STUDENT STUDY GUIDE

AIR TRAINING COMMAND

MISSILE LAUNCH/MISSILE OFFICER

FLIGHT CONTROL SYSTEM

July 1961

COURSE OZR1821B/3121B-4
TECHNICAL TRAINING

FOR INSTRUCTIONAL PURPOSES ONLY

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Missile Launch/Missile Officer
Atlas Branch
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Student Study Guide
13 July 1961

FLIGHT CONTROL SYSTEM

OBJECTIVE

To familiarize the student with the function and physical description of the flight control system and the location, physical description, function, and data flow analysis of its MAJOR components.

INTRODUCTION

The flight control system is the NERVE system of the missile and functioning with the guidance system, to control the missile to achieve the seemingly "impossible" accuracy demanded by an ICBM. In this study guide you will gain an overall knowledge of the functions and description of the flight control system. You will see the relationship of the system's major components with each other and the system's relationship with other systems of the missile.

Terminology

Some commonly used missile terms are explained in the following paragraphs.

* Attitude: The missile's angular position.

Inflight Attitude: X axis vertical, Y axis horizontal, and Z axis approximately coinciding with the trajectory (Figure 2-1).

Pitch: Change in the missile's attitude around its Y axis.

Yaw: Change in the missile's attitude around its X axis.

Roll: Rotation of the missile around its Z axis.

Channel: A collective term that includes all of the components through which signals pass to cause gimbaling of the engines around a given axis. There are three channels in the flight control system; one each for pitch, yaw, and roll signal flow.

Discrete Signal: A signal of a specific level that occurs only once during a given flight trajectory (See Figure 2-2A).

Analog Signal: A signal of a varying nature (See Figure 2-2B).

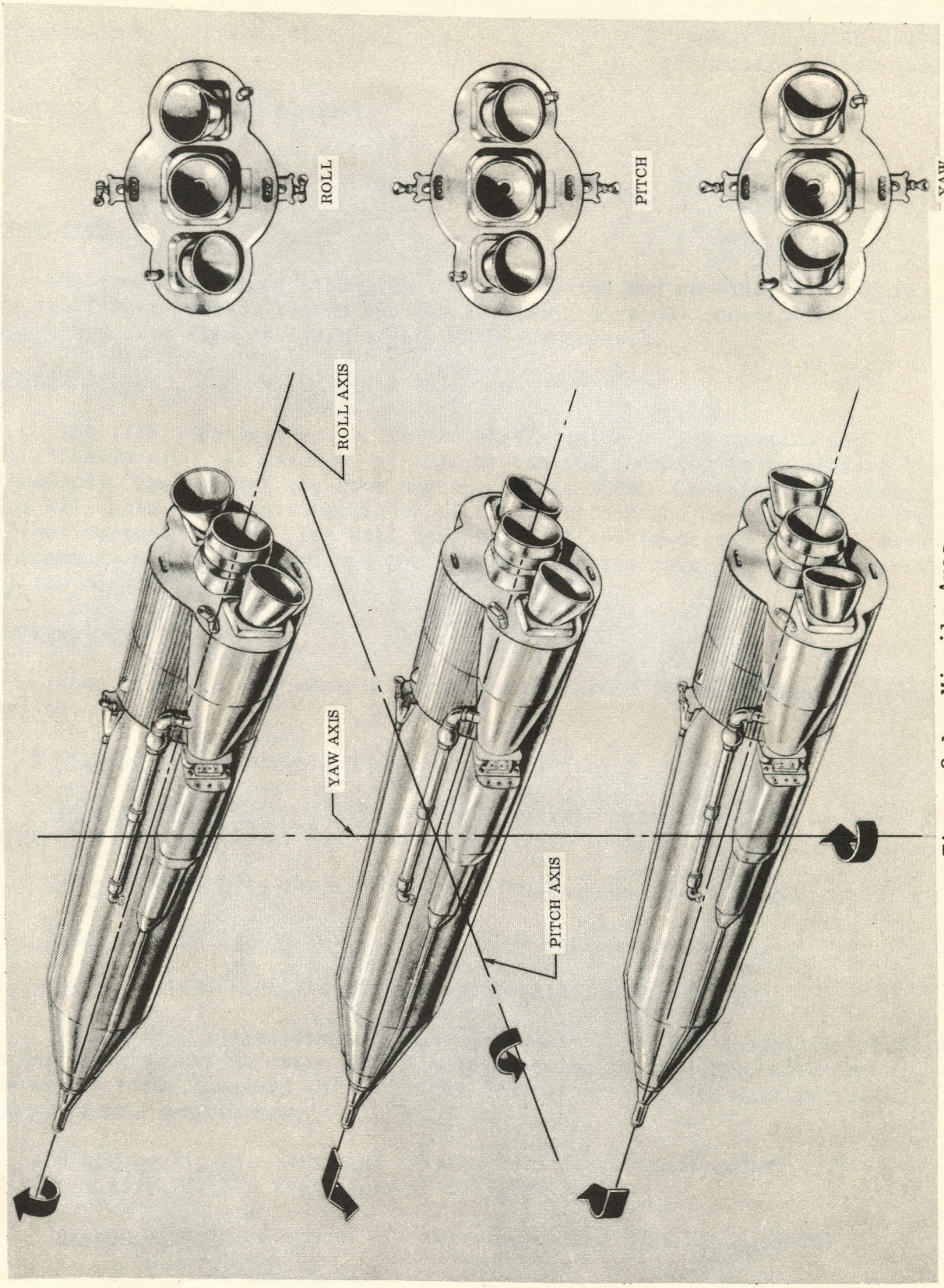
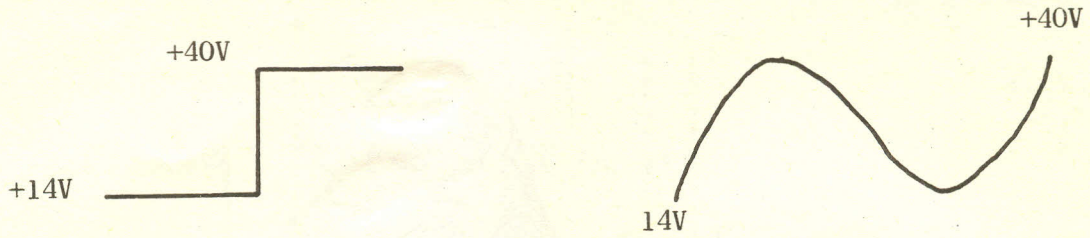


Figure 2-1 - Missile Axes



A. Discrete Signal

B. Analog Signal

Figure 2-2 - Types of Signals

FUNCTIONS

The flight control system performs four basic functions. These functions are listed in the following paragraphs:

1. It accomplishes switching functions at pre-determined times. For example, at exactly "X" seconds after zero time roll program begins.

2. It accomplishes switching functions on commands from guidance. For example, at exactly "X" seconds after guidance generates BECO the flight control system enable pitch and yaw guidance.

3. It stabilizes the missile on all three axes. I.E., it senses and compensates for deviations from the desired flight attitude of the missile.

4. It steers the missile as directed by guidance. Guidance knows where the missile is and therefore, knows if and when a new trajectory needs to be computed and the missile re-aligned with the target.

   The flight control system accomplishes the stabilizing and steering by controlling 10 hydraulic actuators that gimbal the engines as necessary to place the missile in the desired attitude on its three axes.

DESCRIPTION

The major components of the flight control system and the location of each are given in the following paragraphs. (See Figure 2-3)

Three packages (U-1, U-2, and U-3) and the excitation transformer (U-4) are located in the B2 equipment pod.

The remote rate group is located at station number 745.

Associated components of the flight control system consist of ten

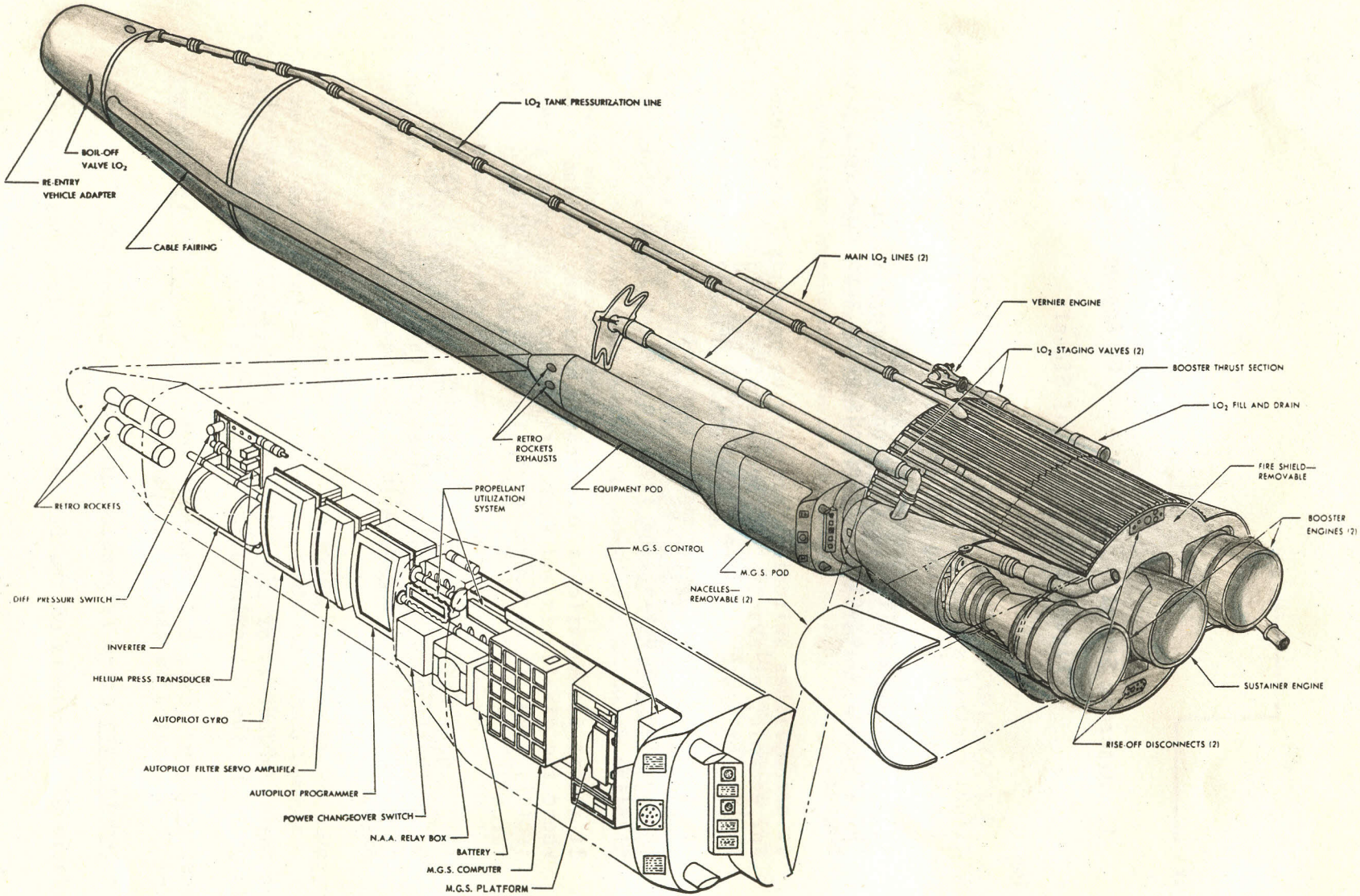


Figure 2-3 - Location of Flight Control System Components

electro-hydraulic actuator assemblies located on the engines, two per engine.

GYRO PACKAGE (U-1)

The Gyro package, referred to as the U-1, performs the following functions:

1. Senses the angular displacement and the rate of angular displacement of the missile is the pitah and yaw axes and only roll rate in the roll axis.

2. Provides electrical output signals proportional to the angular displacement. These signals are used to stabilize the missile.

3. Accepts electrical signals from guidance and changes the references of the displacement gyroscopes accordingly.

NOTE

The pitch and yaw rate gyroscopes have been removed from the U-1 package and placed in a separate package called the remote rate group. At this time detailed information and circuitry changes are not available. For this reason, and because the operation of the circuit has not changed, the pitch and yaw rate gyroscopes will be discussed along with the U-1 package.

Major Components

The U-1 package contains the following components:

1. Roll rate gyroscope.

2. Three displacement gyroscopes.

3. Three displacement gyroscope torque amplifier.

4. Three gyroscope signal amplifiers.

Data Flow Analysis of U-1 Package

Figure 2-4 is a simplified block diagram of the pitch channel in the U-1 package. The operation of the roll and yaw channel is very similar to that of the pitch channel.

Stabilization of the Missile

1. Missile deviation about the "Y" (pitch) axis is sensed by the displacement gyroscope and the rate gyroscope. Both gyroscopes produce output signals (See Figure 2-4).

2. The two signals are "summed" and then amplified by the signal amplifier.

3. The signal is then sent through the U-2 package and on to the actuator assemblies on the engines. The engines will, therefore, be gimbaled to reposition the missile so that its attitude will coincide with the GYRO's reference.

Guidance and Programmer Inputs to the GYRO Package

1. A signal from the programmer itself or from the guidance system (controlled by the programmer) is applied to the torque amplifier. (See Figure 2-4)

2. The amplified signal causes the torque motor to move the gimbal of the displacement GYRO, thus changing the gyroscope's reference.

3. Since the reference of the displacement GYRO has changed in respect to the missile's attitude, a displacement gyroscope signal will be produced just as in the case of missile deviation. Note, however, that only the displacement gyroscope has been affected by the torque amplifier.

Refer to Figure 2-9 for the overall operation of the pitch channel.

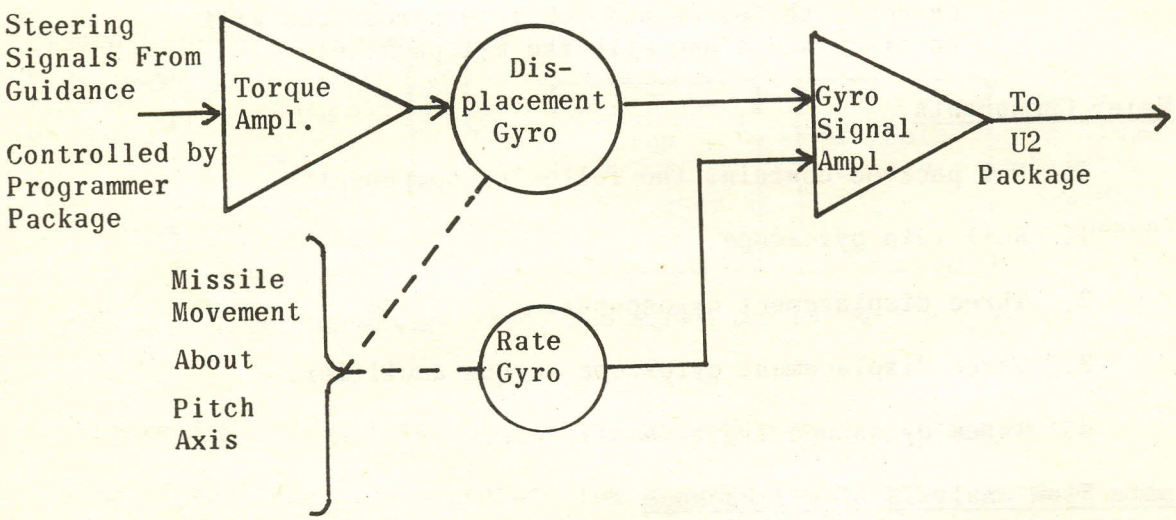


Figure 2-4 - U1 (GYRO) Package Pitch Channel

FILTER-SERVOAMPLIFIER PACKAGE (U-2)

The 3 functions of the filter-servoamplifier package are as follows:

1. Filter and integrate the signals from the GYRO package.

2. Sum the signals from the gyro package with the signals from the feedback transducers at the actuators.

3. Amplify and rectify the summation of the signals so they can control the solenoid operated valves on the actuators.

Major Components

The major components of the U-2 package are:

1. Three demodulators

2. Three filter-integrators

3. Three modulators

4. Ten summing networks

5. Ten servoamplifiers

Data Flow Analysis (Figure 2-5)

Figure 2-5 is a simplified block diagram of the pitch channel in the filter-servoamplifier package.

1. The AC input signal from the U-1 package is applied to the demodulator. The DC output amplitude of the demodulator will be proportional to its AC input, and the DC polarity will be determined by the phase of the input.

2. The filter-integrator then attentuates any undesirable gyro signals from the demodulator output and compensates for any steady state error signals.

3. The signal (pitch in this example) is then modulated and the AC output of the modulator is sent to five summing networks, five servoamplifiers and then to the pitch actuator assemblies on all five engines.

   NOTE: Since the five "paths" for the signal are identical, let us consider only one for this analysis.

4. The summing network "adds" the modulated signal with the signal from the feedback transducer on the actuator assembly.

5. The summation of the two signals is then amplified and rectified by the servoamplifier and the DC signal, positive or negative, is routed to the actuator assembly on the engine.

   Refer to Figure 2-9 for the overall operation of the pitch channel.

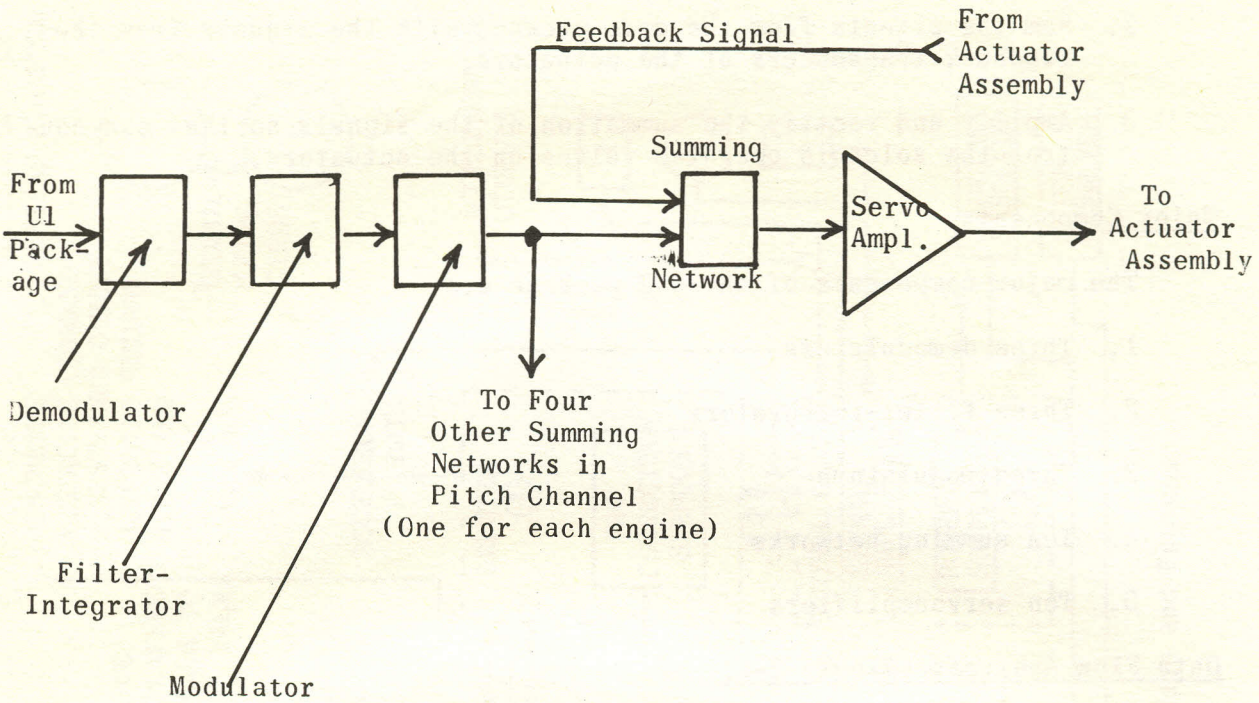


Figure 2-5 - U2 (Filter-Servoamplifier) Package Pitch Channel

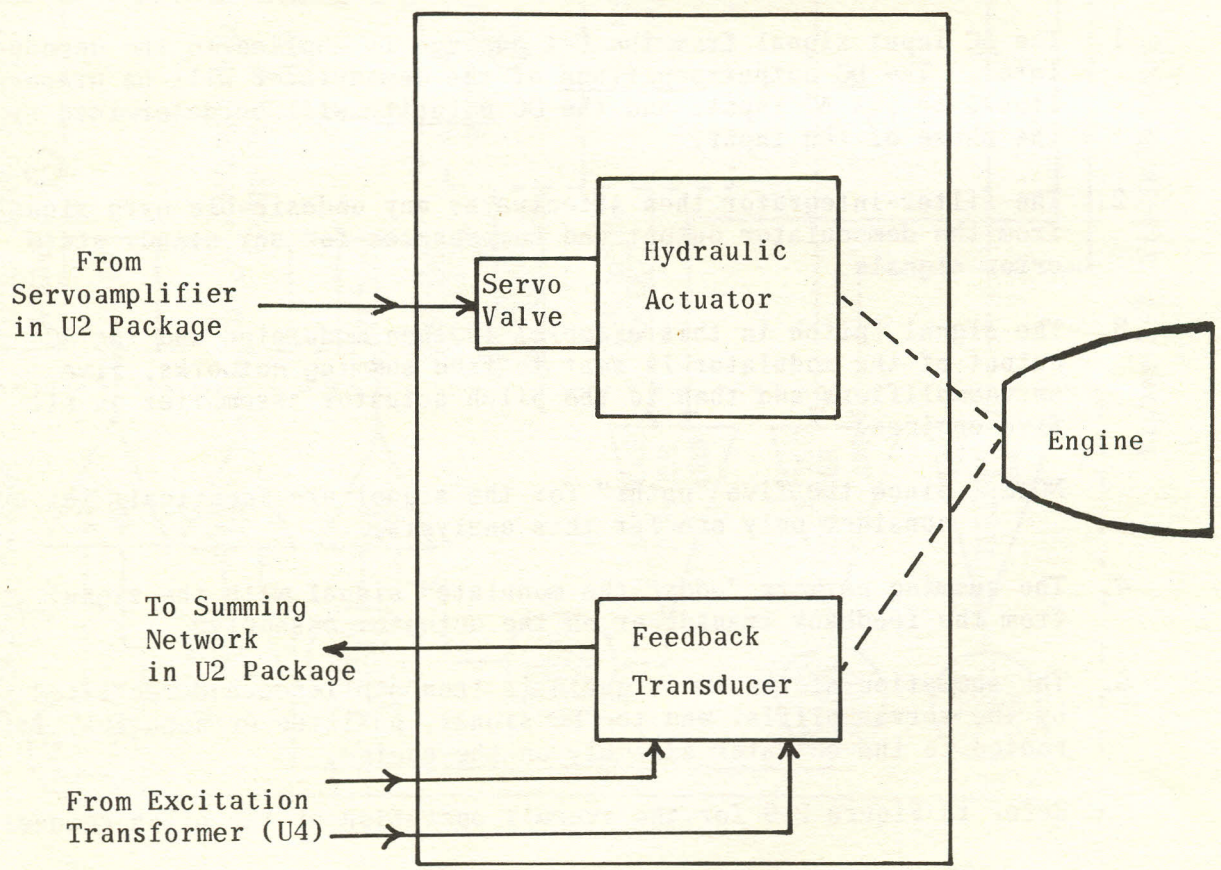


Figure 2-6 - Electro-Hydraluic Actuator Assembly

ELECTRO-HYDRAULIC ACTUATOR ASSEMBLY

There are two electro-hydraulic actuator assemblies on each of the five engines.

Functions

The three functions of the actuator assembly are:

1. Gimbal the engines to steer and/or stabilize the missile.

2. Convert a low power electronic signal input to a hydraulic force capable of gimbaling the engine.

3. Provide a feedback signal to the servoamplifier.

Major Components

The major components of the actuator assemblies are:

1. Hydraulic actuator

2. Solenoid-operated servo valve

3. Variable induction transducer

Operation (Figure 2-6)

Figure 2-6 shows the components of the assembly and Figure 2-7 shows the tie-in between the U-2 package and the engines. Refer to these as you study the following analysis.

1. The input signal from the servoamplifier in the U2 package is a DC signal. The polarity of this signal determines which way (up or down) the engine is to be gimbaled in the pitch channel.

2. This signal controls the servo valve which directs the hydraulic pressure to drive the actuator piston in the desired direction.

3. As the engine is gimbaled by the actuator, the "slug" of the feedback transducer is also displaced. This causes a feedback signal to be sent to the summing network at the servoamplifier.

4. The feedback signal is 180^{o} out of phase with the servoamplifier input signal that displaced the "slug" and the engine. Therefore, when the engine and the transducer "slug" have moved a sufficient amount, the feedback signal will be of sufficient amplitude to null the GYRO signal at the servoamplifier summing network. The engine will therefore, stop gimbaling. It will remain in its new position until the GYRO signal amplitude changes and again disturbs the null condition.

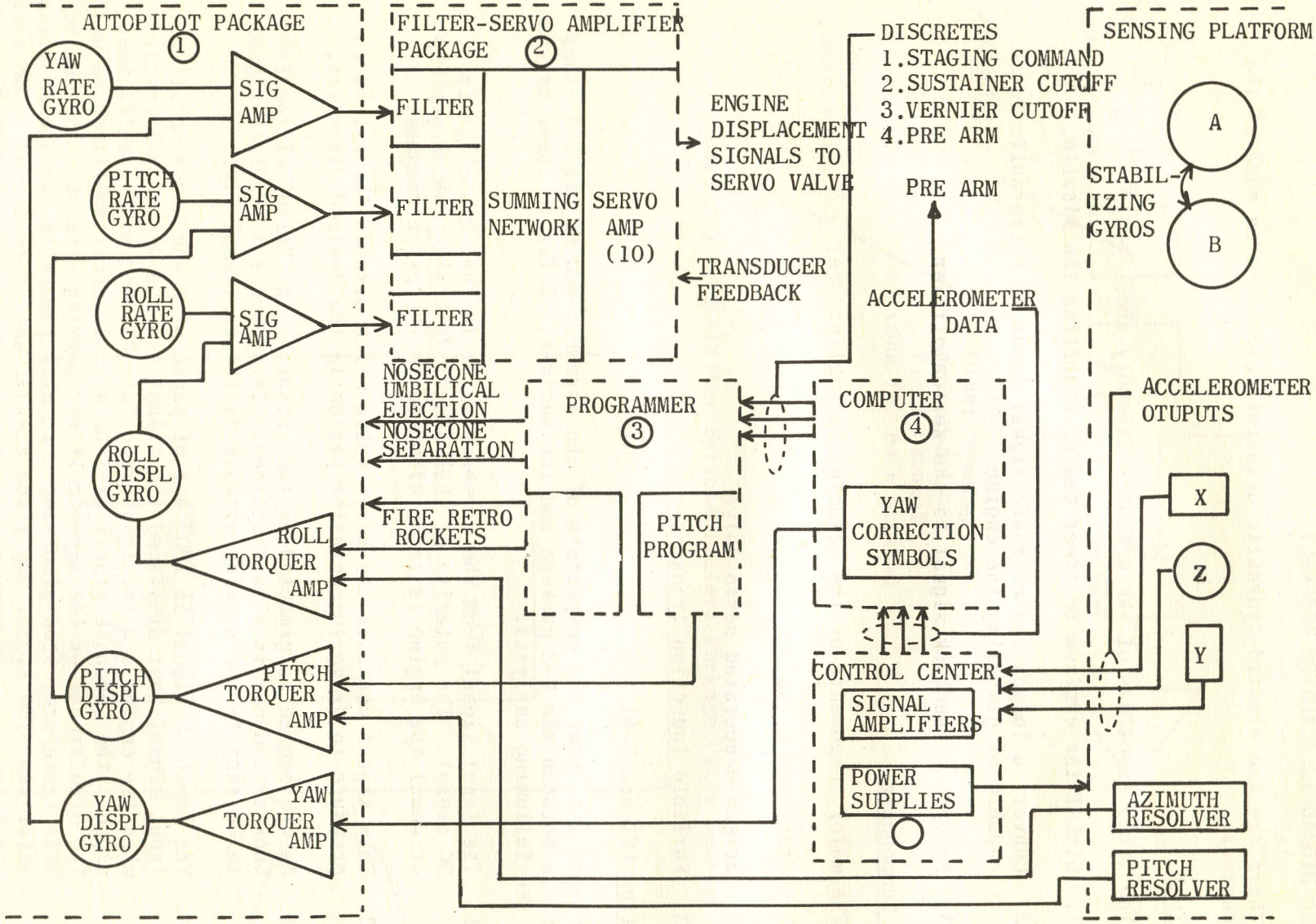


Figure 2-7 Tie-In Between U2 Package and Engines

Refer to Figure 2-9 for the overall operation of the pitch channel.

EXCITATION TRANSFORMER

The excitation transformer, referred to as the U-4 package has the following functions:

1. Furnish excitation for the ten feedback transducers.

2. Furnish the voltage to the two "Vernier Engine Pitch" servoamplifier summing networks for biasing the vernier engines.

   Vernier biasing voltage is used to increase the angle between the vernier engines and the tank section. This prevents damage of the aft end of the missile by the vernier engines' exhaust.

Operation

The transformer primary is connected to 115V AC, 400 CPS. Its secondary supplies the excitation for the feedback transducers at all times. The connection of the vernier biasing voltage to the summing networks is one of the switching functions of the programmer package.

Refer to Figure 2-9 for the overall operation of the pitch channel.

PROGRAMMER PACKAGE (U-3)

The programmer package(U-3) performs the following functions:

1. Provides a "time" reference for various functions of the flight control system as well as for other missile systems.

2. Generates a predetermined pitch voltage that causes the missile to assume the desired flight attitude on its pitch ("Y") axis.

3. Accomplishes predetermined switching functions, such as jettison booster section, fire retrorockets, etc.

4. Furnishes enabling "Gates" to give guidance control of certain components in the flight control system for steering the missile.

Major Components

The major components of the programmer package are:

1. Counter

2. Time diode matrix

3. Logic unit

4. Pitch voltage generator

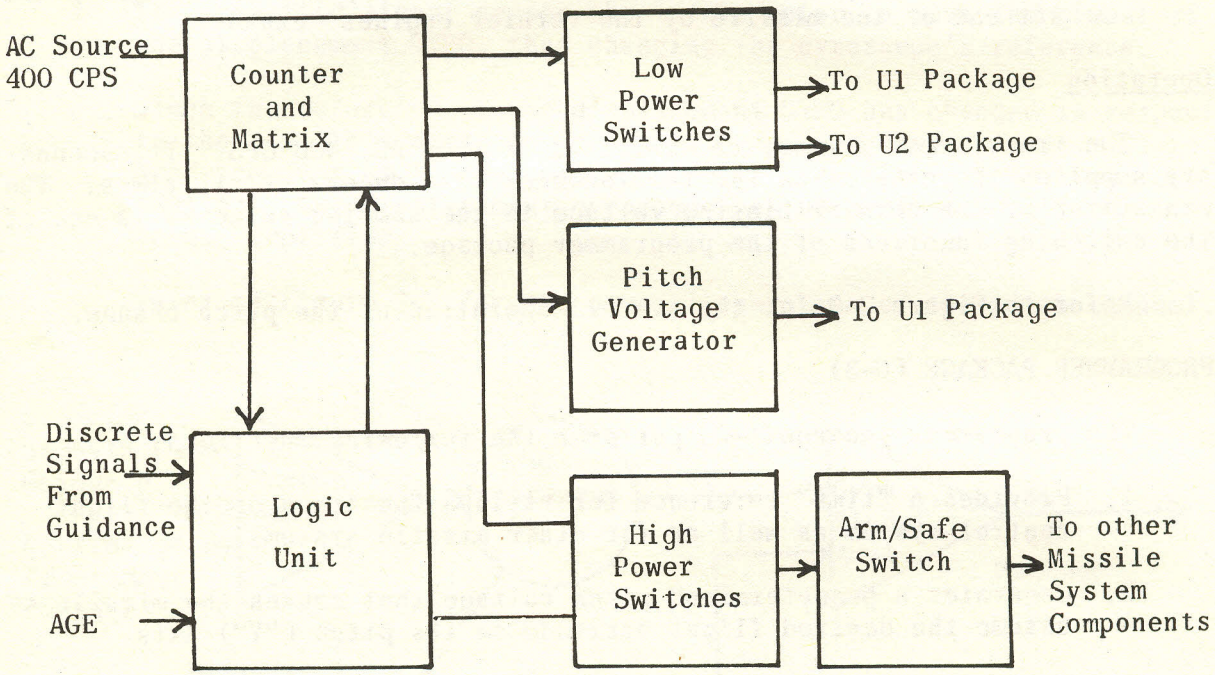
5. Arm/safe switch

6. Low power switches

7. High power switches

Operation (Figure 2-8)

The counter, controlled by the logic unit, establishes the time reference. It is connected to the diode matrix which produces the necessary time pulses.



NOTE: All interconnecting lines represent two or more wires.

Figure 2-8 - Simplified Block Diagram, Programmer Package (U3)

Some of the time pulses operate low power switches which perform such functions as zeroing the booster engines, deactivating certain actuators at predetermined times, and allowing guidance signals to reach the torque amplifiers in the GYRO Package.

Some time pulses are used in the logic unit to "enable" the gates which allow guidance discrete signals into the programming.

Other time pulses control the high power switches which jettison the booster section, fire retrorockets, and perform other functions.

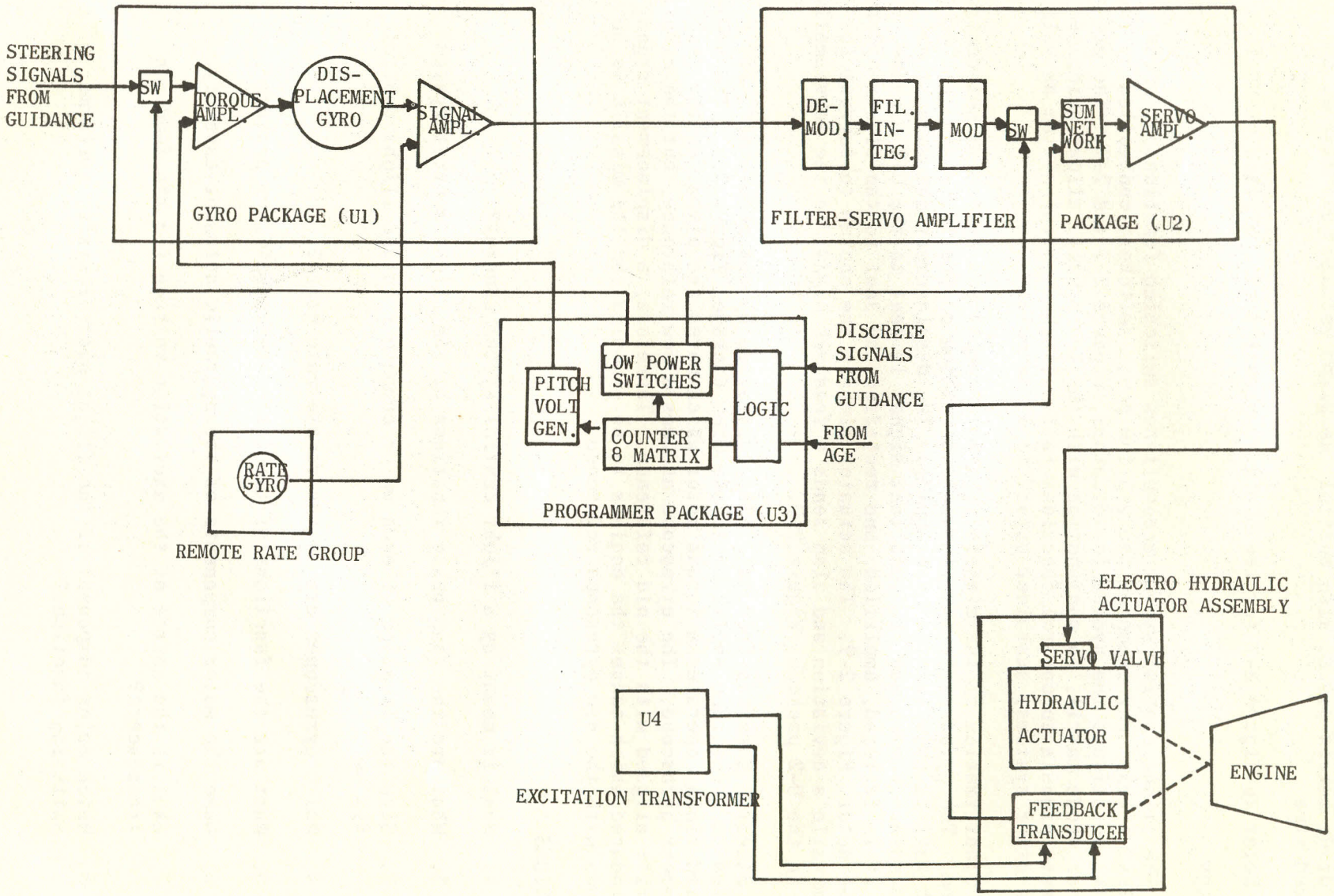


Figure 2-9 - Simplified Block Diagram of Pitch Channel

Diode matrix pulses also control the pitch voltage generator at the desired time.

Refer to Figure 2-9 for the overall operation of the pitch channel.

SUMMARY

The flight control system accomplishes switching functions at predetermined times. For example, the U-3 low power switches, controlled by the matrix, deactivate the hydraulic actuators, Figures 2-7 and 2-9. The programmer diode matrix, in conjunction with the logic unit, allows guidance discrete signals to control functions in the flight control system as well as in other systems, sustainer cutoff as an example.

Stabilization of the missile is also accomplished by the flight control system. The gyros sense the missile's deviation on the three axes. (The pitch axis is used here as an example.) The displacement and rate signals produced are summed and the resultant signal is sent to the U-2 package. Here it is filtered, amplified, and rectified and sent to the electrohydraulic actuator, Figure 2-9. The actuator gimbals the engine to correct for the missile's deviation and also sends a feedback signal to the servoamplifier in the U-2 package, Figure 2-9.

Steering commands from guidance, controlled by the programmer, are applied to the torque amplifier in the GYRO package, Figure 2-9. The amplified signal operates a torque motor which moves the gimbal of the displacement gyroscope. The gyroscope assumes a new reference, but the missile is still aligned with the old reference. Therefore, a displacement signal is produced which causes the engines to be gimbaled and the missile to be aligned with the new gyroscope reference.

QUESTIONS

1. What is meant by a flight control system channel?

2. What are the four basic functions of the flight control system?

3. Give the location of each major component in the flight control system.

4. Which gyroscopes are in the remote rate group?

5. What are the functions of the filter-servoamplifier package?

6. Name the major components of the hydraulic actuator assembly.

7. What is the source of the excitation voltage for the feedback transducers?

8. Which major component of the flight control system performs switching functions?

9. What is a discrete signal?