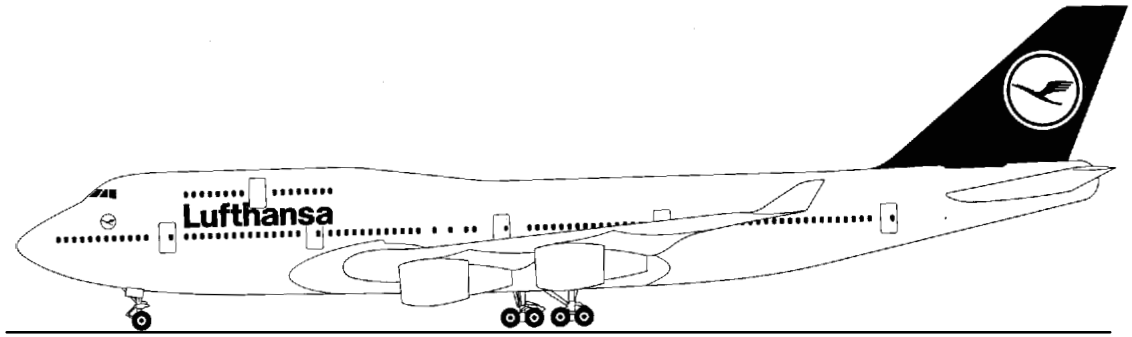
Lufthansa Technical Training

Training Manual B 747-400



ATA 22-1 1 AFDS INTERLOCKS

ATA Spec. 104 Level 3

Book No:

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Technical Training GmbH
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Issue: May 2001
For Training Purposes Only

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ATA 22-1 1 AFDS INTERLOCKS

AUTOPILOT ENGAGE INTERLOCKS

Introduction

The autopilot engage interlock circuits in the FCC monitor the operation, power and components of the AFDS. When normal conditions exist, the circuits allow the autopilot to engage and to remain engaged. When the circuits detect certain non-normal conditions, the autopilot disengages or is prevented from engagement.

Autopilot Servos

There are two kinds of servos for aileron control. These are central lateral control package (CLCP) and lateral autopilot servo. The left and right autopilots use CLCPs and the center autopilot uses a lateral autopilot servo. The servos for elevator control are elevator autopilot servos. The servos for rudder control are rollout power control packages. These will be referred to as aileron servos, elevator servos and rudder servos in this section.

Autopilot Engine

Autopilot Engage starts by a push of the CMD button on the MCP. This makes the engage request.

in addition to proper input power (115v ac and 28v dc), these AFDS components must be valid to engage:

- Flight control computer
- Mode control panel
- Aileron and elevator A/P servos

Data and conditions monitored on the cross-channel inputs and sensors must also be proper to engage. The FCC supplies ARM and ENGAGE voltage to the aileron, elevator and rudder servos.

Manual Disengage

The operation of either the A/P disengage switch or the disengage bar disengages the autopilot.

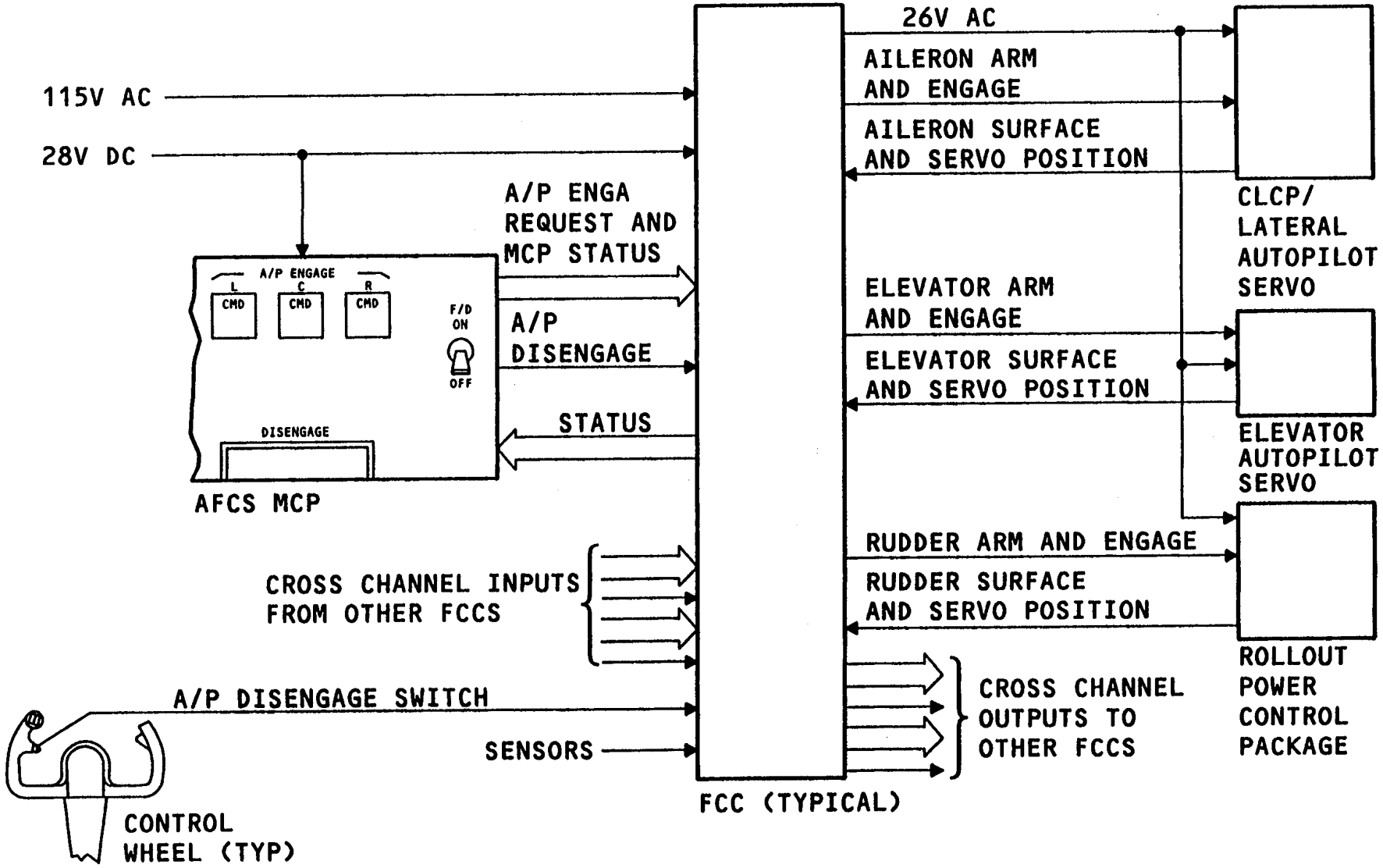

Figure 1 AUTOPILOT ENGAGE INTERLOCKS

ENGAGE INTERLOCK INPUTS

Power

Ac and dc power is required to enable A/P engagement. The 28v DC STBY BUS must be present to engage the autopilot. If an autopilot is engaged, loss of this BUS does not disengage the autopilot.

A/P Engage Request

A/P engage starts by a push of the engage button on the AFDS MCP. The A/P engage logic in the FCC receives the A/P engage request and MCP status and starts the engage process.

A/P Disengage

The method for the pilot to disengage the autopilot is to use the disengage bar switches or the A/P disengage switches.

Cross Channel Data

The right and center FCCs send engage status and cross channel data to the left FCC.

Autotrim Valid

Autotrim valid from the stabilizer trim/rudder ratio module (SRM) is required to stay engaged if single channel.

Sensor Data

Valid inner loop sensor data is required to engage the AFDS. Valid autoland sensor data is required for multichannel engagement.

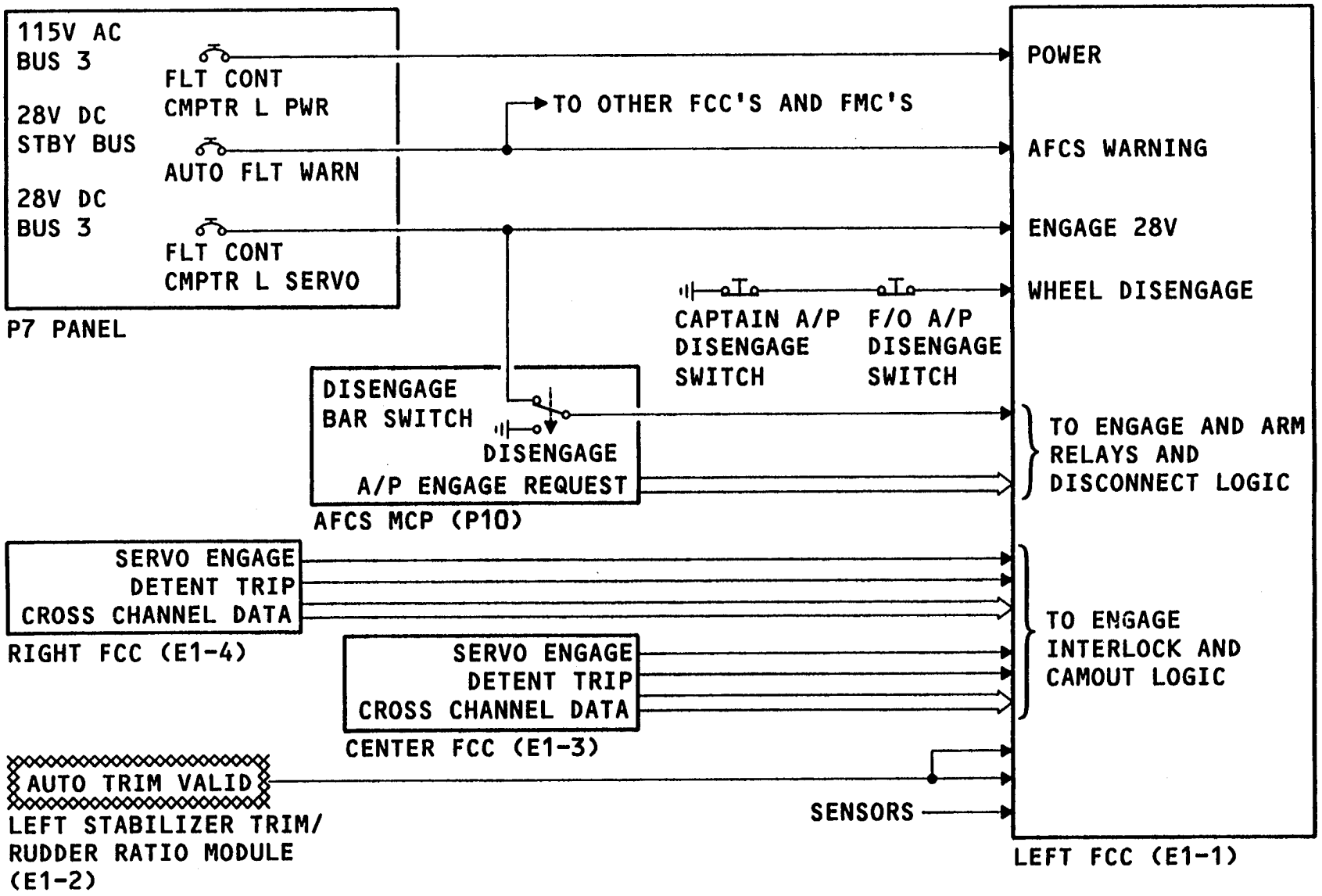

Figure 2 ENGAGE INTERLOCK INPUTS

ENGAGE INTERLOCK OUTPUTS

Power

The servo LVDTs and surface LVDTs in the aileron, elevator and rudder servos receive 26v ac from the FCC.

A/P Solenoids and LVDTS

Arm and engage discretes energize the solenoids in the aileron, elevator and rudder servos. The FCC monitors the servo and surface LVDTs for synchronization.

Cross Channel Data

The left FCC supplies servo engage status, detent trip status and cross-channel data to the right and center FCCs.

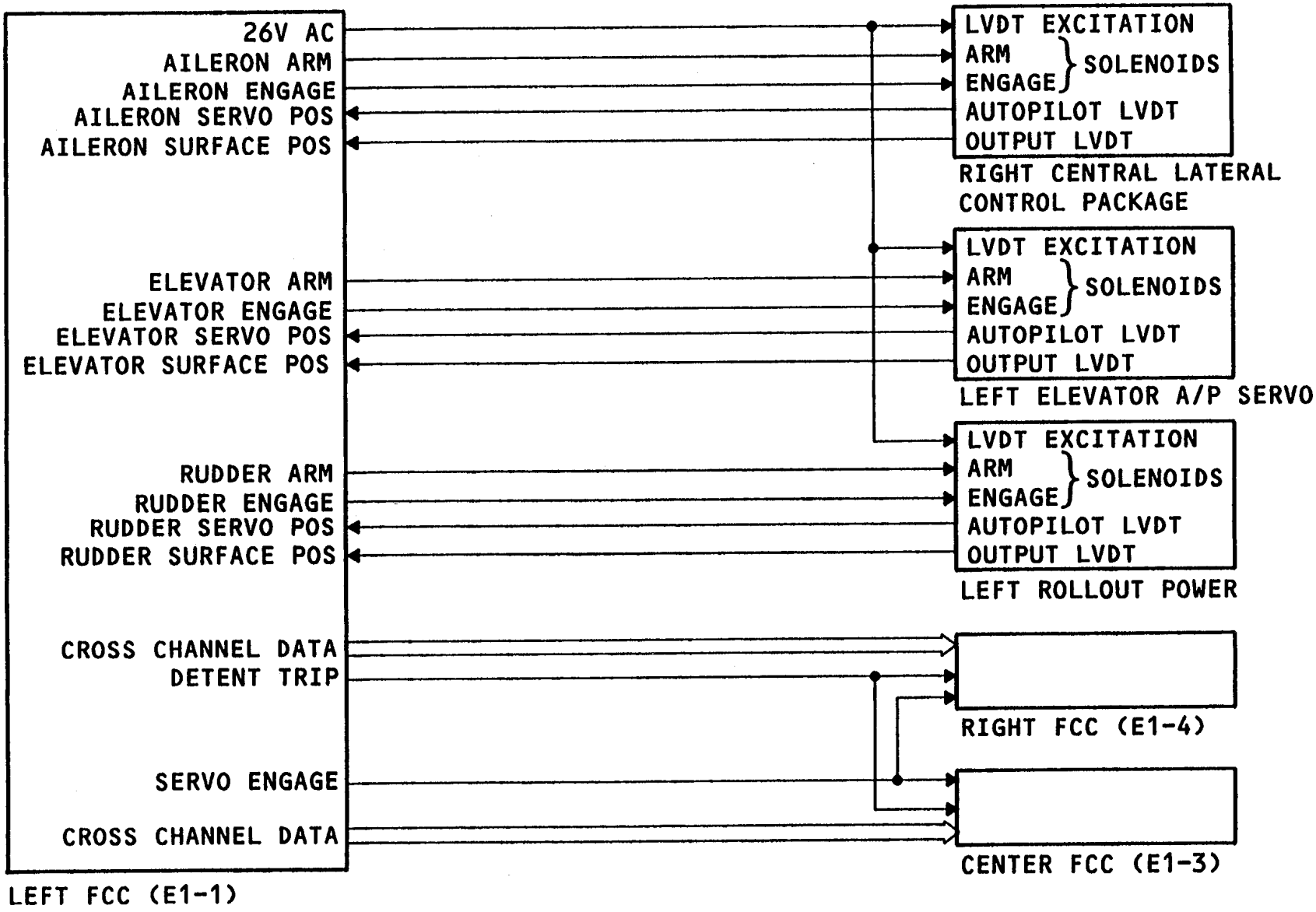

Figure 3 ENGAGE INTERLOCK OUTPUTS

ENGAGE INTERLOCK OPERATION

Power

DC power arms the contacts of four relays in the FCC. DC is also applied through the disengage bar switch to energize the ARM and ENGAGE relays.

Elevator and Aileron Arm

The arm phase of autopilot engagement starts by a push of the CMD pushbutton. The request goes through the data bus to the ELEV/AIL ARM logic. With normal conditions, the logic energizes the ELEV/AIL ARM relay. This energizes the ARM solenoids in the aileron and elevator servos. The CMD light on the MCP comes on and the CMD annunciation on the PFD. shows.

Elevator and Aileron Engage

At the end of the arm phase, engage status is initiated by the ELEV/AIL ENGAGE logic. The ELEV/AIL ENGAGE relay energizes. This energizes the ENGAGE solenoids in the aileron and elevator servos.

Rudder Arm

Rudder arm begins with multi-channel arm. The RUDDER ARM logic energizes the RUDDER ARM relay. This energizes the ARM solenoid in the rudder servo.

Rudder Engage

When multi-channel engage begins, the RUDDER ENGAGE logic energizes the RUDDER ENGAGE relay. This energizes the ENGAGE solenoid in the rudder servo.

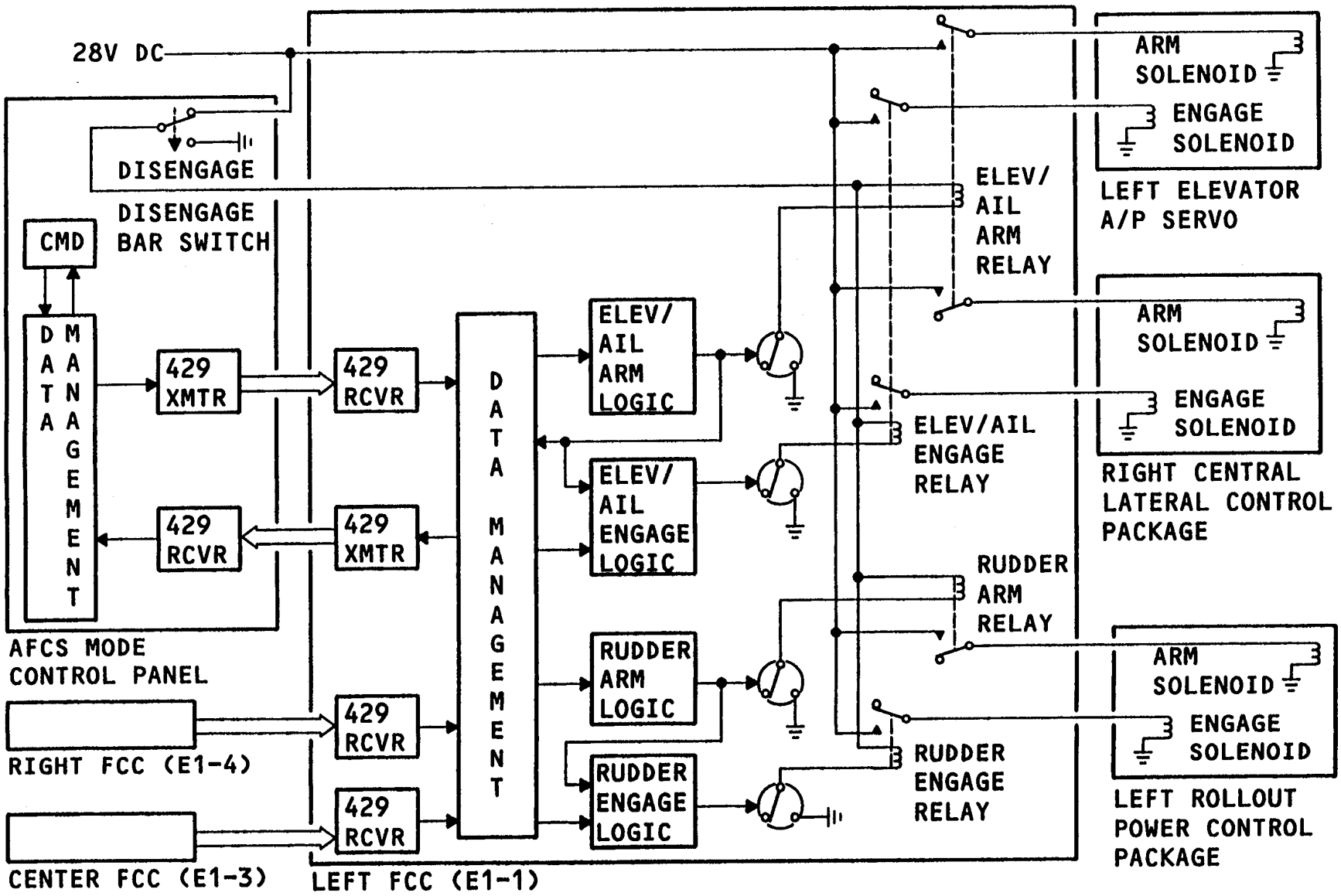

Figure 4 ENGAGE INTERLOCK OPERATION

ELEVATOR/AILERON ARM AND ENGAGE LOGIC

Elevator/Aileron Arm

At arm initiation, with the conditions as shown, this will occur:

- ELEV/AIL ARM logic provides the ground for the ELEV/AIL ARM relay.
- HYD ARM voltage is applied to the aileron and elevator servos.
- ELEV/AIL ENGAGE logic is enabled.
- ARM removal conditions and faults are monitored.

Arm initiation, arm inhibit faults, arm removal conditions and arm removal faults will be discussed later.

Elevator/Aileron Engage

With ARM and other conditions as shown, this will occur:

- ELEV/AIL ENGAGE logic provides the ground for the ELEV/AIL ENGAGE relay.
- HYD ENGAGE voltage is applied to the aileron and elevator servos.
- SERVO ENGAGE logic is produced and sent to the other FCCs.
- ELEV/AIL ENGAGE removes the arm logic.

Engage initiation, engage removal conditions and engage removal faults will be discussed later.

Data Management

Data from the ELEV/AIL arm and engage logic hardware is sent to data management. This information is provided as cross channel data to the other FCCs and as data to the AFCS MCP. It is also used for mode control logic.

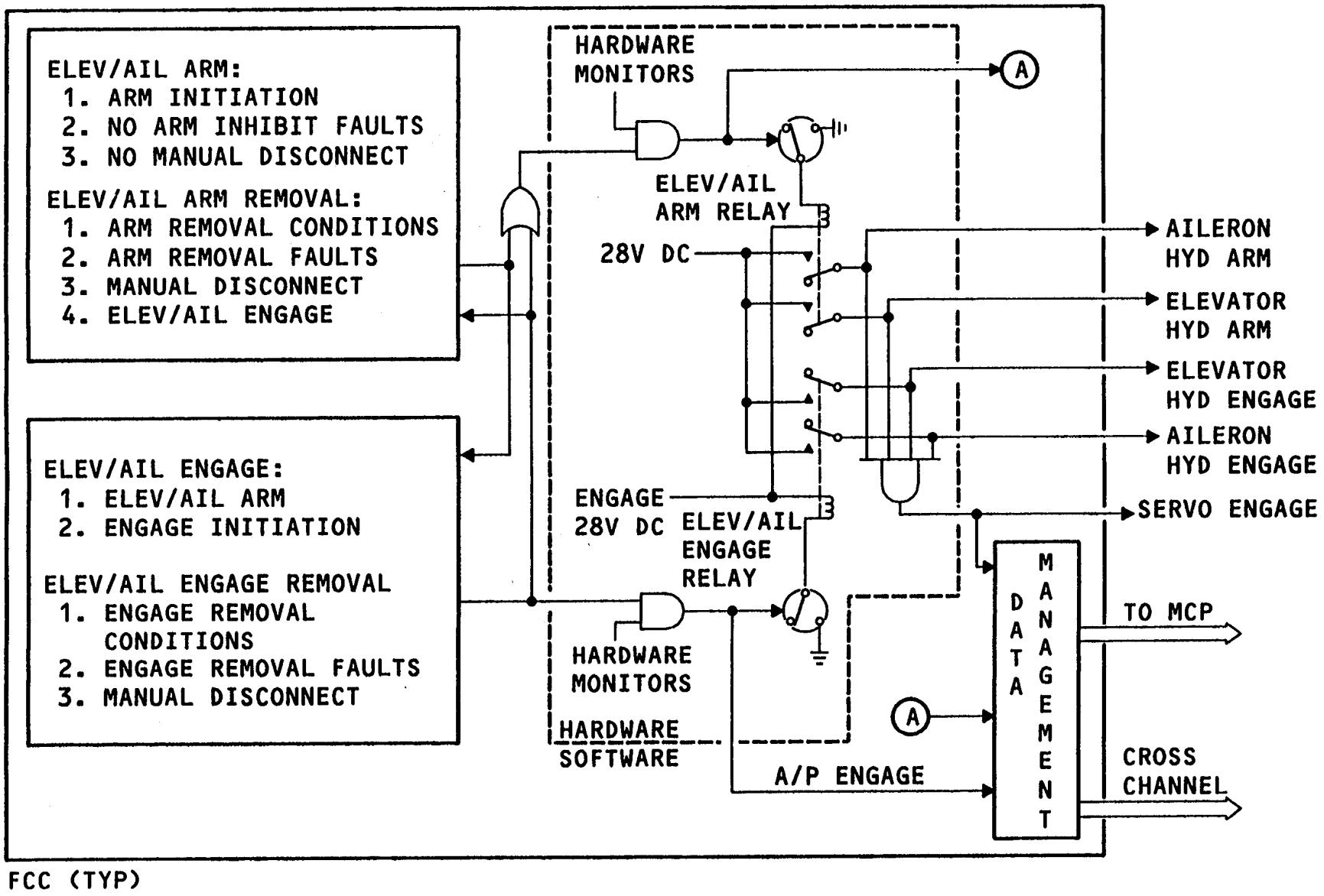

Figure 5 ELEVATOR/AILERON ARM AND ENGAGE LOGIC

RUDDER ARM AND ENGAGE LOGIC

Rudder Arm

At multi-channel arm (FOREIGN SERVO ENGAGE and LOCAL ARM or LOCAL SERVO ENGAGE and FOREIGN ARM) and with the conditions as shown, the rudder arm logic provides the ground for the rudder arm relay. This sends rudder arm to the rollout power control package.

Rudder arm removal faults will be discussed later.

Rudder Engage

At multi-channel engage (LOCAL SERVO ENGAGE and FOREIGN SERVO ENGAGE) and with the conditions as shown, the rudder engage logic provides the ground for the rudder engage relay. This sends rudder engage to the rollout power control package.

NOTE: THE TERM FOREIGN USED IN THIS SECTION REFERS TO THE RELATIVE LEFT OR RELATIVE RIGHT AUTOPILOT CHANNEL. THE TERM LOCAL REFERS TO THE AUTOPILOT CHANNEL CONTAINING THE LOGIC.

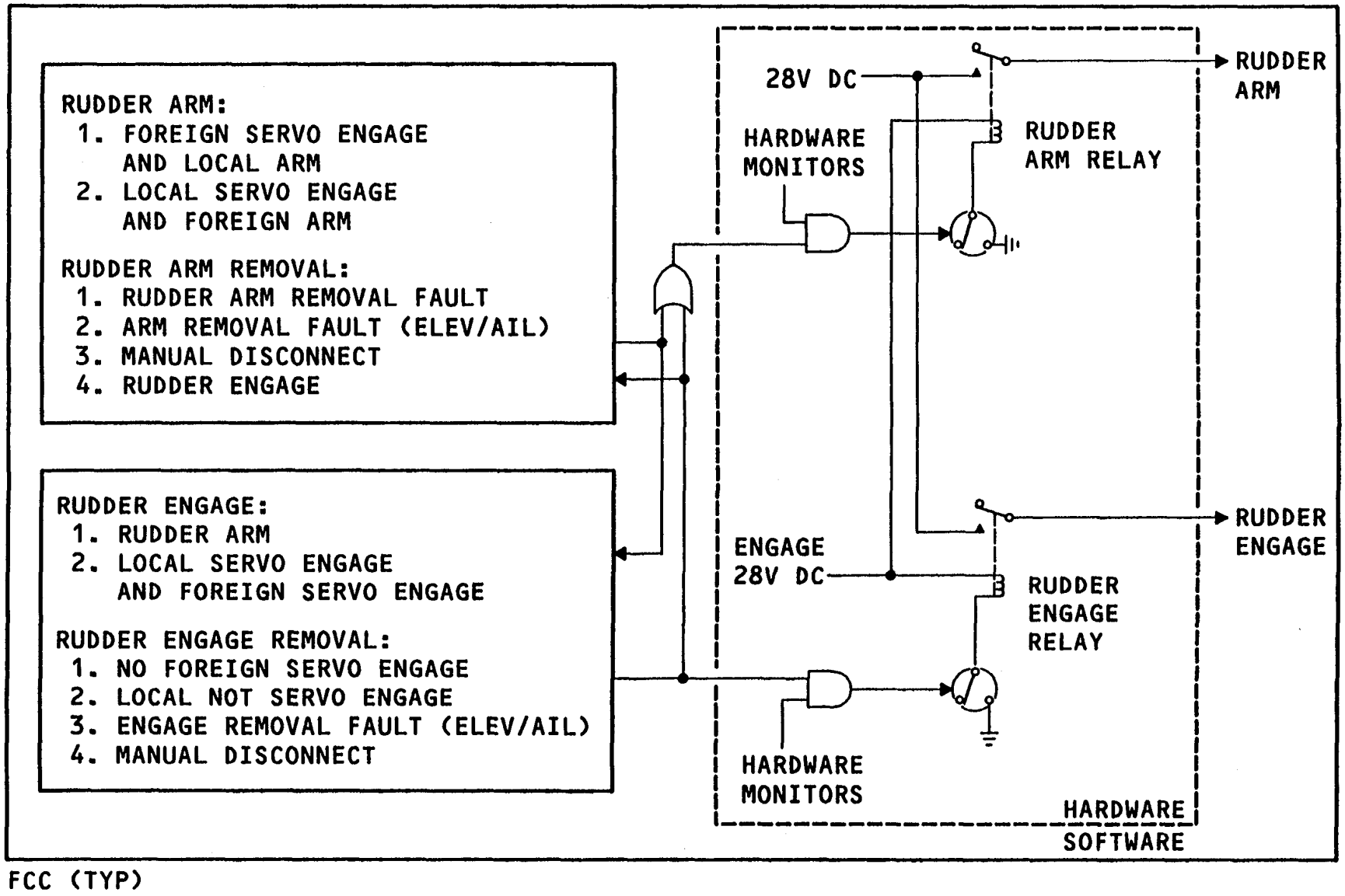

Figure 6 RUDDER ARM AND ENGAGE LOGIC

ARM INITIATION, INHIBIT & REMOVAL CONDITIONS

Arm Initiation

Arm initiation occurs in one of two ways. If there is no other autopilot channel armed or engaged, a command request from the MCP is required. Multichannel arm occurs when the approach mode is selected if there is an autopilot channel engaged.

Arm Inhibit

Three conditions inhibit the autopilot from the arm condition. These are:

- Power monitor fail
- Any solenoid energized
- Mode control panel not valid

The power monitor looks at all internal and external power necessary for the FCC to operate. This includes standby 28 v dc for warning logic.

Monitors on the arm and engage outputs of the FCC can tell if voltage is applied to any of these solenoids. If an arm or engage solenoid is energized before arm status, it means either the arm or engage relay has failed or a

short with a powered wire has occurred external to the FCC. This is called a hot short.

The MCP must be valid for arm initiation to occur because mode requests and the engage request come from there.

Arm Removal Conditions

Two conditions remove the arm status. The first is if another autopilot channel was engaged and that channel disengages. The second is if during single channel arm, the pilot has more than 25 degrees of control wheel movement.

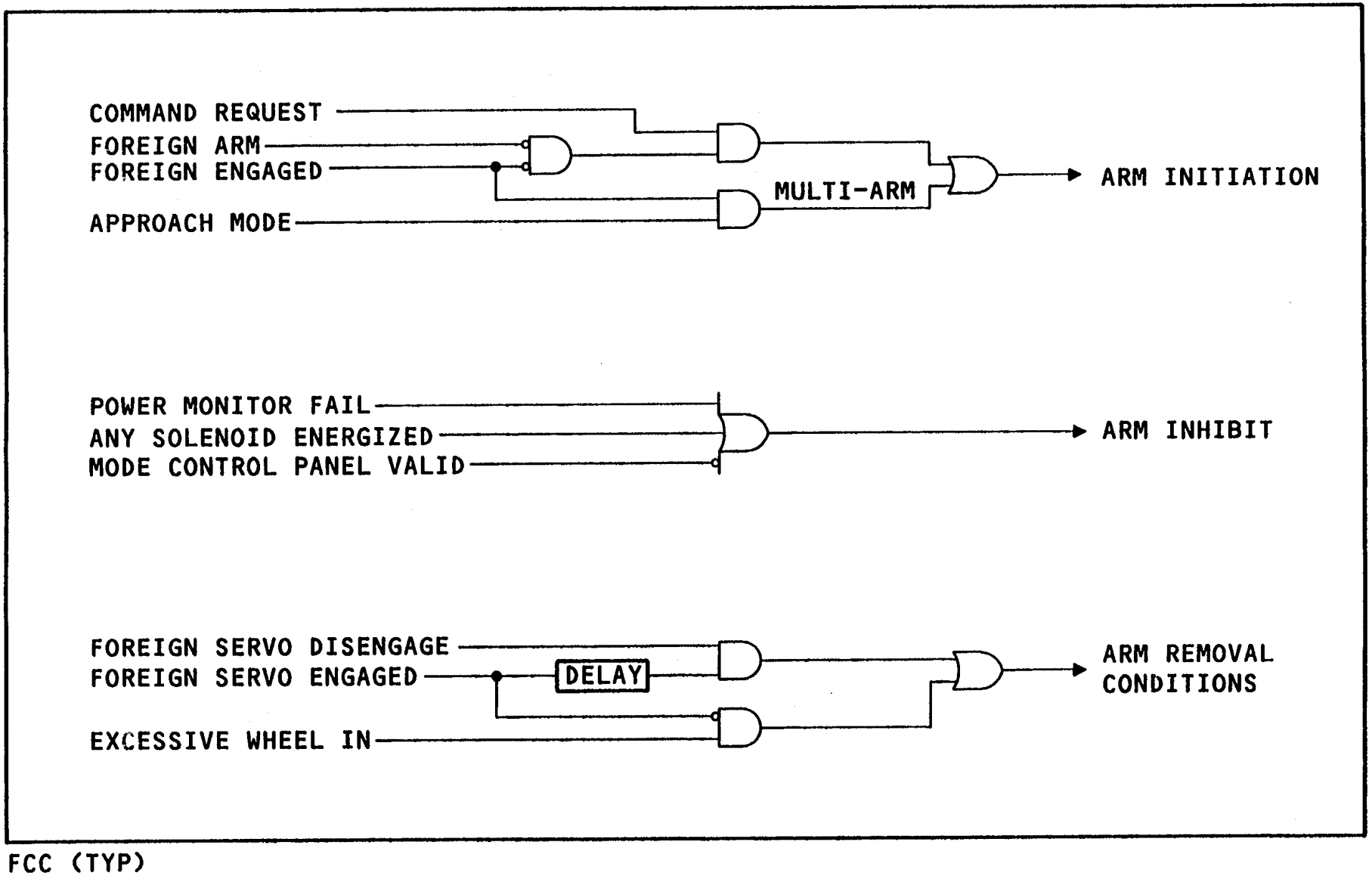

Figure 7 ARM INITIATION, INHIBIT & REMOVAL CONDITIONS

ARM REMOVAL FAULT LOGIC

Elev/Ail Arm Removal Fault

Faults which cause arm removal under any engaged conditions or status are described as follows:

- The FCC monitors program pins for proper parity.
- A servo loop monitor compares the FCC command with the servo position.
- The FCC monitors the autopilot servo LVDTs (arm and engage) for proper voltages to make sure there are no open or short circuits.
- The FCC monitors the engage solenoids for a hot short during arm status.
- The FCC compares autopilot servo position with surface position during arm to make sure the servo remains synchronized.
- The FCC monitors inner loop sensors for a dual failure.
- The FCC does continuous self-tests (wrap-around, input-output, etc.) and memory tests.

During multi-channel arm status, the autoland sensors are monitored for a dual failure.

During single channel arm, the rudder arm and engage solenoids are monitored for a hot short.

For single channel operation, the FCC aileron command is limited. Because of this, there is a monitor to make sure the FCC does not make a command larger than 25 degrees of control wheel. The FCC tests this monitor during single channel arm. if this test (called the aileron exceedance pre-engage test) fails, arm is removed.

Rudder Arm Removal Fault

During rudder arm status, similar conditions are monitored for the rudder servo as for elevator/aileron arm. In addition, internal FCC monitors and inner loop sensor monitors affect rudder arm.

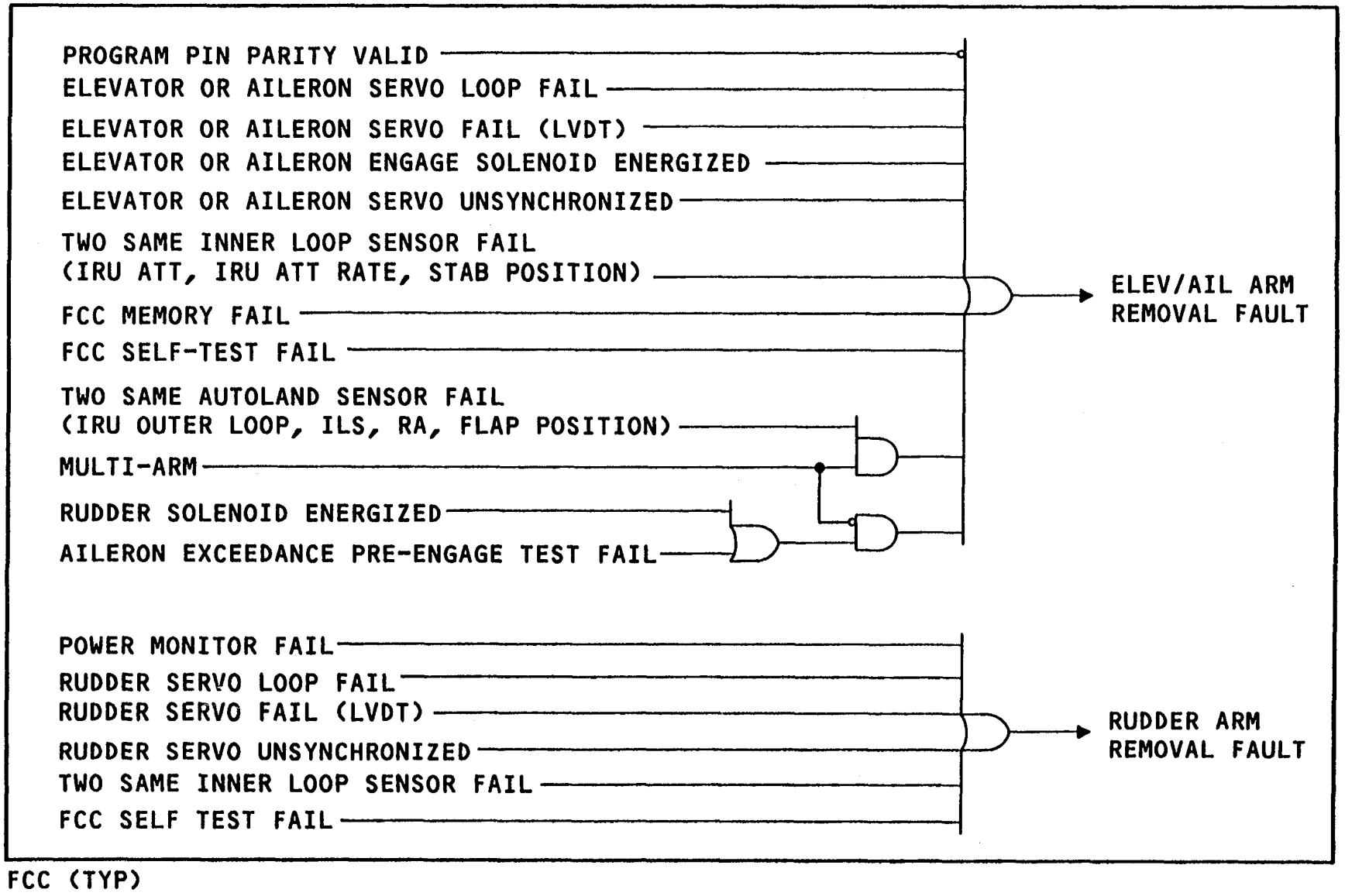

Figure 8 ARM REMOVAL FAULT LOGIC

ENGAGE INITIATION & REMOVAL CONDITIONS

Engage Initiation

For single channel engagement, engage initiation follows directly after arm status. For multi-channel engagement, the arm status remains until the conditions for multi-channel are satisfied. These conditions are:

- Localizer capture
- Glide slope capture
- Radar altitude less than 1500 feet
- Airplane track within 2 degrees of the adjusted runway heading

The FCC calculates adjusted runway heading during approach based on localizer deviation, airplane track and runway heading from the ILS system. The FCC adjusts for a maximum difference of 5 degrees between actual runway heading and that from the ILS system.

Engage Removal Conditions

The FCC monitors certain conditions which cause the autopilot to disengage. If multi-channel, conditions for multichannel are monitored. If proper

conditions do not exist, the autopilot disengages. If single channel, these conditions cause the autopilot to disengage:

- Loss of autotrim valid 1 and 2
- Airplane on the ground (rad alt less than 5 feet) during the flare mode

When the transition from a multi-channel go-around to a cruise mode occurs, the autopilot channel first-in-command stays engaged and the other autopilot channels disengage.

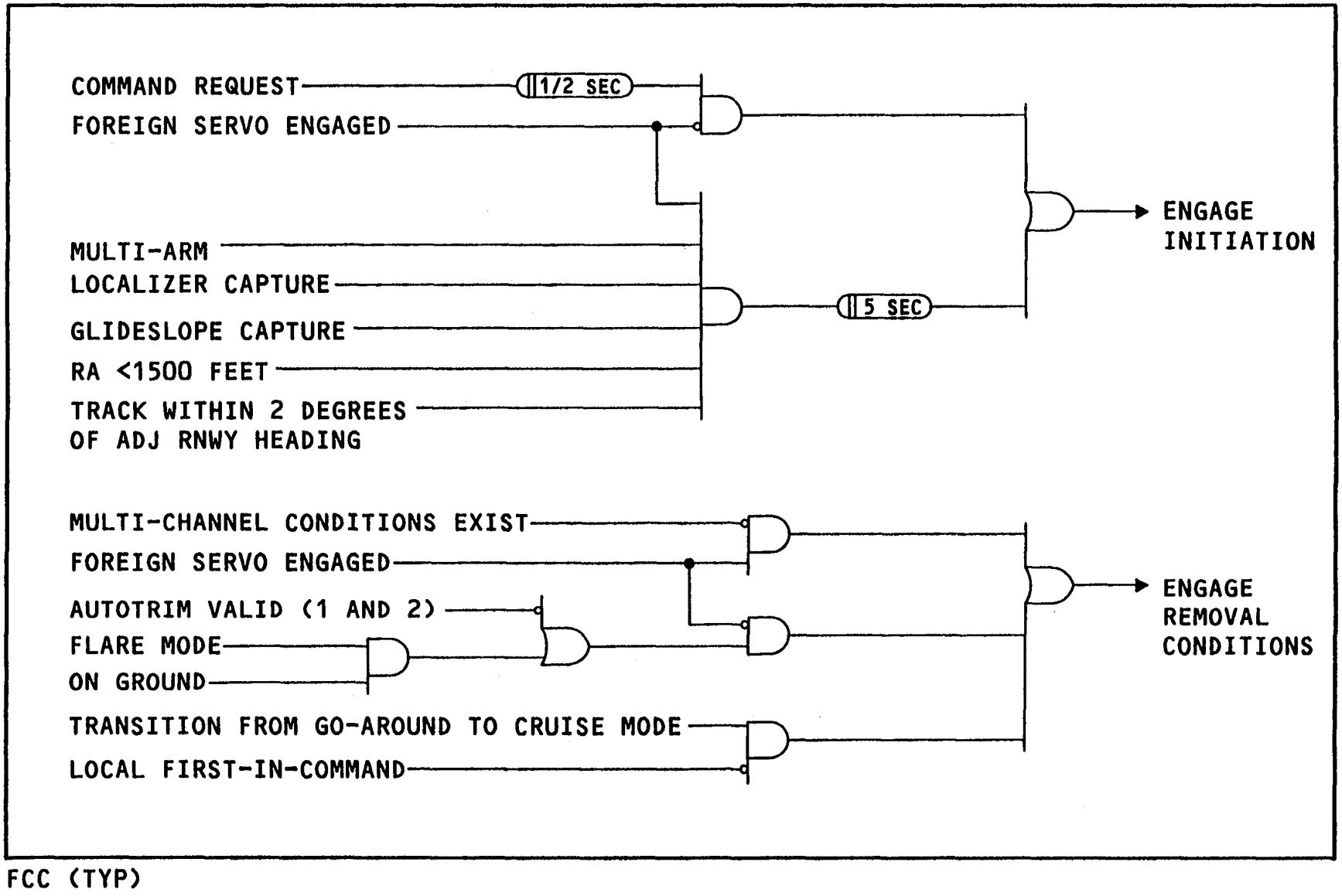

Figure 9 ENGAGE INITIATION & REMOVAL CONDITIONS

ENGAGE REMOVAL FAULT LOGIC

General

Some of the faults which cause engage removal are the same as some of the faults which cause arm removal. These were discussed previously. Only the faults which are unique to engage removal are discussed here.

Multi-Channel Engaged

The faults which cause engage removal during multi-channel engagement are:

- Program pins not compatible
- Rudder servo or servo loop fail
- Two same autoland sensor fail

For program pin compatibility, the program pin status is voted between the FCCs and the channel which disagrees with the other two disengages.

Single Channel Engaged

During single channel engaged, the autopilot disengages if it tries to make an aileron command larger than 25 degrees of wheel movement. This is caused by a trip of the aileron

exceedance monitor. Also during single channel engaged, if the FCC detects a fault which would cause it to be not able to capture or hold altitude.

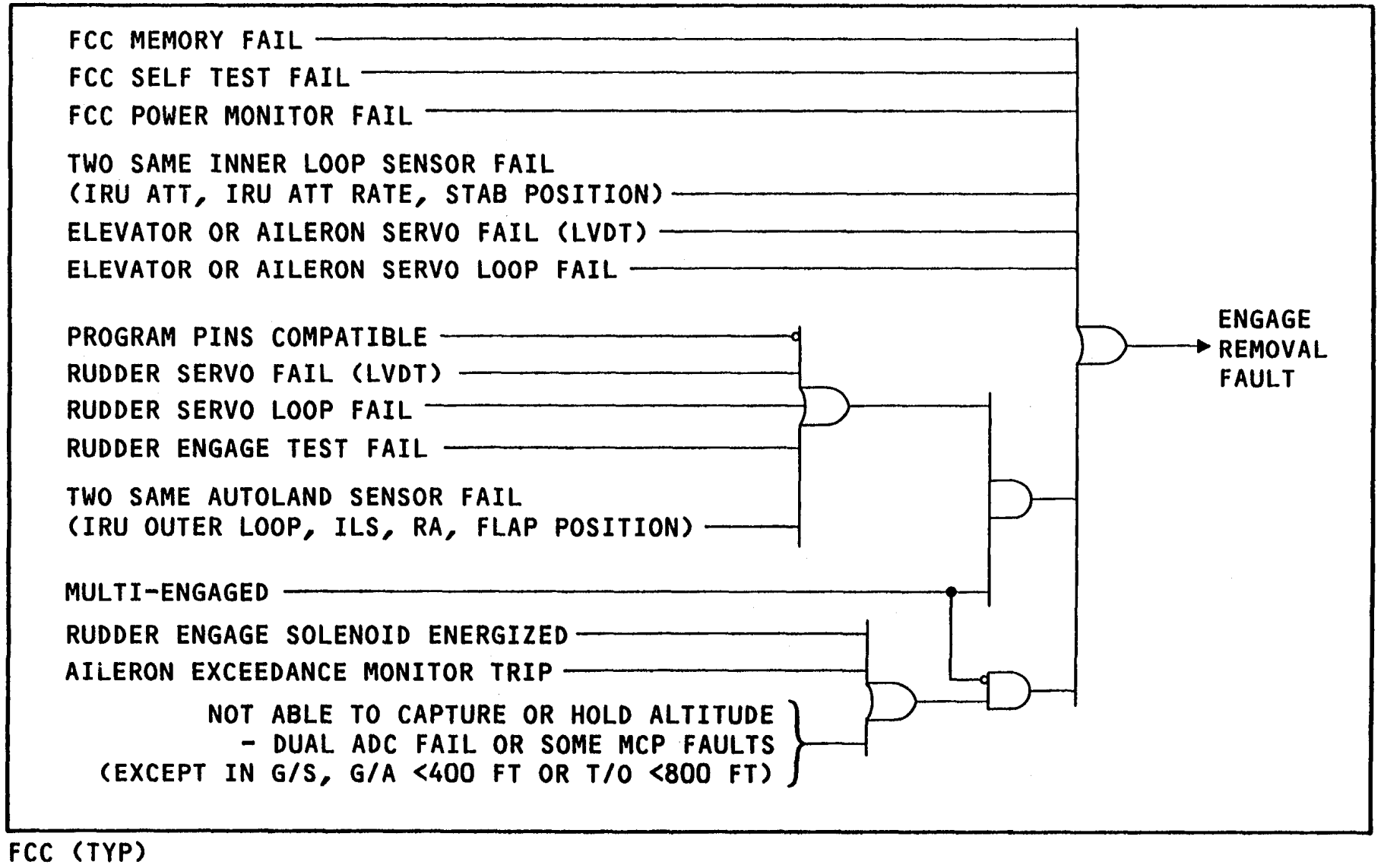

Figure 10 ENGAGE REMOVAL FAULT LOGIC

HARDWARE MONITOR LOGIC

General

The hardware monitor logic gets arm and engage signals from software logic as previously discussed. If conditions are proper, this logic energizes the arm and engage relays. The hardware logic required for arm and engage is:

- Not disengaged from wheel switches
- Power supply valid
- Computer valid
- Not power-up test inhibit
- Detent logic
- Camout logic

The power-up test inhibit makes sure that the autopilot can not engage during an FCC power-up.

Detent Logic

The detent logic compares the servo position and the surface position from the autopilot servo LVDTs. A detent condition exists if the servo position is equal to the surface position for all three servos (elevator, aileron and rudder). A loss of the detent condition from this logic causes an autopilot disengage only if the autopilot is multi-channel engaged. If single channel engaged, this logic causes an autopilot caution annunciation.

Camout Logic

The camout logic in each FCC monitors the detent status and engage status of the other FCCs. Relative left or right channel camout causes the local channel to disengage if the foreign channel disengages with a detent trip and if it is the only other channel engaged. In other words, for dual channel engaged, if one channel has a detent trip, both channels disengage. If triple channel engaged, a detent trip disengages only the channel which has the detent trip.

Non-Isolated Disconnect

During dual channel engagement, a detected failure of two same inner loop or autoland sensors causes a hardware disengagement.

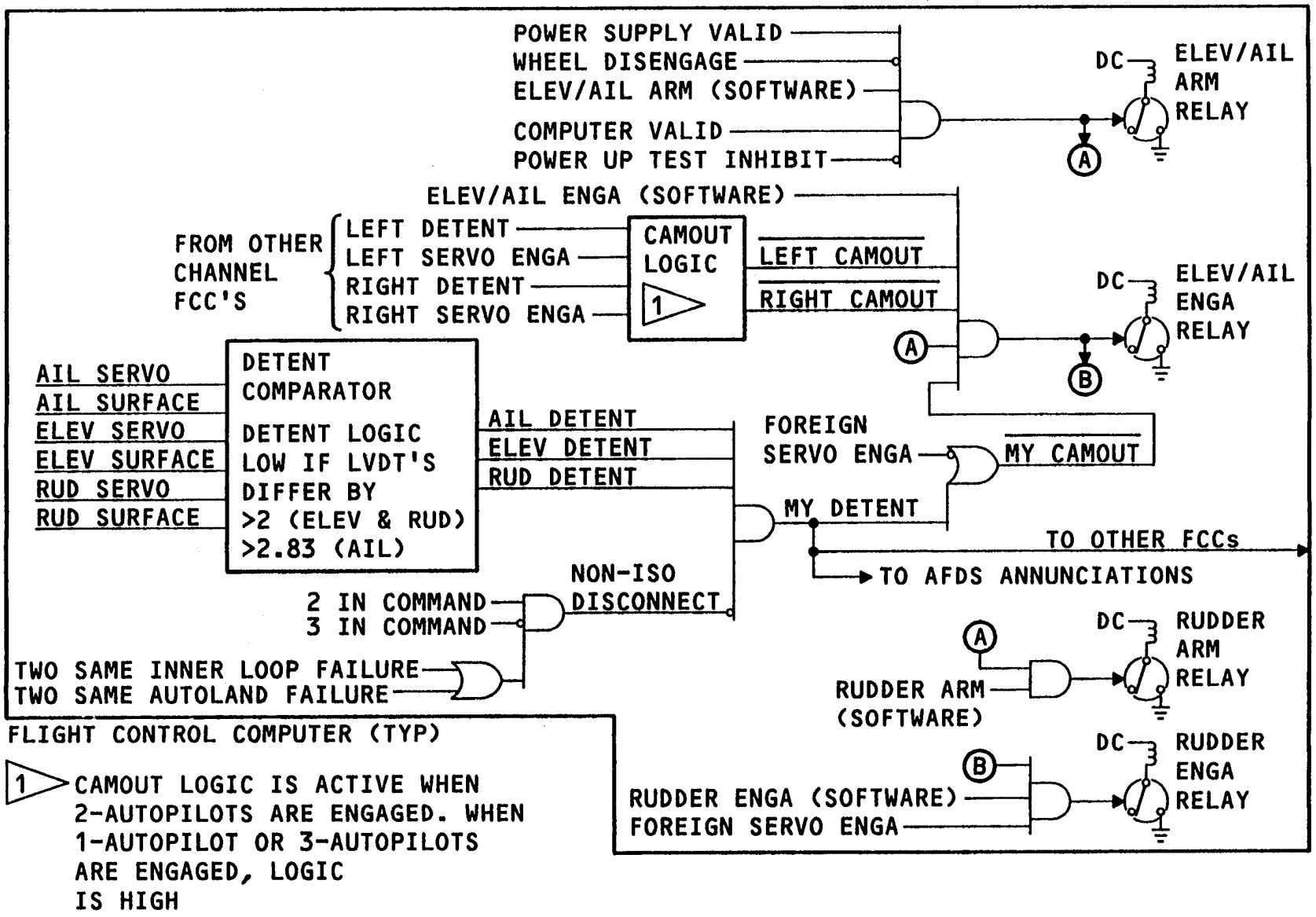

Figure 11 HARDWARE MONITOR LOGIC

FIRST-IN-COMMAND LOGIC

General

First-in-command logic is used during multi-channel operation. This logic is used to determine which autopilot channel or channels disengage when the change is made from the go-around mode to a cruise mode (roll or pitch). The channel which has first-in-command status remains engaged and the other channels disengage at this change.

Since it is possible for the autopilot channel which has first-in-command status to disengage, it is necessary to have a method to transfer this status to one of the other channels.

First-In-Command Transfer

If the left autopilot has first-incommand status and disengages, the status transfers to the right autopilot. If the right has first-in-command status and disengages, the status transfers to the center autopilot. Similarly, first-incommand status transfers from the center autopilot to the left.

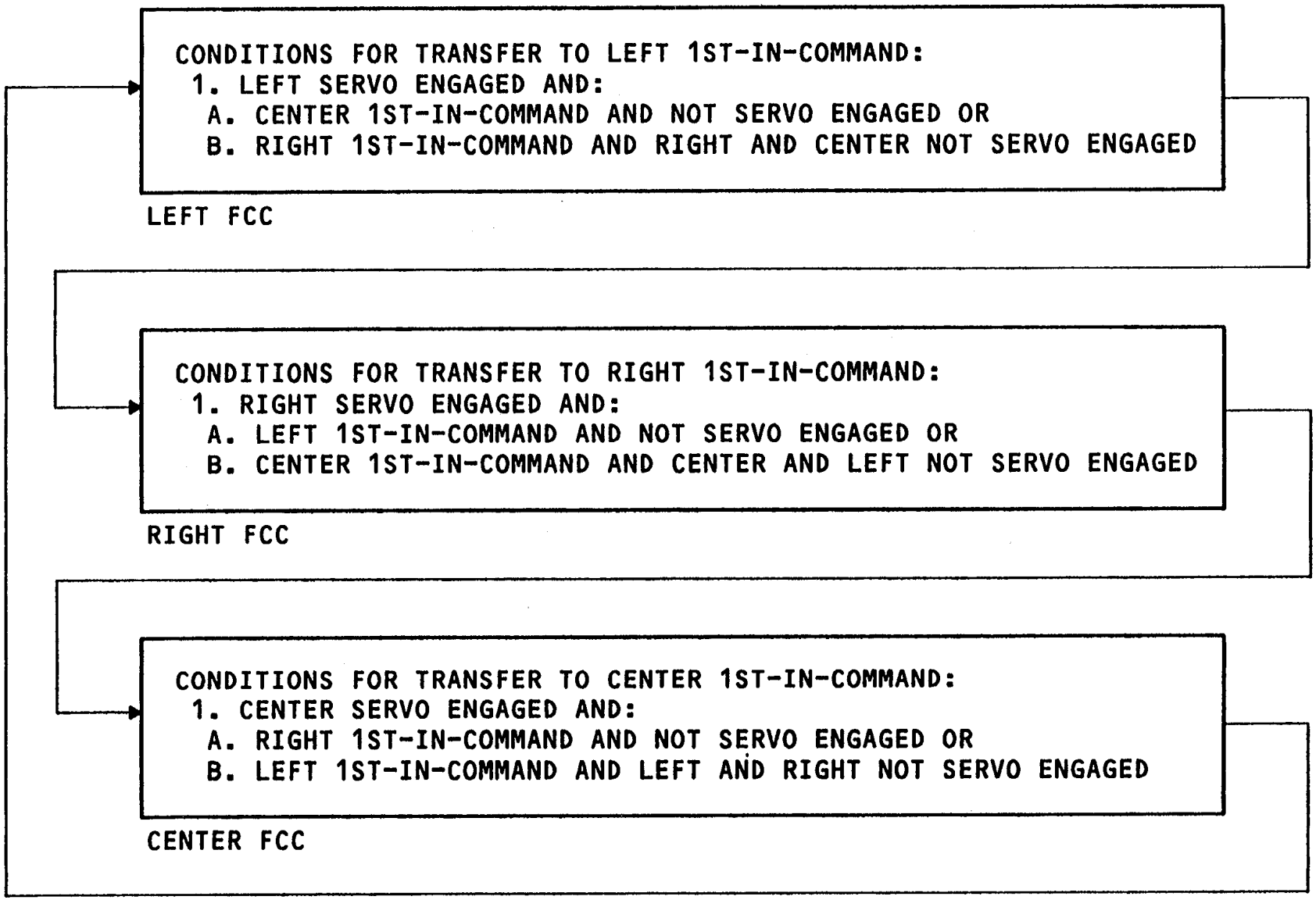

Figure 12 FIRST-IN-COMMAND LOGIC

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