/Flight Control Loads/Actuation Test Final Report. D365-10095-1, The Boeing Company, Apr. 1983.

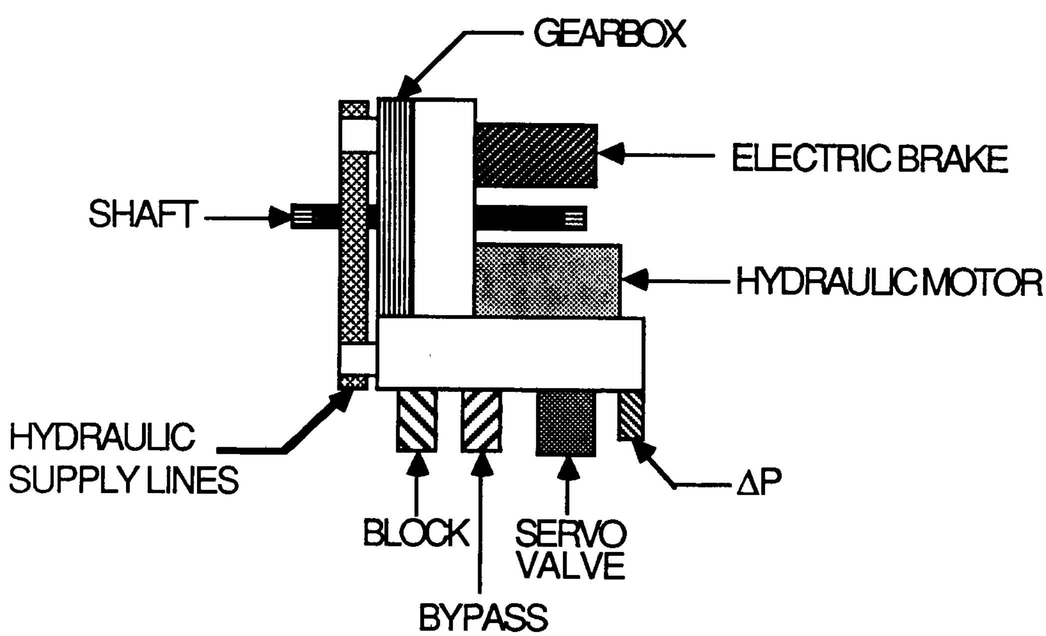
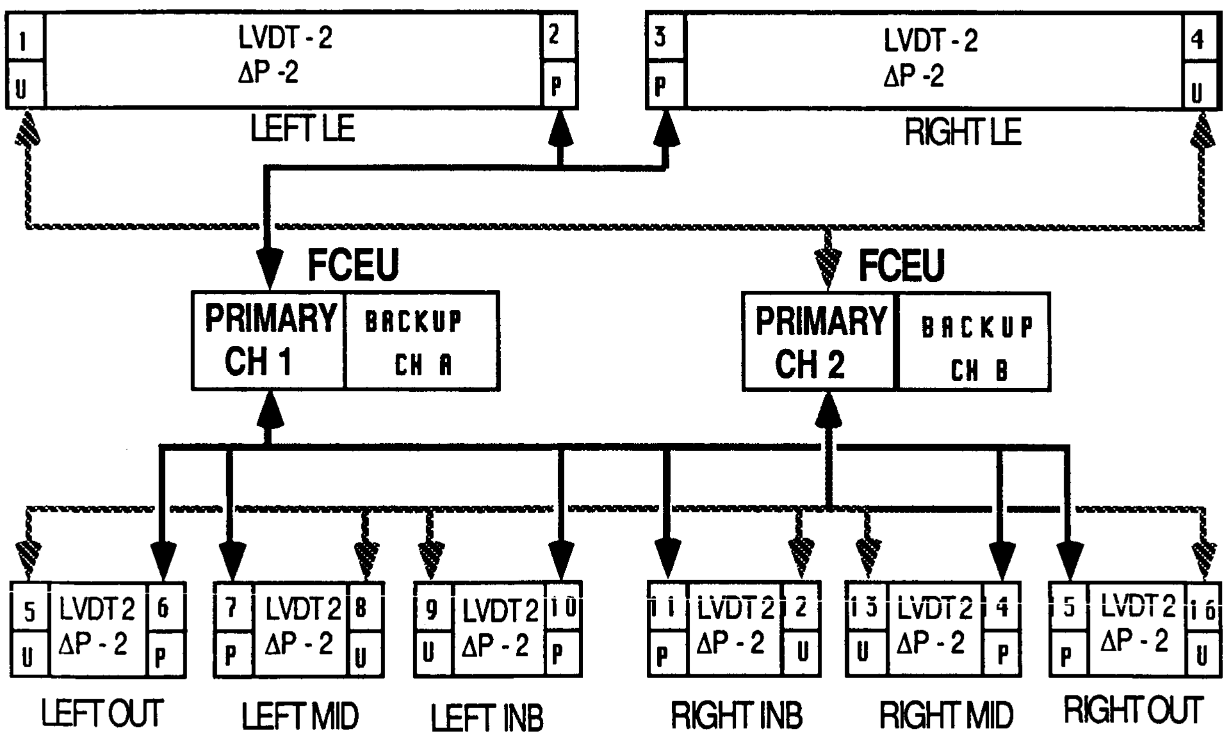


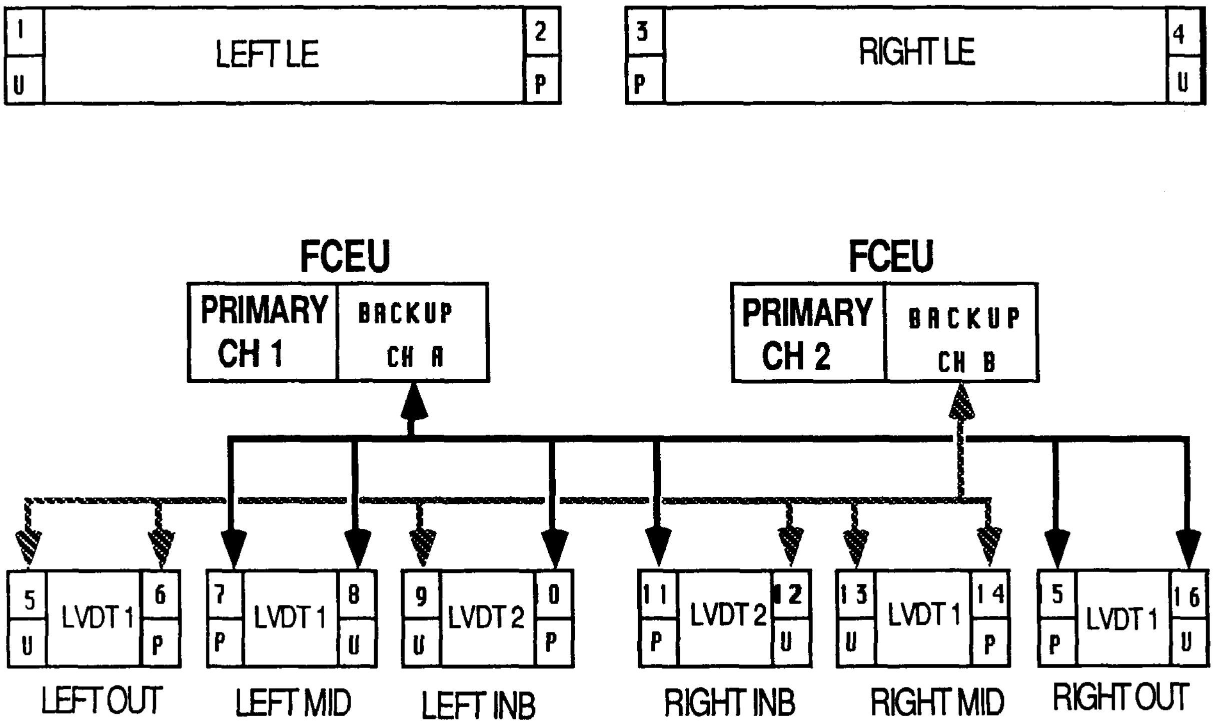
Figure 1. Power drive unit.



NOTES: (1) The signal flow is a 2 way path.
from FCEU - commands
to FCEU - ΔP, LVDT's

(2) No. - PDU number
(3) P - primary hydraulics
U - utility hydraulics

Figure 2. System architecture - Primary FCS.



NOTES: (1) The signal flow is a 2 way path.
from FCEU - commands
to FCEU - LVDT's

(2) No. - PDU number
(3) P - primary hydraulics
U - utility hydraulics

Figure 3. System architecture - Backup FCS.

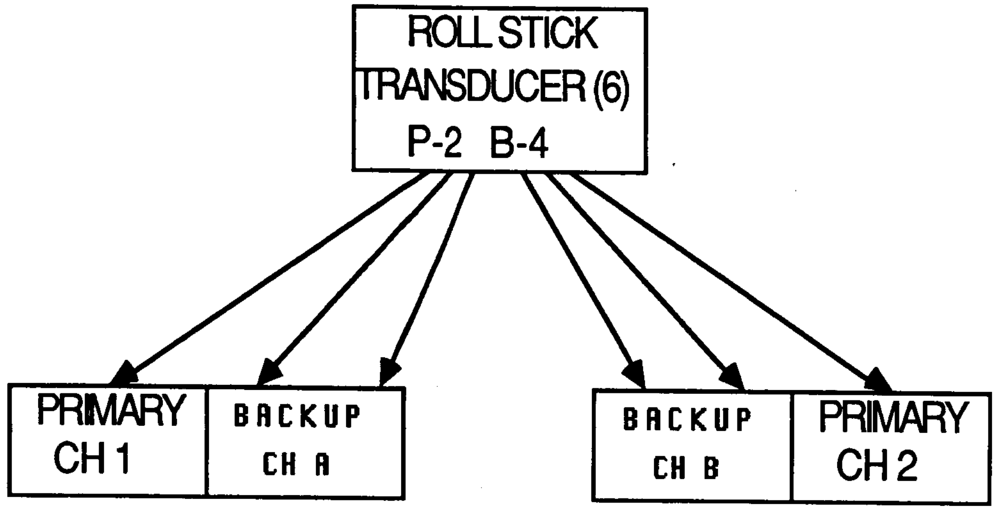


Figure 4. Roll stick architecture.

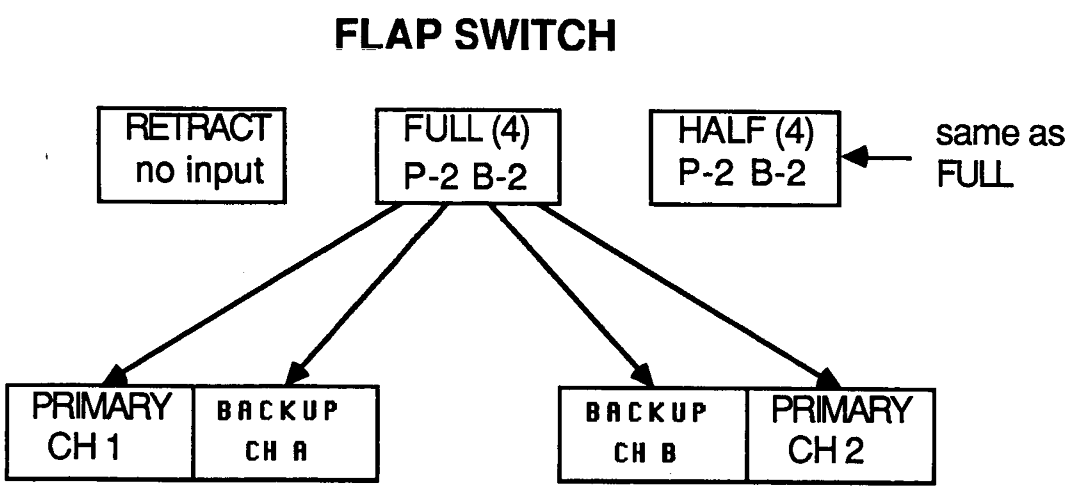


Figure 5. Flap switch architecture.

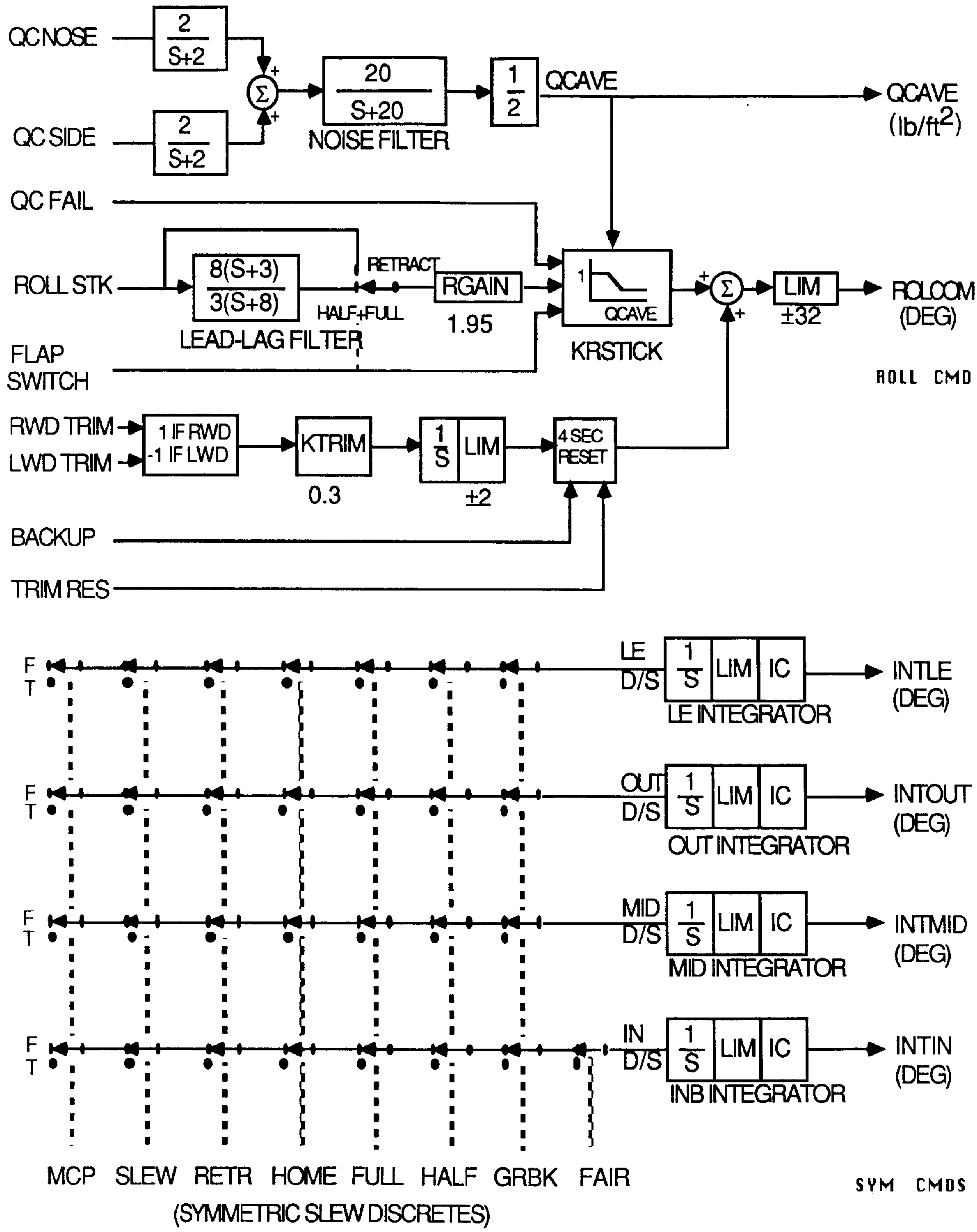


Figure 6. MAW commands (roll/symmetric).

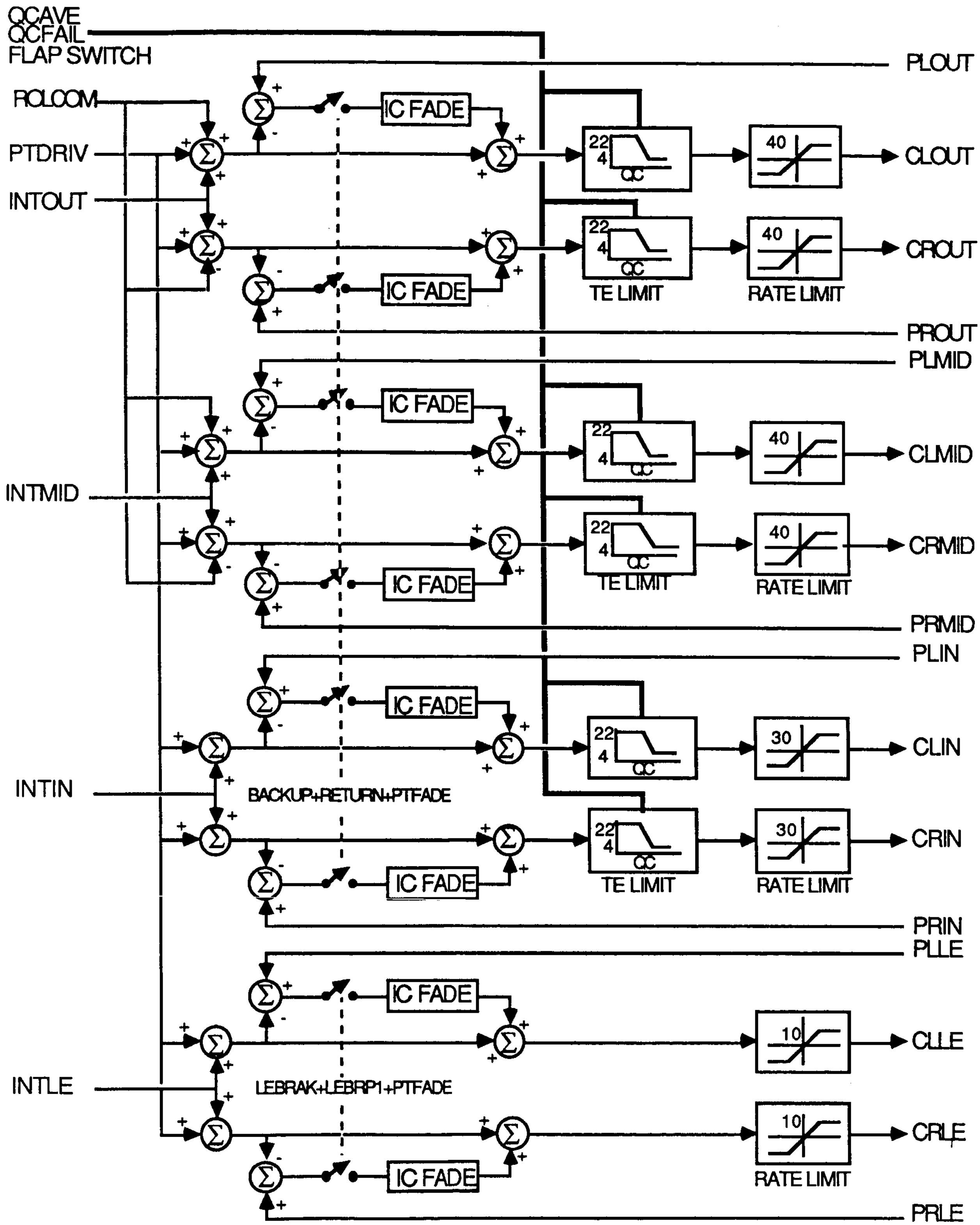


Figure 7. MAW servo commands.

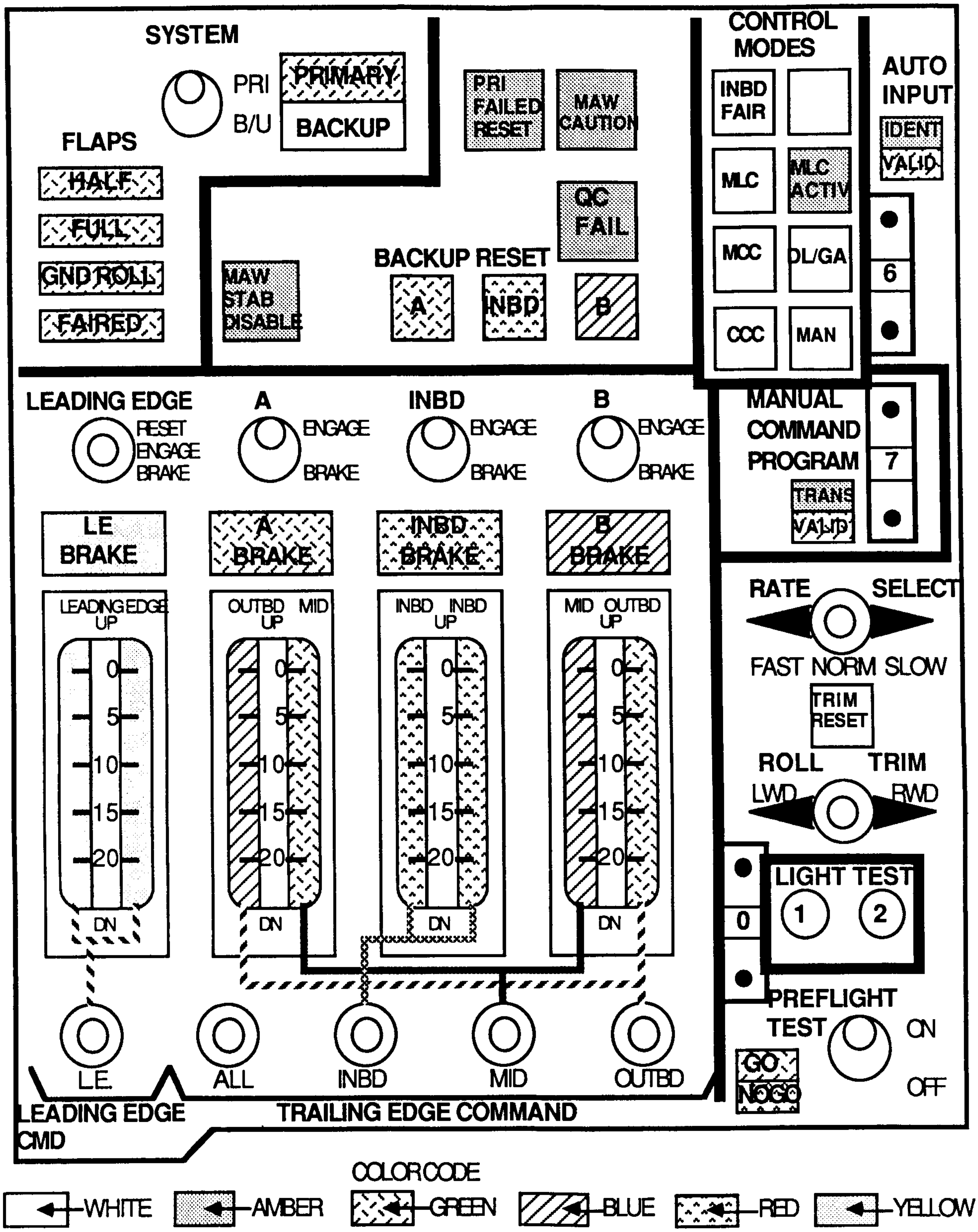


Figure 8. MAW control and display panel.

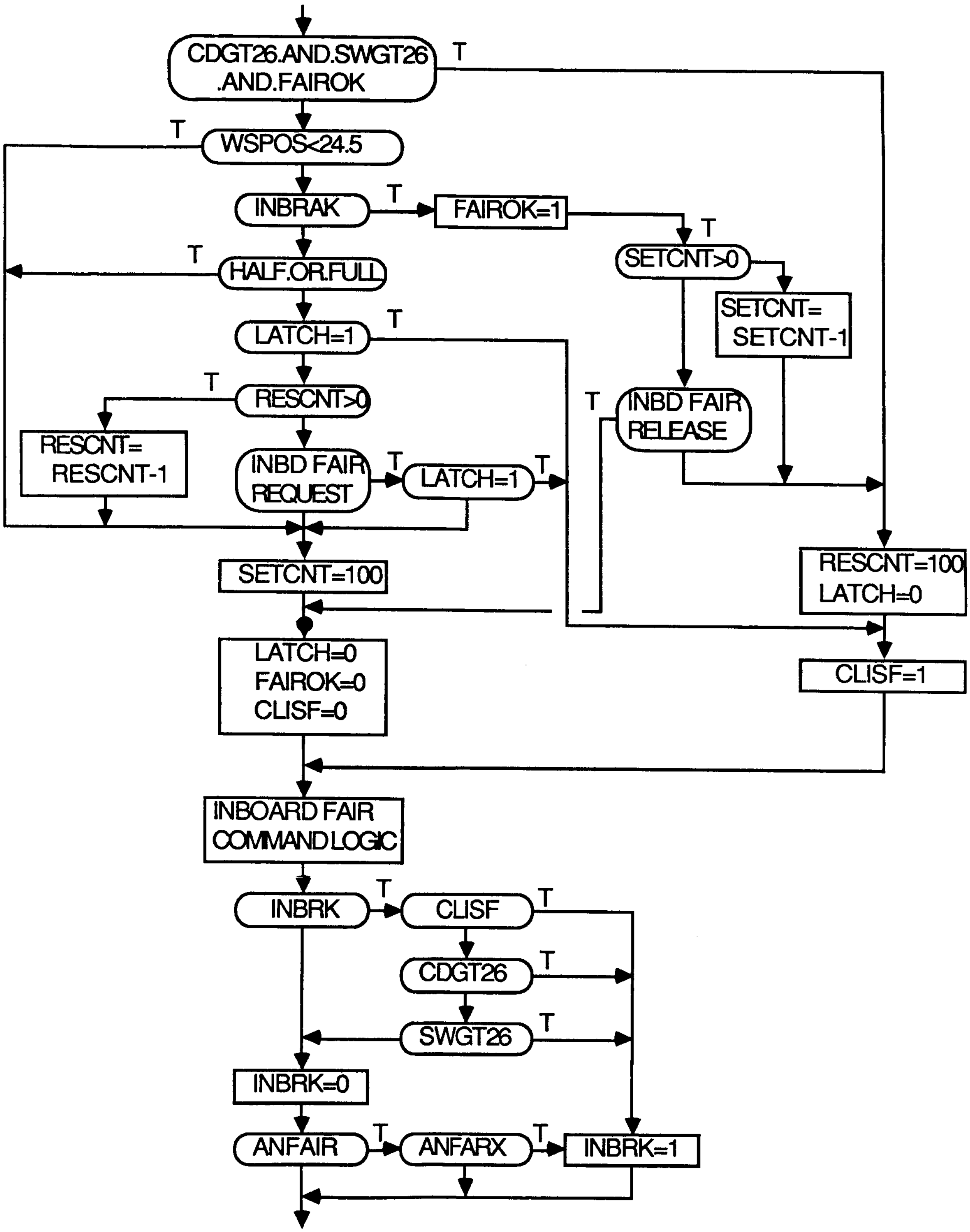


Figure 9. Wing sweep logic - Primary.

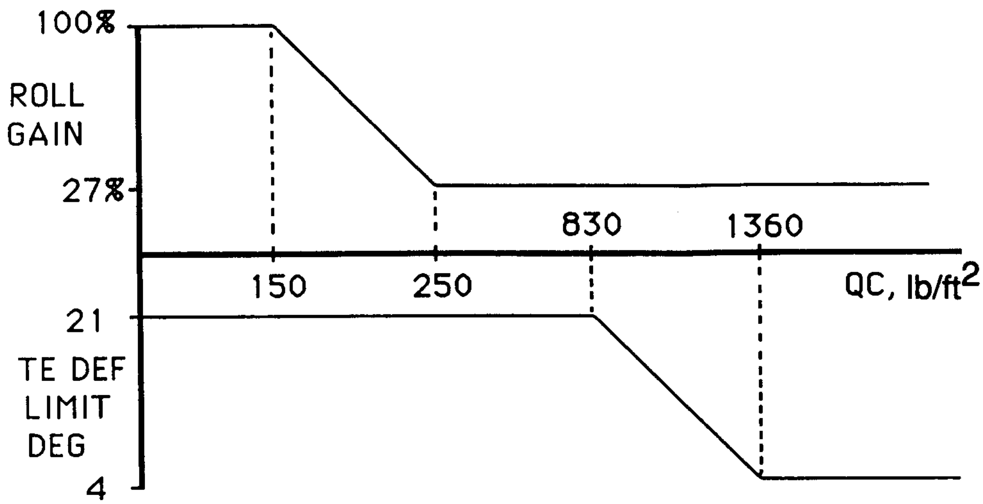


Figure 10. Roll gain and TE deflection limit schedules with QC

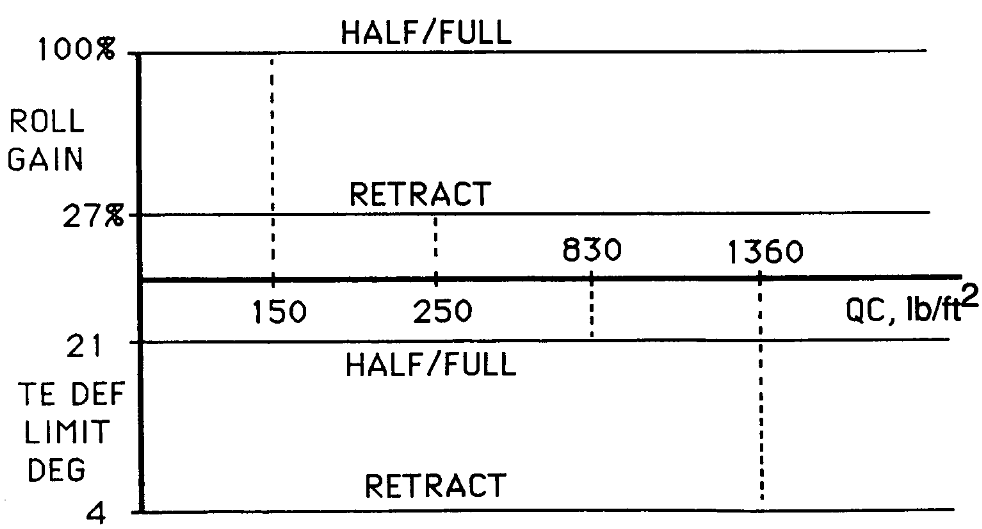


Figure 11. Roll gain and TE deflection limit schedules with QC fail.

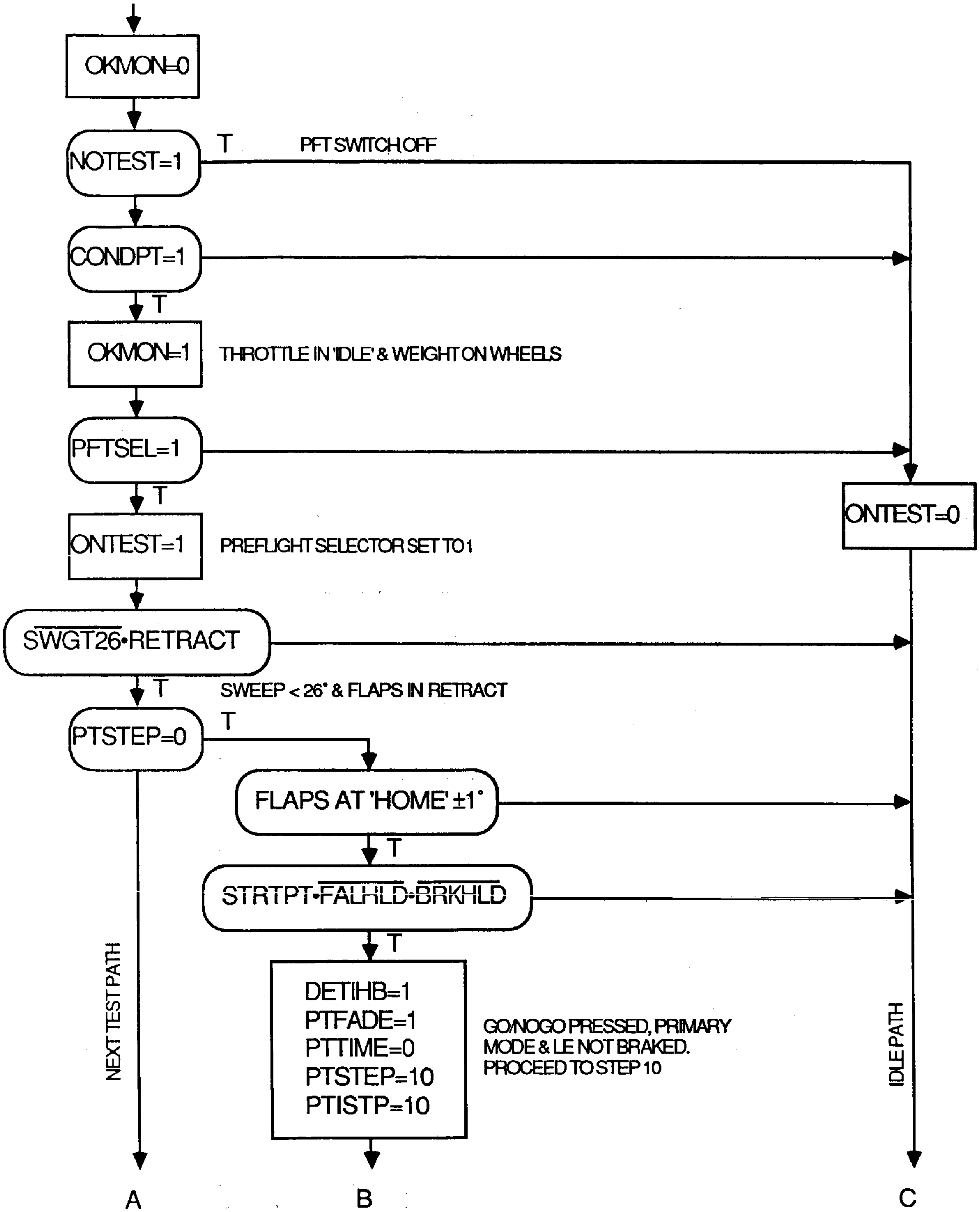


Figure 12. Preflight test flow diagram.

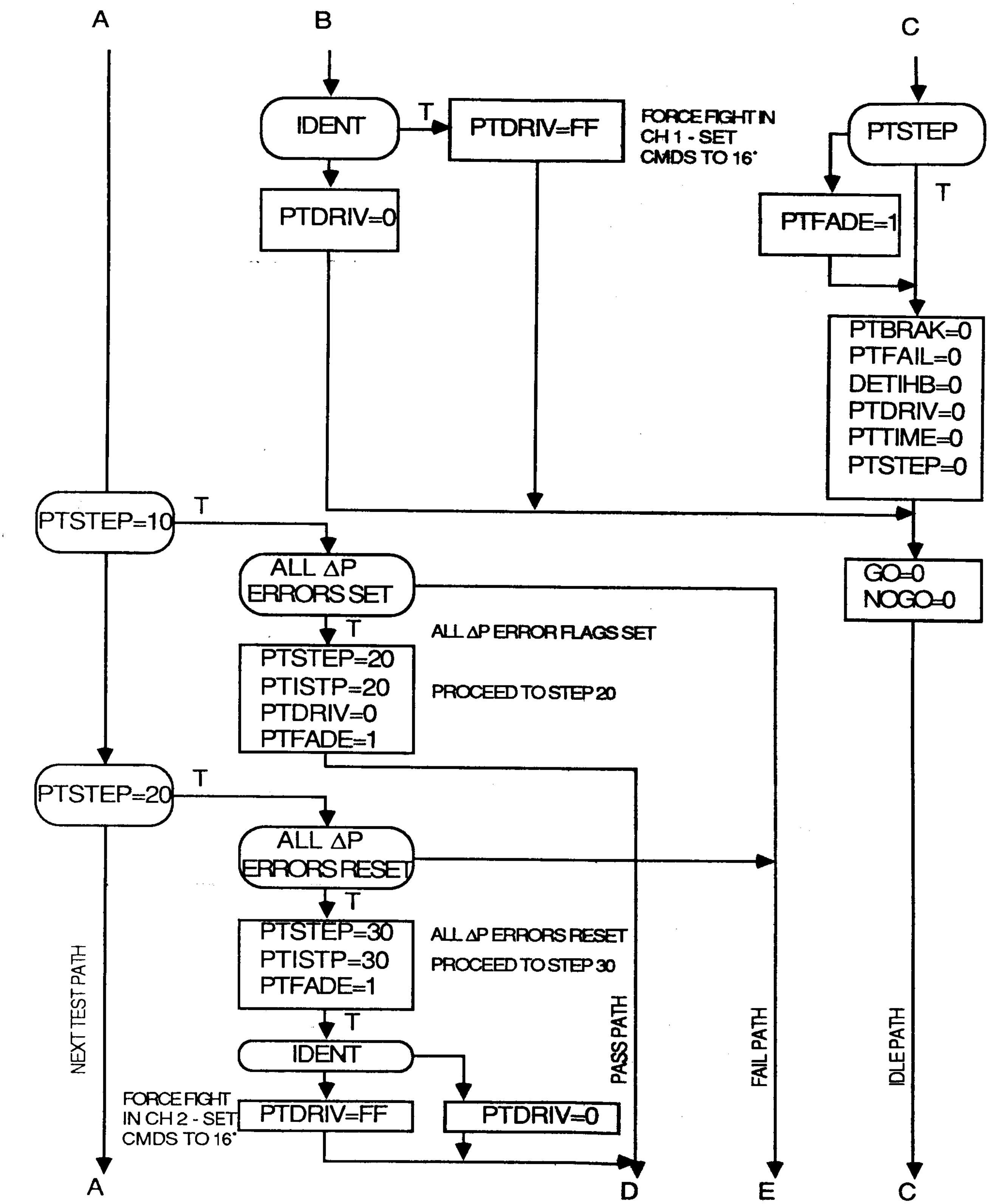


Figure 12. Preflight test flow diagram - continued.

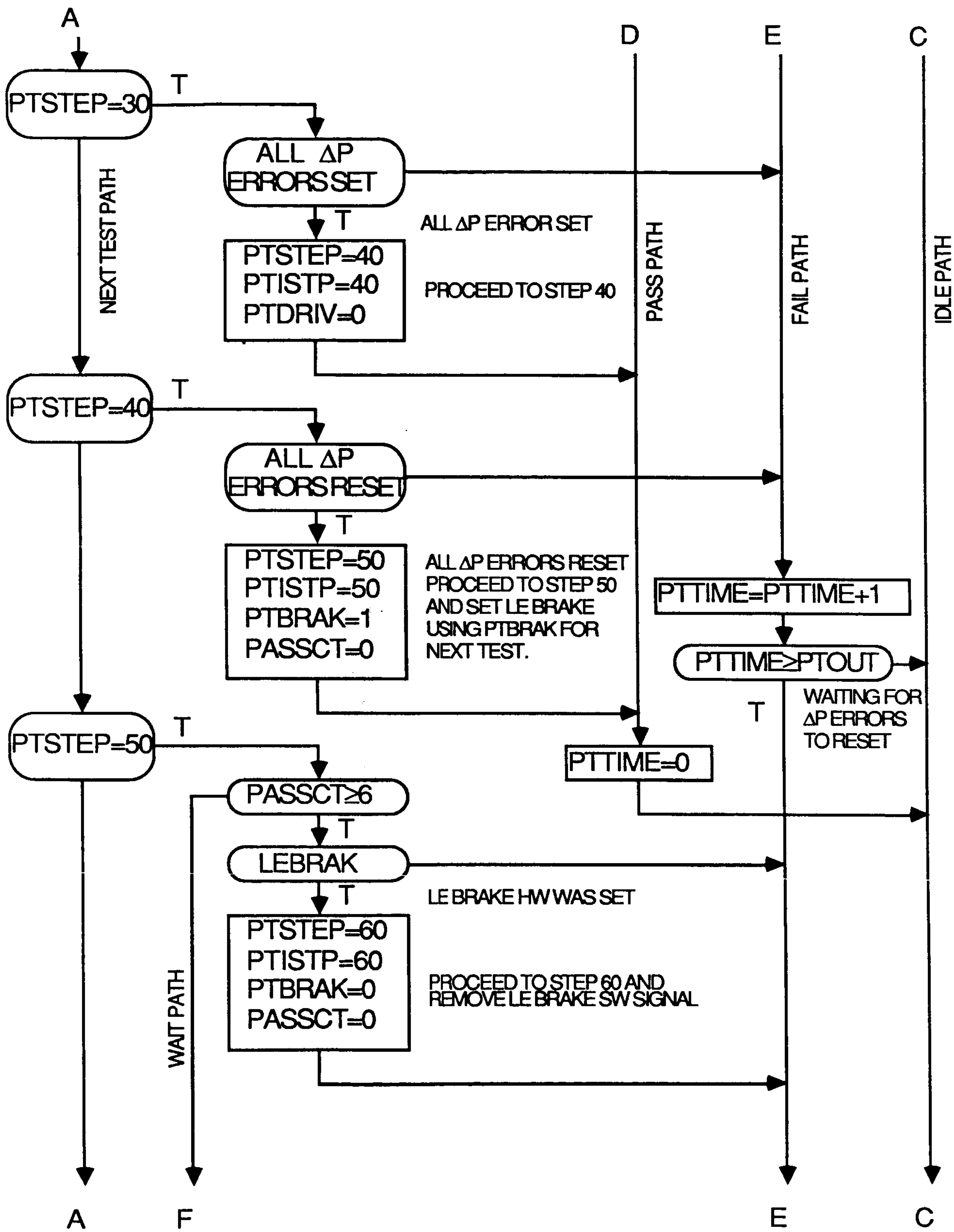


Figure 12. Preflight test flow diagram - continued.

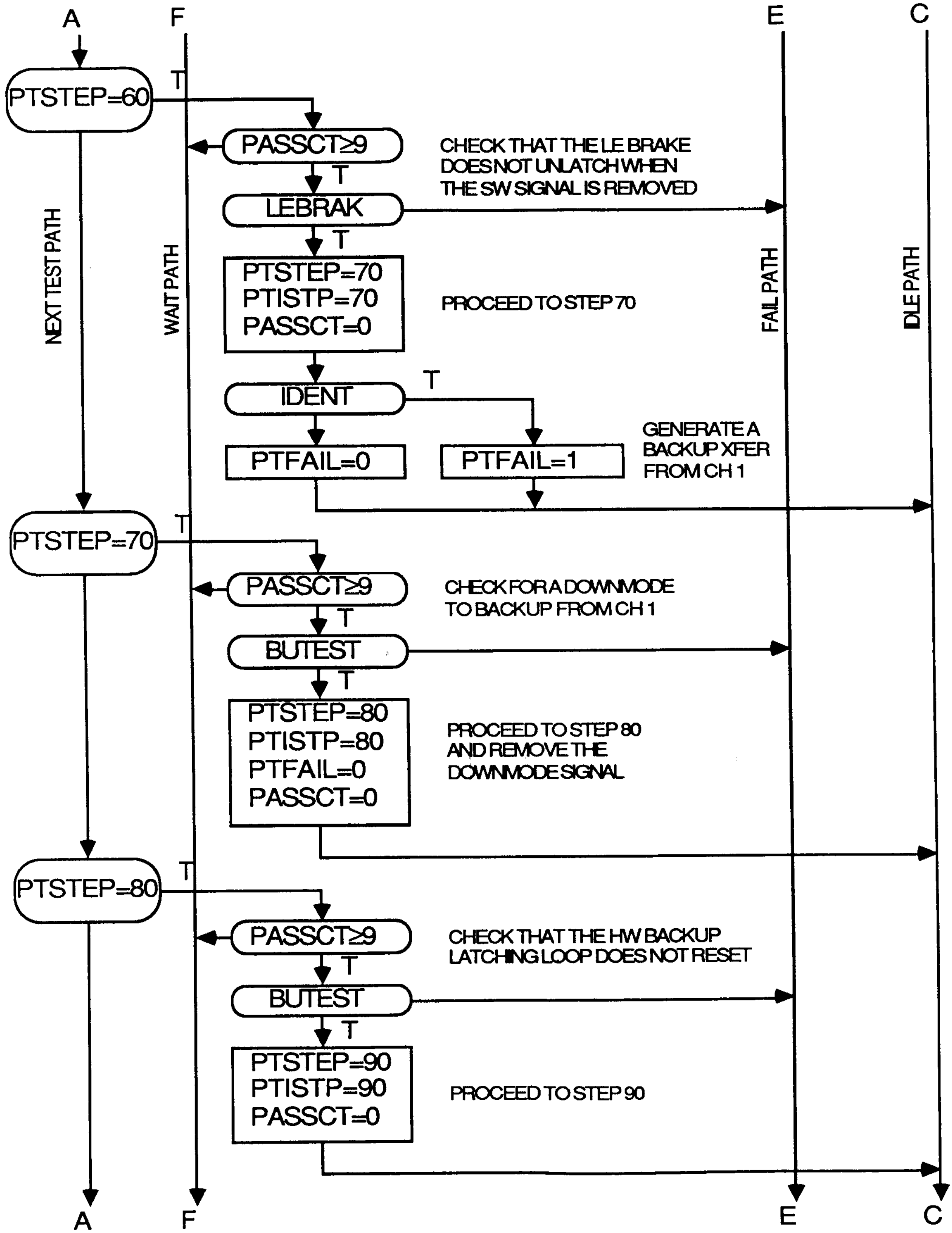


Figure 12. Preflight test flow diagram - continued.

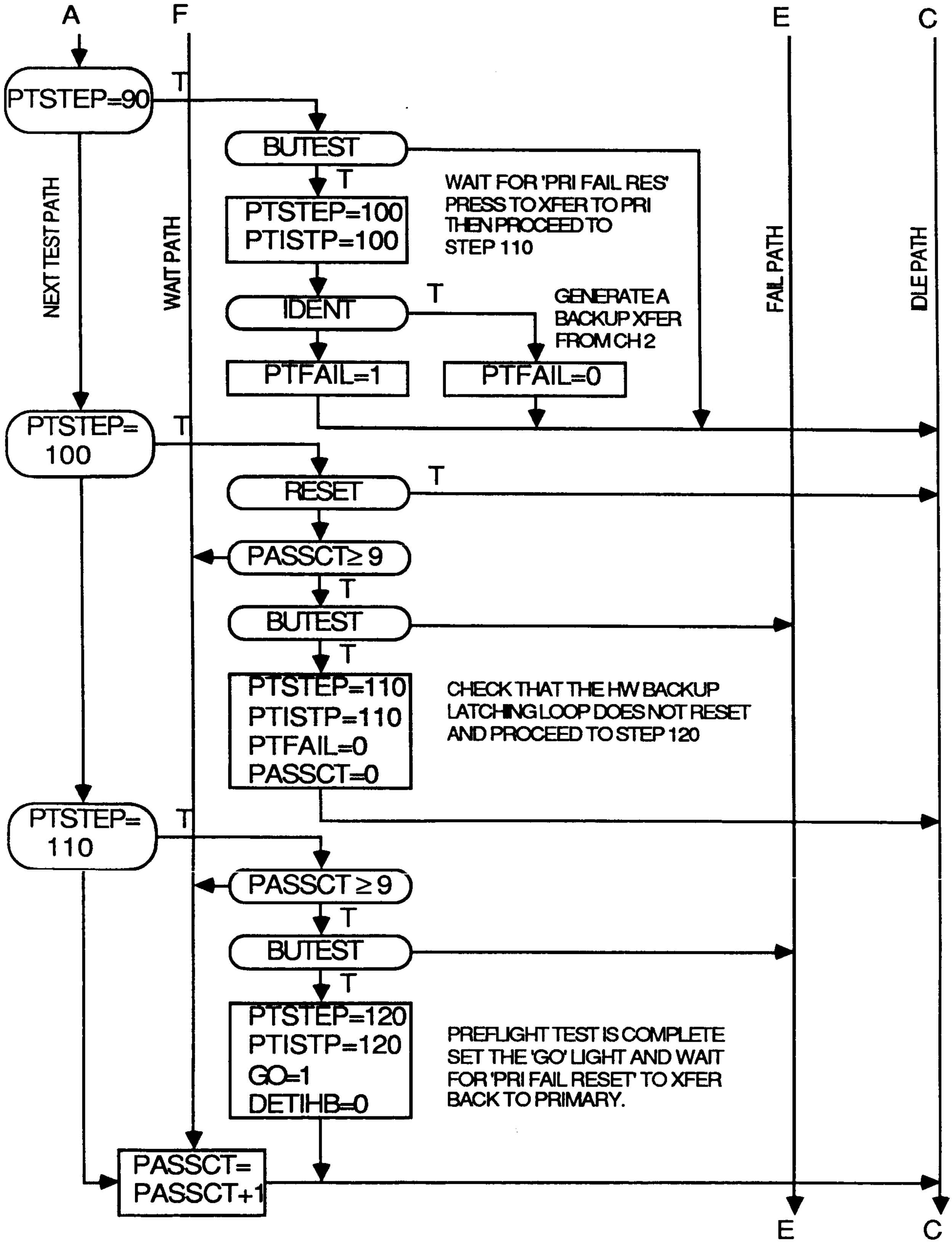


Figure 12. Preflight test flow diagram - continued.

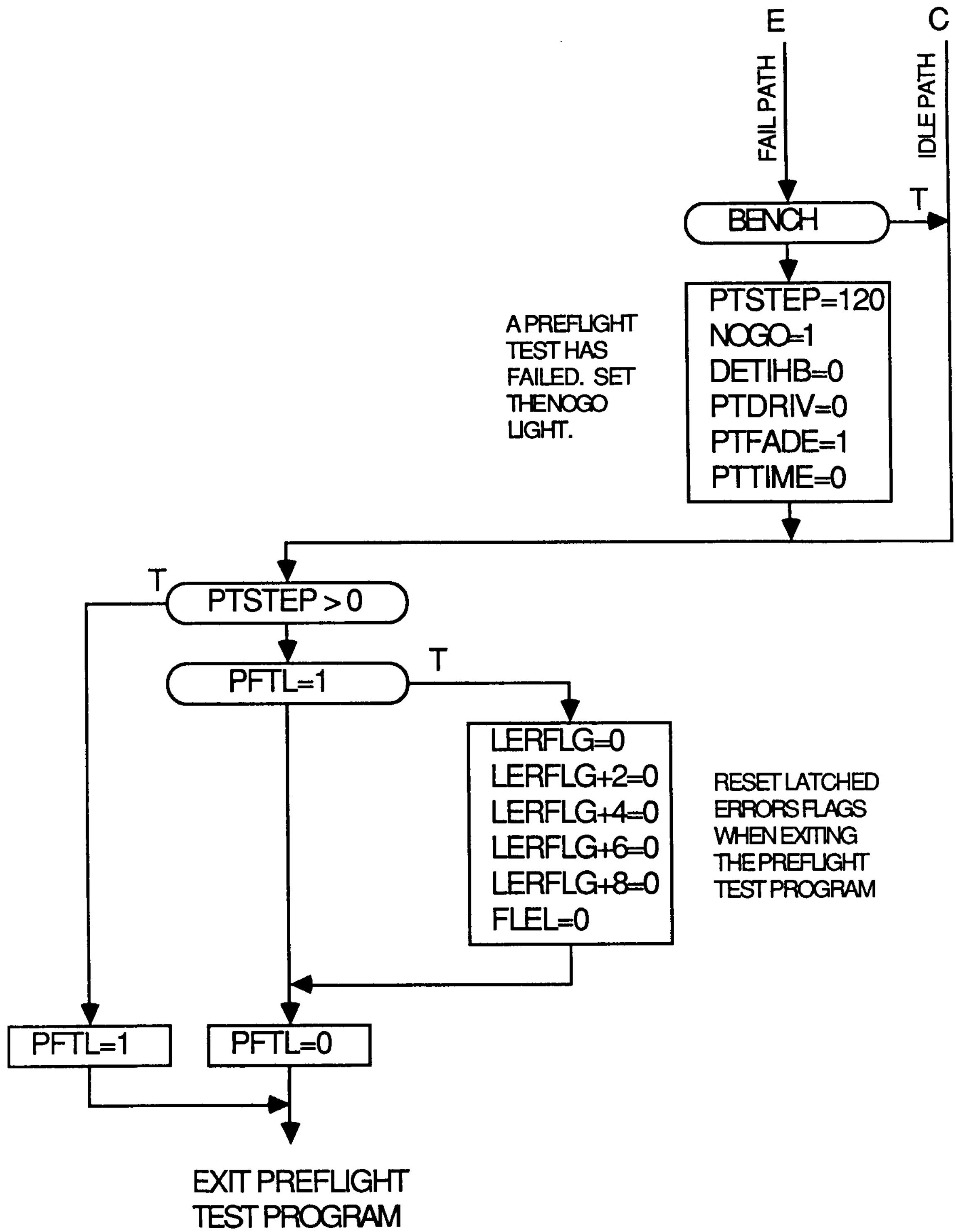


Figure 12. Preflight test flow diagram - concluded.

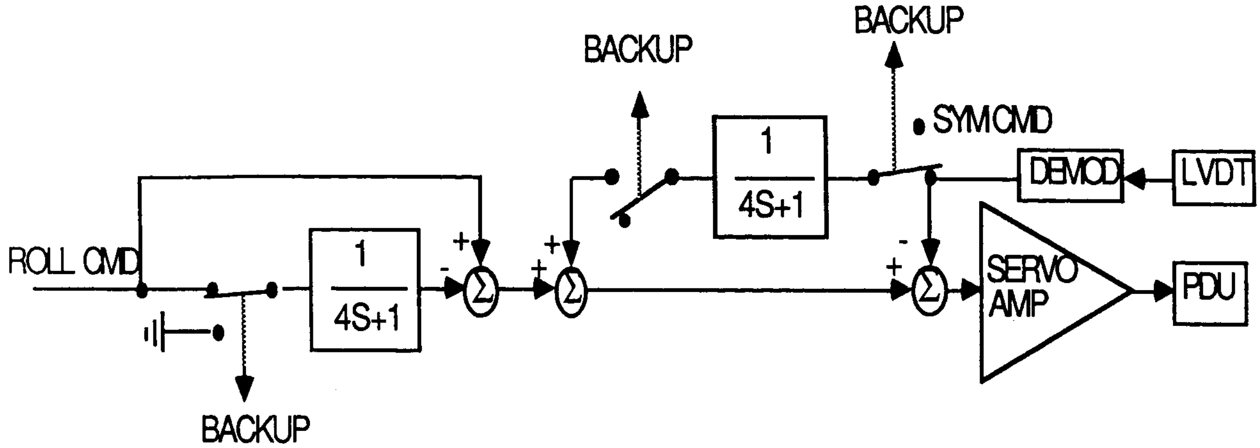


Figure 13. Backup command fade-in.

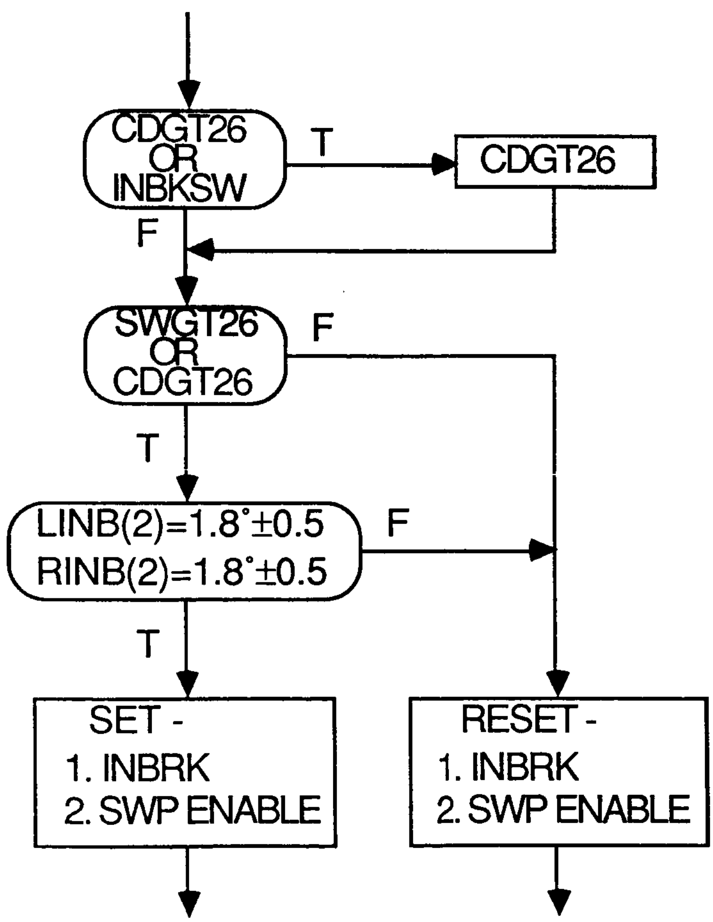


Figure 14. Wing sweep logic - Backup system.

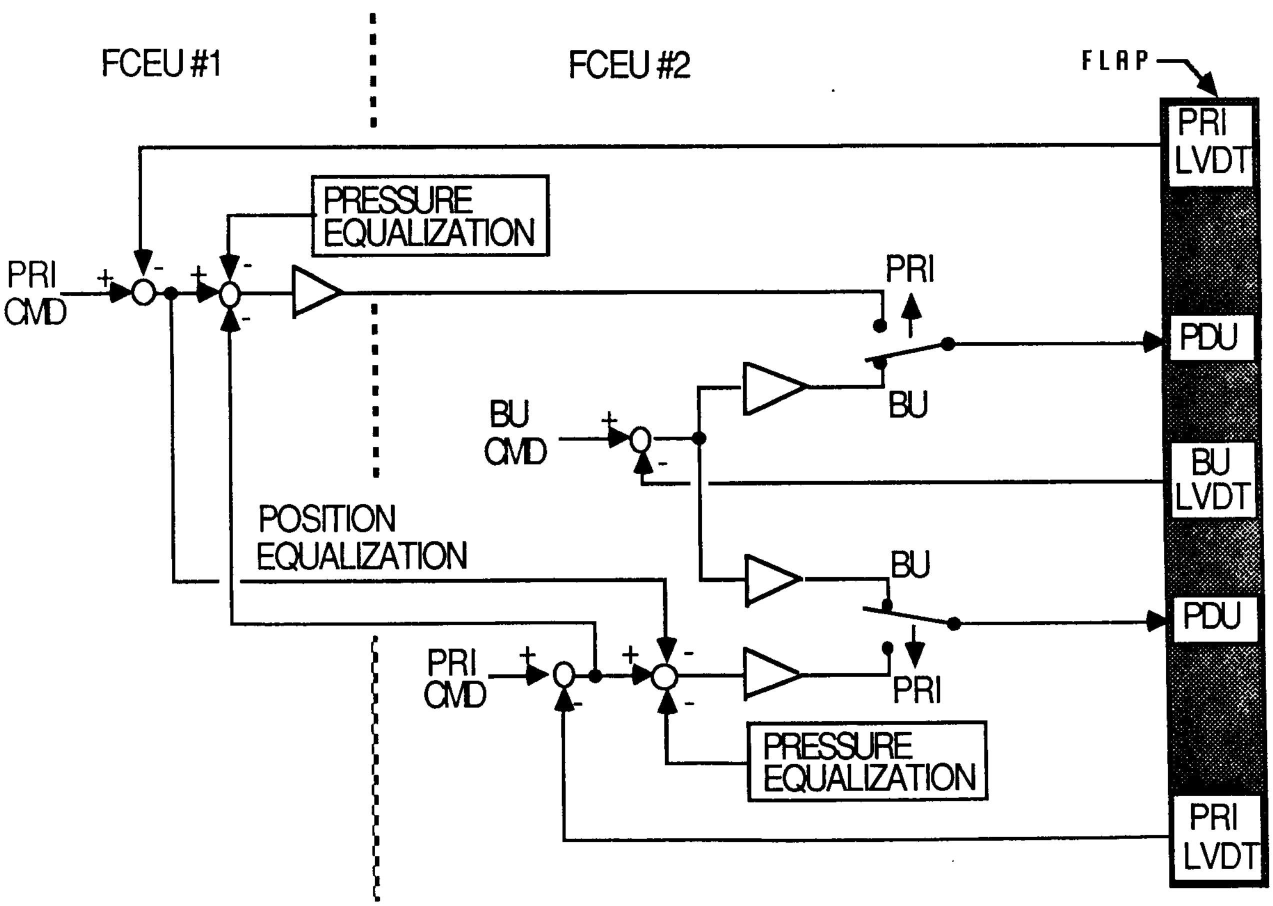


Figure 15. Servo feedback electronics.

APPENDIX - MAW FAIL ANNUNCIATOR DESCRIPTION

This appendix contains details of the MAW panel annunciator light interpretation. The flight control system redundancy management for both primary and backup and possible failures to generate these situations are discussed.

Primary Failures - Stay in Primary

1. Annunciation - QC FAIL

   Redundancy management -
   (a) Flap switch in HALF or FULL - fix the roll gain at 100 percent and allow full authority for the TE flaps.
   (b) Flap switch in RETRACT - fix the roll gain at 27 percent and set the TE flap limit at 4° down. If the TE flaps have been slewed down, they will drive to 2°.

   Possible failures/causes -
   (1) ΔQC probes differ by 100 lb/ft^2. This could be caused by unusual airplane manuvering. Failure is resettable if the probes agree within 100 lb/ft^2.

2. Annunciation - LE BRAKE
   MAW CAUTION (flashing)

   Redundancy management -
   Set Leading Edge brakes in current position.

   Possible failures/causes -
   (1) Flap position - Δ3° difference between the left and right LE positions. (This can be confirmed by the LE cockpit meters.) This failure is not resettable. This could be caused by any of the four LE brakes or the four blocking valves sticking in any one of the LE flap PDU's.
   (2) Flap command - Δ1.5° difference between channel 1 and 2 commands. This could be caused by an LE command input discrete difference, such as, an open LE SLEW discrete.

(3) Flap ideal model - $\Delta 5^\circ$ error between the LE ideal flap position model and the actual position. This could be caused by an open or nonfunctioning leading edge LVDT (any one of 4).

(4) Servo differential pressure - $\Delta p \geq 3600$ lb/ft^2 of force fight across an LE flap surface. This could be caused by a stuck LE brake, blocking valve, failed Δp transducer, or binding in the LE linkage. The Δp is the difference between ch 1 and 2 for a given flap surface.

3. Annunciation - MAW CAUTION (flashing)

Redundancy management -
None.

Possible failures/causes -
Flap ideal model - $\Delta 5^\circ$ error between any mid or outboard flap ideal position model and the actual position. This could be caused by an open or nonfunctioning roll flap LVDT. Also, continued and rapid roll stick cycling causes the hydraulics to bleed down, contributing to the error between the ideal model and the actual position.

4. Annunciation - IDENT (flashing)
MAW CAUTION (flashing)

Redundancy management -
None in the primary system. The power-up IDENT values are used for differentiation purposes. The new input IDENT discretes are monitored and a FIDENT fault is set whenever the discretes are the same (both false or both true).

If the backup system is entered, the roll flaps commanded from the faulted IDENT FCEU will be opposite in direction during roll stick inputs. This effect will neutralize the MAW rolling control and instead produce a speedbrake effect. The only roll control will come from the stabilator.

CAUTION - The faulty IDENT discrete can be determined immediately from TM data to the control room, however, if the TM is unavailable and it is neccessary to fly in the backup system, the pilot must set the brake in the failed backup system. If the good backup system is braked, the remaining backup channel will produce opposite flaperon roll control. This could be catastrophic because the differential tail might be overpowered by the two remaining flaperons. The failed backup system can be determined by applying roll control and observing which flaperon set is opposite to the stick commands.

Possible failures/causes -

The IDENT discrete in both FCEU's are receiving the same value. This could result from the following causes: (1) the IDENT wire to channel 1 breaks, (2) IDENT wire to channel 2 is grounded, (3) discrete converter failure in either FCEU fails.

Primary Failures - Downmode to Backup

1. Annunciation - LE BRAKE
   BACKUP
   PRI FAIL RESET
   MAW CAUTION (flashing)

Redundancy management -

The commands are faded gently through a 4-sec time constant first-order filter when a static primary system transfers to backup. However, transfers will be abrupt if the primary system is in rapid motion prior to the downmode. For any downmode the leading edge flaps are braked in their existing position.

Possible failures/causes -

(1) Flap command - $\Delta 1.5^{\circ}$ difference between channel 1 and 2 commands for any TE surface (inboard, mid, or outboard). This could be caused by a TE command input discrete difference. Examples would be the following:
   (1) Open ALL TE, IN, MID, OUT SLEW discretes up or down
   (2) Open HALF or FULL flap switch discrete
   (3) Open MAW roll trim discrete.

(2) Flap ideal model - $\Delta 5^{\circ}$ error between the left or right inboard ideal flap position model and the actual position. This could

be caused by an open or nonfunctioning inboard LVDT (any one of 4).

(3) Servo differential pressure - $\Delta p \geq 3600$ lb/ft^2 of force fight across any TE flap surface. This could be caused by a stuck TE brake (12 total), blocking valve (12 total), failed Δp transducer (12 total), or binding in any TE linkage.

(4) Output discretes - difference in a common output discrete. This could be caused by only one channel declaring a model fault for a given roll flap. (A model fault sets the MASTER discrete to light the MAW CAUTION annunciator and only one MASTER discrete is set.)

(5) Stick monitor - a 0.8 volt of disagreement for the primary stick transducer has been detected. This could be caused by a open winding in one of the transducers or a faulty stick monitor chip.

(6) Power supply - The power supplies for each FCEU are dual (one generator and one battery per channel). Even if an engine failed, the main power bus would get power from the other side and no redundancy would be lost. However, a single failure in the power supply monitor chip in either box (5 volt, ±15 volt, or 26 vac) would cause the loss of the primary system.

(7) Hydraulic pressure - low primary or utility hydraulic pressure less than 1200 lb/ft^2 or failed hydraulic pressure monitor chip.

(8) Built-in tests - (1) ROM memory sum check, (2) cross channel data transfer, (3) RAM memory check (at power up only), and (4) watchdog timer. These cannot be reset.

Backup Failures - Do Not Set Brakes

1. Annunciation - QC FAIL (backup sensed)

Redundancy management -

This failure is declared independently of the primary system, however, the QC inputs are identical.

(a) Flap switch in HALF or FULL - fix the roll gain at 100 percent and allow full authority for the TE flaps.

(b) Flap switch in RETRACT - fix the roll gain at 27 percent and set the TE flap limit at 4° down.

(c) If the QC fail is declared in only one of the backup channels, then only that channel will be affected by the QC fail RM logic.

Possible failures/causes -

(1) ΔQC probes differ by 100 lb/ft^2. This could be caused by unusual airplane manuvering. Failure is resettable if the probes agree within 100 lb/ft^2.

(2) Faulty QC fail monitor chip. A latch could be set due to a noise spike.

2. Annunciation - A and B STATUS
MAW CAUTION (flashing)

Redundancy management -

None. This test is executed only while the system is in the primary system. It tests for a command difference between backup channels A and B. The failed backup system cannot be determined from this test alone; however, once a transfer to backup is made, other fault tests would likely cause the brakes to be set in the failed channel.

Possible failures/causes -

Aliveness monitor comparision - cross backup channel command error greater than 0.5 volts between channel A and B. This could be caused by an open discrete in the flap switch. For example, if the A backup FULL discrete were open when the flap switch was placed in the FULL position, this type of error would be declared. If the backup system were entered under these conditions, the A flaps would drive to 2° (RETRACT) and the B flaps would stay at 18° (FULL). The inboard flaps would be braked at 18° because of a model fault.

3. Annunciation - A and/or B STATUS momentarily flash

Redundancy management -

None. (Flaps are in HALF or FULL.)

Possible failure/causes -

Roll flap ideal model - Δ5° error between the mid or outboard roll flaps ideal position model and the actual position. The A or B status lights will light only during the time the fault is being detected. This situation can exist only if the flap switch is in HALF or FULL. The most common cause is continued rapid stick cycling.

4. Annunciation - None on MAW panel. A/C LOW HYDRAULICS

Redundancy management -
Bypass valves all opened on failed hydraulic PDU's. All the backup flaps are being driven at one end only and by one PDU. All backup functions still exist; however, possible slower roll flap rates and greater tendency for model faults also exist.

Possible failure/causes - loss of a hydraulic system or failure of a hydraulic pressure transducer.

Backup Failures - Set A, B, and/or INBD Brakes

1. Annunciation- A, B, or INBD STATUS

Redundancy management -
Set the brakes for the A, B, and/or INBD flaps, depending on which flap set has declared a fault. The unbraked flaps will continue to function. When the system is in primary, set the annunciators only.

Possible failures/causes -
(1) Valve current comparision - test for a disagreement in the PDU commands from a given backup channel to a particular flap(s). This could be caused by a faulty operational amplifier to one of the PDU commands.
(2) Position limit - one of the TE flaps has exceeded the QC position limit. This could be caused by one of the flaps exceeding the TE down position limit while the TE flaps were being QC limited (fig. 10).
Also, this error would result if a QC fail occurred and the flap switch was positioned from FULL to RETRACT.
(3) Flap ideal model - $\Delta 5^{\circ}$ error between the ideal roll flap position model and the actual position. (This is only for the

flap switch in the RETRACT position.) This could be caused by continued and rapid stick cycling or a nonfunctioning LVDT.

(4) Stick monitor - A 0.8 volt disagreement has occurred in a stick transducer set for either the A or B backup systems. This could be caused by an open winding in one of the transducers or a failed stick monitor fault.

(5) Power supply - Each partitioned backup system has a dual redundant power supply (one generator and one battery per channel). Even if an engine failed, the main power bus would get power from the other side and no redundancy would be lost. However, a single failure in the power supply monitor chip in either box (5 volt, ±15 volt, or 26 vac) would cause the loss of the flaps driven by that backup system, including the inboard flaps.

1. Report No. NASA TM-88267	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle AFTI/F-111 MAW Flight Control System and Redundancy Management Description		5. Report Date February 1987
		6. Performing Organization Code
7. Author(s) Richard R. Larson		8. Performing Organization Report No. H-1368
		10. Work Unit No. RTOP 533-02-11
9. Performing Organization Name and Address NASA Ames Research Center Dryden Flight Research Facility P.O. Box 273 Edwards, CA 93523-5000		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The wing on the NASA F-111 transonic aircraft technology (TACT) airplane was modified to provide flexible leading and trailing edge flaps; this modified wing is known as the mission adaptive wing (MAW). A dual digital primary fly-by-wire flight control system was developed with analog backup reversion for redundancy. This report discusses the functions, design, and redundancy management of the flight control system for these flaps.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Advanced fighter technology integration; Fault isolation; Flight control system; Mission adaptive wing; Redundancy management; System architecture	Unclassified — Unlimited Subject category 05

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	71	A04

*For sale by the National Technical Information Service, Springfield, Virginia 22161.