RUFAS II
Final Report

Including
Data for Operation and Maintenance

by

Richard D. Benton
Glenn D. Bryant
Martin F. Jue
J. E. Thomas

INSTITUTE OF ENGINEERING TECHNOLOGY
MISSISSIPPI STATE UNIVERSITY

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REMOTE UNDERWATER FISHERIES ASSESSMENT SYSTEM (RUFAS II)

Final Report on the design and development of a towed, unmanned observation platform to operate to a depth of 2400 feet. Operation and maintenance data are included.

by

Richard D. Benton, Principal Investigator
Glenn D. Bryant, Mechanical Systems
Martin F. Jue, Electrical Systems
J. E. Thomas, Coordinator

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Mr. Wilber R. Seidel of the National Marine Fisheries Service is the Co-Principal Investigator for this project. His valuable contributions to this work are gratefully acknowledged.

The United States Geological Survey operates a magnificent tow tank test facility at the Mississippi Test Facility, Bay St. Louis, Mississippi. This 12 x 12 x 450 foot facility was made available for full scale operation and development tests of the RUFAS II system. The result was no corrections required when the first at sea trials were conducted. The assistance of Drs. Verne Snyder and Stan Sauer of USGS and Mr. Richard Johnson of MSU-NASA in arranging to make this facility available is gratefully acknowledged.

RUFAS II was entirely designed and fabricated by faculty and students from the Mississippi State University Institute of Engineering Technology with assistance from a number of other MSU engineering departments. Mr. Pat Swan, Mr. Wayne Livingston, and Mr. Jim Henson of the Department of Aerospace Engineering provided support in mechanical fabrication, precision machining, and photography. Mr. Lynn Cook of the Department of Agricultural Engineering helped in the preparation of the titanium pressure spheres.

Mr. Jim Kellum of the Electrical Engineering Department provided many valuable services.

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OVERVIEW

The RUFAS II (Remote Underwater Fisheries Assessment System) was successfully demonstrated in the Gulf of Mexico in August 1973. The system is a towed, unmanned, controlled, underwater vehicle for rapid bottom and midwater resource survey. It is used to collect pictorial data on midwater and ocean bottom conditions and resources down to 2,400 feet. At towing speeds up to 4 knots, the system allows rapid surveys of relatively large ocean areas.

The vehicle, a vane-controlled, towed, hydrodynamic body, senses pitch, roll, and height above bottom. A feedback control system maintains the height above bottom selected by the operator on the towing vessel. This control system maintains the vehicle within the accuracy of the down looking sonar. The at-sea tests indicate the system can follow ocean floor contours of 30^{0} at a towing speed of 2.5 knots.

RUFAS II is equipped with two separate camera recording systems. The forward looking television camera is controlled in pan, tilt and focus by the shipboard operator. Monitors on the operator's console repeat the picture that is being recorded on video tape. Illumination is furnished by two thallium-iodide, forward looking lights that move with the camera. Sea trials at night indicate that the system could be improved by the use of a low light level camera.

The permanent record of objects on the bottom is provided by a 35mm motion picture camera that is intervalometer-controlled. The lighting system is a high intensity strobe light. The camera, which is housed

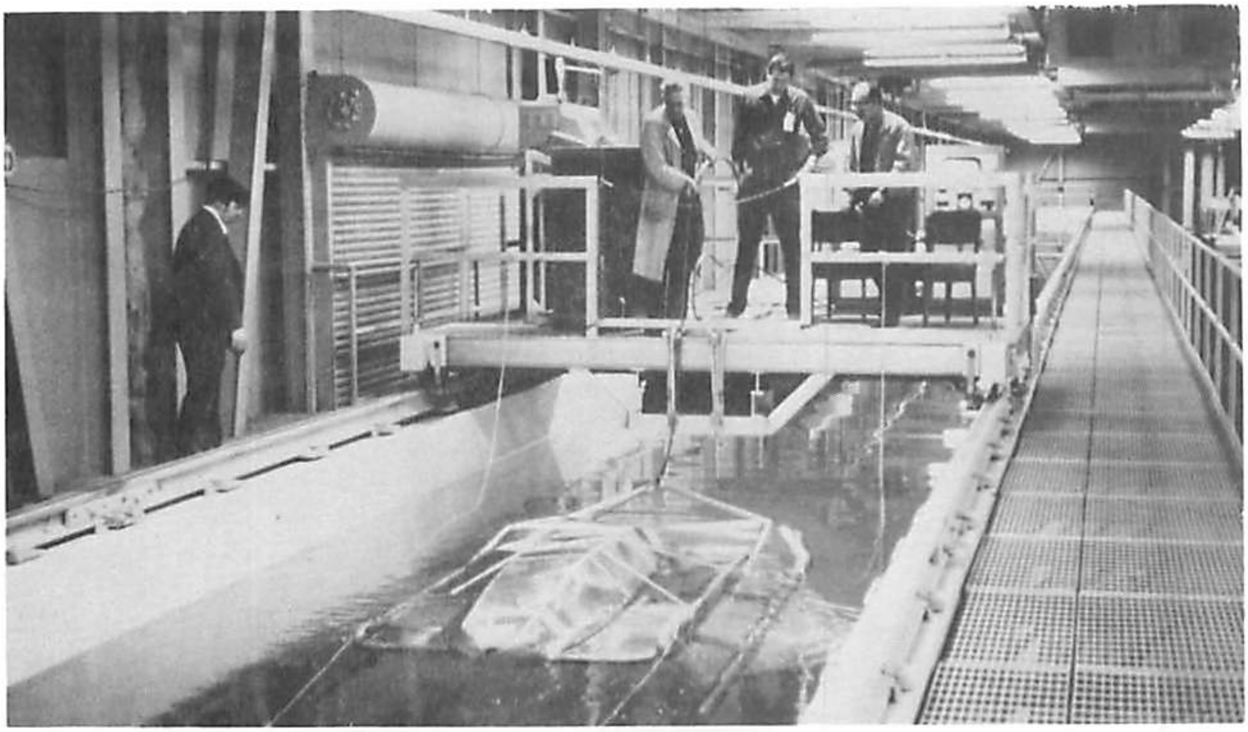

Figure OV-1. RUFAS II being prepared for tow test in the United States Geological Survey hydrological lab at the Mississippi Test Facility.

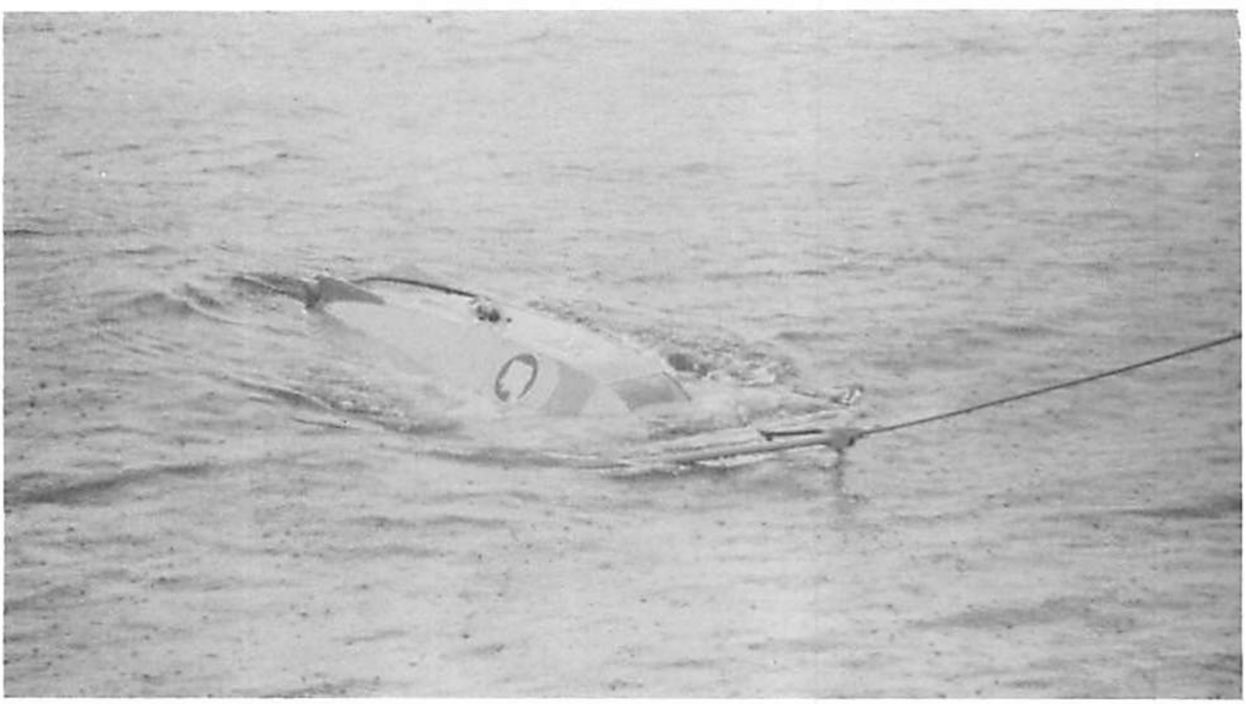

Figure OV-2. RUFAS II breaks the surface after successful tow test in the Gulf of Mexico.

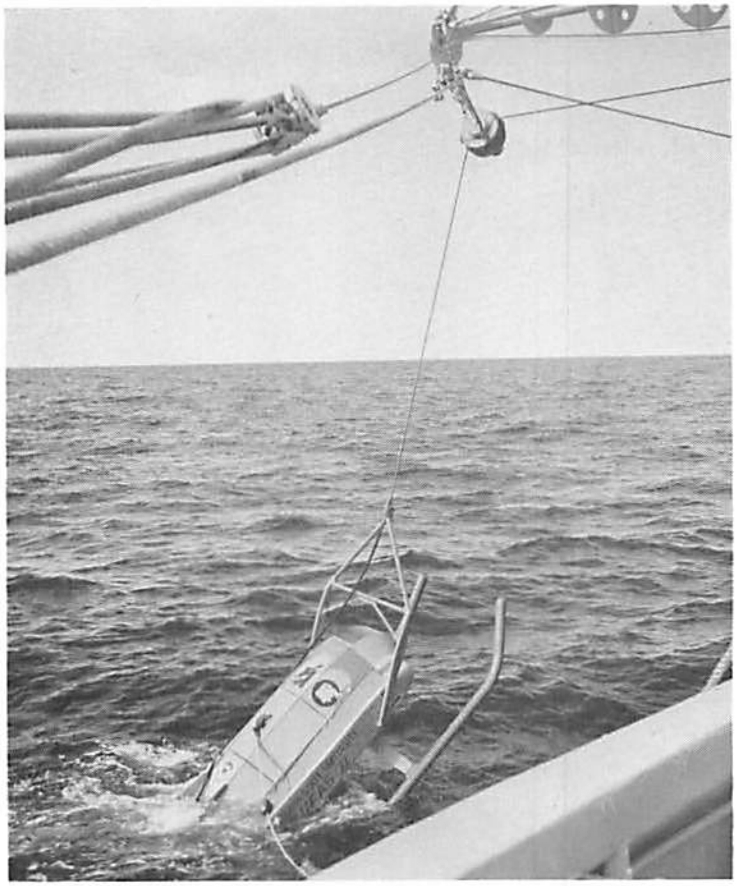

Figure OV-3. RUFAS II being lifted out of the water.

Figure OV-4. RUFAS II is lowered to the deck of the NOAA Research vessell OREGON II after successful sea test.

in a pressure tight sphere, can take overlapping photos for 24 hours without changing film.

Control of the vehicle and its equipment is accomplished over a down-link telemetry system from the operator's console. Information, except the television picture from the sled, is transmitted to the console over an up-link telemetry system. The television picture and telemetry signals move over a single coaxial cable. A redundant phase-lock-loop telemetry system over hardwire assures continuity of the control commands. The capacity of the telemetry systems can be expanded to accomodate the control of other instrumentation that might be added for other missions.

Towing and information transfer is accomplished over a single cable. The cable has an RG-58 coaxial core, four power conductors, and a twisted pair of signal conductors under a forged, balanced-torque, double steel armor, towing cable. The electrical power is transmitted at 500 volts, three phase, 60 hertz over solid conductors.

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ILLUSTRATIONS

1. INTRODUCTION

RUFAS II (Remote Underwater Fisheries Assessment System) is an unmanned, towed, underwater vehicle whose mission is bottom and midwater surveillance under remote control and monitoring from the towing vessel on the surface. The RUFAS II system was designed to operate to a depth of 2,400 feet.

The value of an operational RUFAS II in gathering data required for better definition of resources on the Continental Shelf and Slope out to 2,400 feet is not difficult to visualize. The amount of information that can be gathered may well be useful to more segments of the marine community than those merely associated with biological resources. Geology and mineral resources could be revealed as well as various physical oceanographic phenomena.

The development of this system followed the successful design, development, and operation of a shallow water (300 feet) RUFAS I system by the National Marine Fisheries Service. RUFAS II is considered an extension of RUFAS I with increased depth capability (2,400 feet) necessitating stronger pressure vessels and a much more complete towing system. The chief difference between RUFAS I and RUFAS II is in the deeper operating capability and increased flexibility of the latter. The 400 fathom depth requirement demanded stronger pressure vessels and a much longer cable presenting critical design requirements. The longer cable of the RUFAS II system dictated the requirement of reducing the cable diameter. This, in turn, required the system electronics to be more elaborate.

There is a great interdependence of variables associated with this system. For instance, cable size was determined by the electrical requirements for power, communications, and control. Structural requirements depended on vehicle drag, cable drag, cable immersed weight, shock loads from ship motion, etc. Cable weight, lift, and drag, in turn, influenced the angle and curve of the cable, which is important for the vehicle to have the required maneuverability for bottom surveillance.

1.1 System Capabilities Desired for RUFAS II

The National Marine Fisheries Service supplied the Mississippi State University Institute of Engineering Technology with their desired operational capabilities and performance criteria for the RUFAS II system. These operational capabilities which are outlined below established the preliminary design criteria. The handling, control, data acquisition, cable design, and other vehicle functions differ between a shallow water and deep water vehicle. These functions and systems were designed within the modular system concept for the two depth range applications instead of separate vehicle designs.

I. Shallow water, 0-100 fathoms, functional requirements:

   A. Maneuverability to conduct any midwater resource survey or observation of fishing gear, trawls, oceanographic hardware, etc.

      1) Vertical control and positioning required over a 50 fathom range

   B. Bottom and midwater viewing for explorations to 100 fathoms

      1) TV cameras

a) Pan and tilt for bottom viewing and midwater scanning

b) Video tape recording

c) Wide-angle high resolution image

d) Low light sensitivity capabilities

2) Movie and still camera modules

a) 35mm negative format

b) Steroscopic photography

3) Lighting systems as required for mission objectives

a) Flood lamps

b) Strobe lamps

4) Echo ranging equipment

a) A directional receiver on RUFAS II for locating fishing equipment, etc.

b) Forward looking sonar for obstacle warning and avoidance

II. Deep water, 100-400 fathoms, functional requirements:

A. Maneuverability to conduct bottom surveys down to 400 fathoms

1) Vertical maneuverability from bottom to 25 fathoms above bottom for survey and obstacle avoidance

2) Forward looking sonar for obstacle warning

3) Towing speed from 1 to 2½ knots

4) Operation with cable lengths as required to achieve design depth

B. Bottom viewing and explorations in 100 to 400 fathoms range

1) TV cameras

a) Pan and tilt for bottom viewing and scanning

b) Video tape recording

c) Low light sensitivity capabilities

2) Movie and still camera modules

a) 35mm negative format

b) Steroscopic photography

3) Lighting systems as required for mission objectives

1.2 RUFAS Equipment Configuration

The equipment layout for the RUFAS II vehicle is shown in the cutaway view (Figure 1). Watertight integrity was obtained by enclosing most electrical equipment and the film camera inside two, 28-inch diameter spheres. The spheres used here are surplus helium storage spheres made of 6AL4V titanium alloy heat treated to a minimum yield of 146,000 psi. These spheres were extensively modified for RUFAS service in order to save time and money. However, standard deep submergence aluminum spheres are commercially available for this application.

1.2.1 Material

Aluminum alloy (6061) was the primary material used to construct the RUFAS II vehicle (Figure 2). Fiberglass members were molded for springs and where double-curved surfaces were required. Plexiglass windows are used to make the vehicle streamlined and to prevent motion of the vehicle when the TV camera and lights are moved by the pan and tilt mechanism.

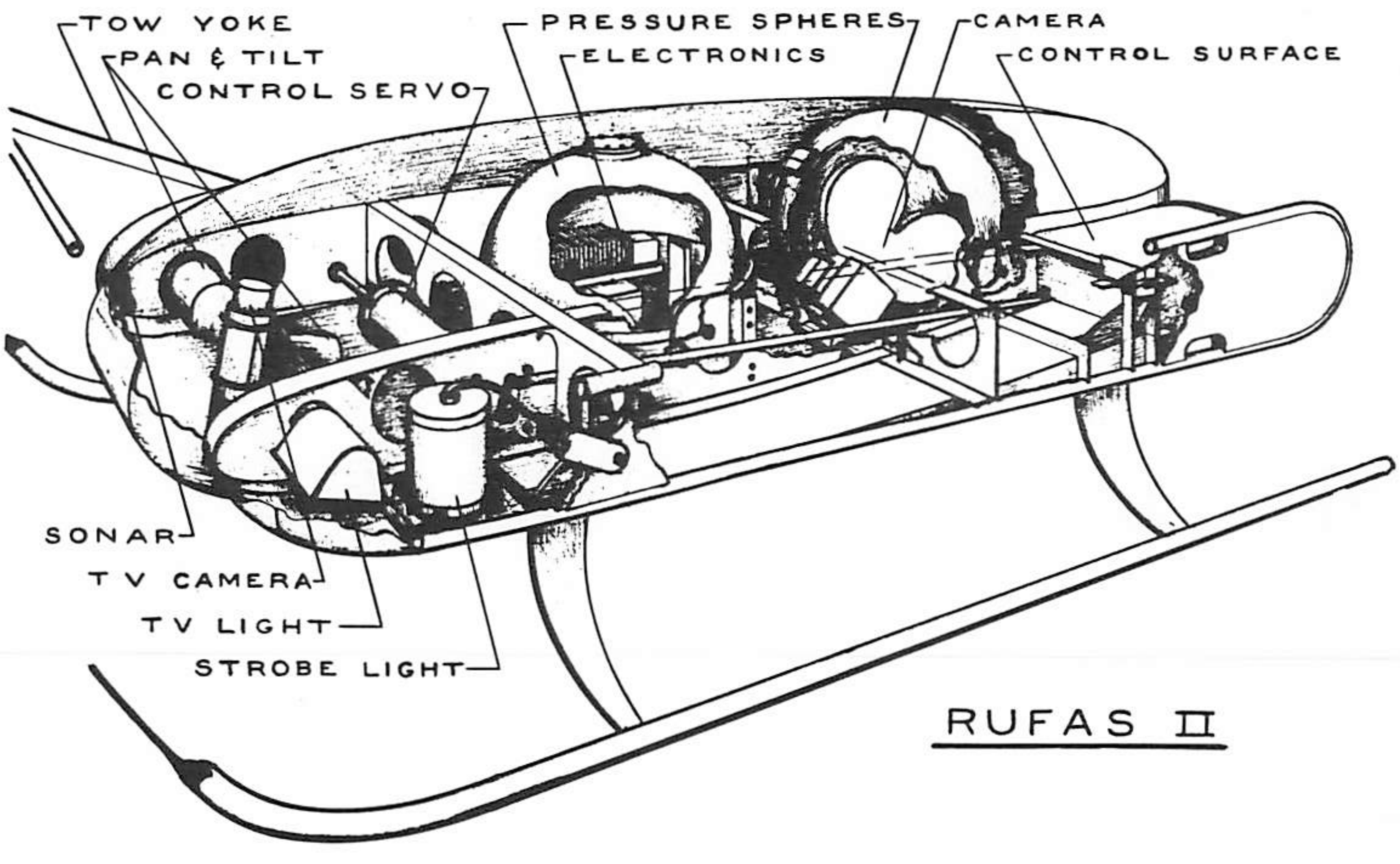


Figure 1. Cutaway view of the RUFAS II vehicle.

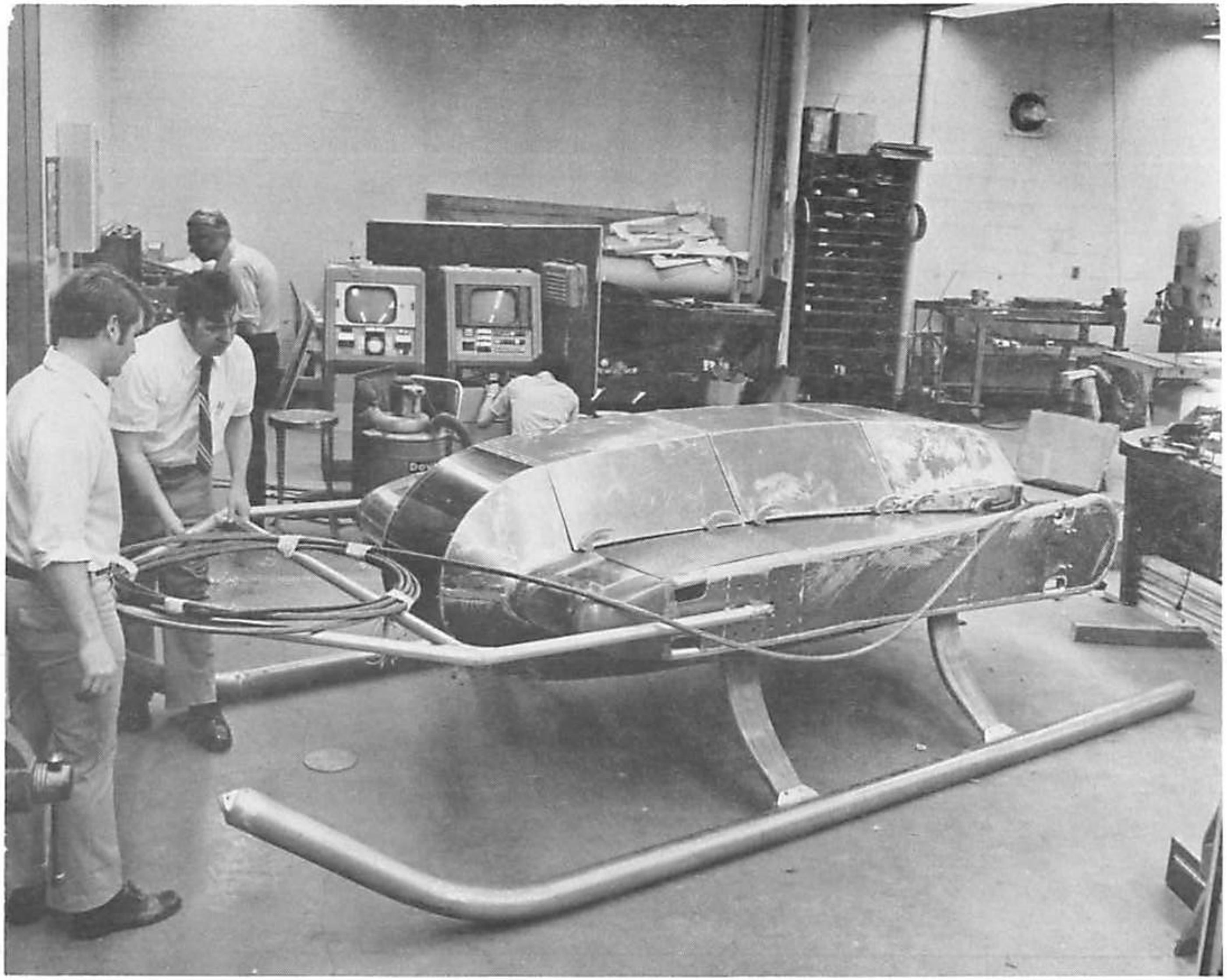


Figure 2. RUFAS II vehicle being prepared for initial tow tank test.

1.2.2 Television System

The television system for RUFAS used a Hydro Products Model TC 125 camera mounted on pan and tilt mechanism (Figure 3) of our design. Two Hydro Products Model LT-7 Thallium Iodide lights, which are also mounted on the pan and tilt mechanism, provide illumination for the TV camera. Ballast transformers for the lights are located in the rear sphere. On board the towing ship, two 14" solid state 10 MH_z television monitors are provided for the RUFAS operators and a Westinghouse Model TG30C27A video tape recorder completes the television system.

1.2.3 Data Camera System

The data camera used on RUFAS II is a Flight Research Company Model IV 35mm camera with a 16.5mm Angeniux lense. This camera is equipped with a 1,000 foot film magazine which gives the RUFAS II system 2.5 times the film capacity of the RUFAS I system. Illumination for the film camera is provided by the Hydro Products Model PF720 200 watt second strobe light. The camera is intervalometer-controlled.

1.2.4 Sonars

The RUFAS II system used two Heath Model MI-101 digital depth sounders. One of these modified sonar units has its transducer mounted so that it measures the vehicle height above bottom. The transducer for the second sonar unit is pendulum mounted in such a way that it measures the clearance ahead. This forward looking unit has been modified to ignore target returns within 80 feet of the

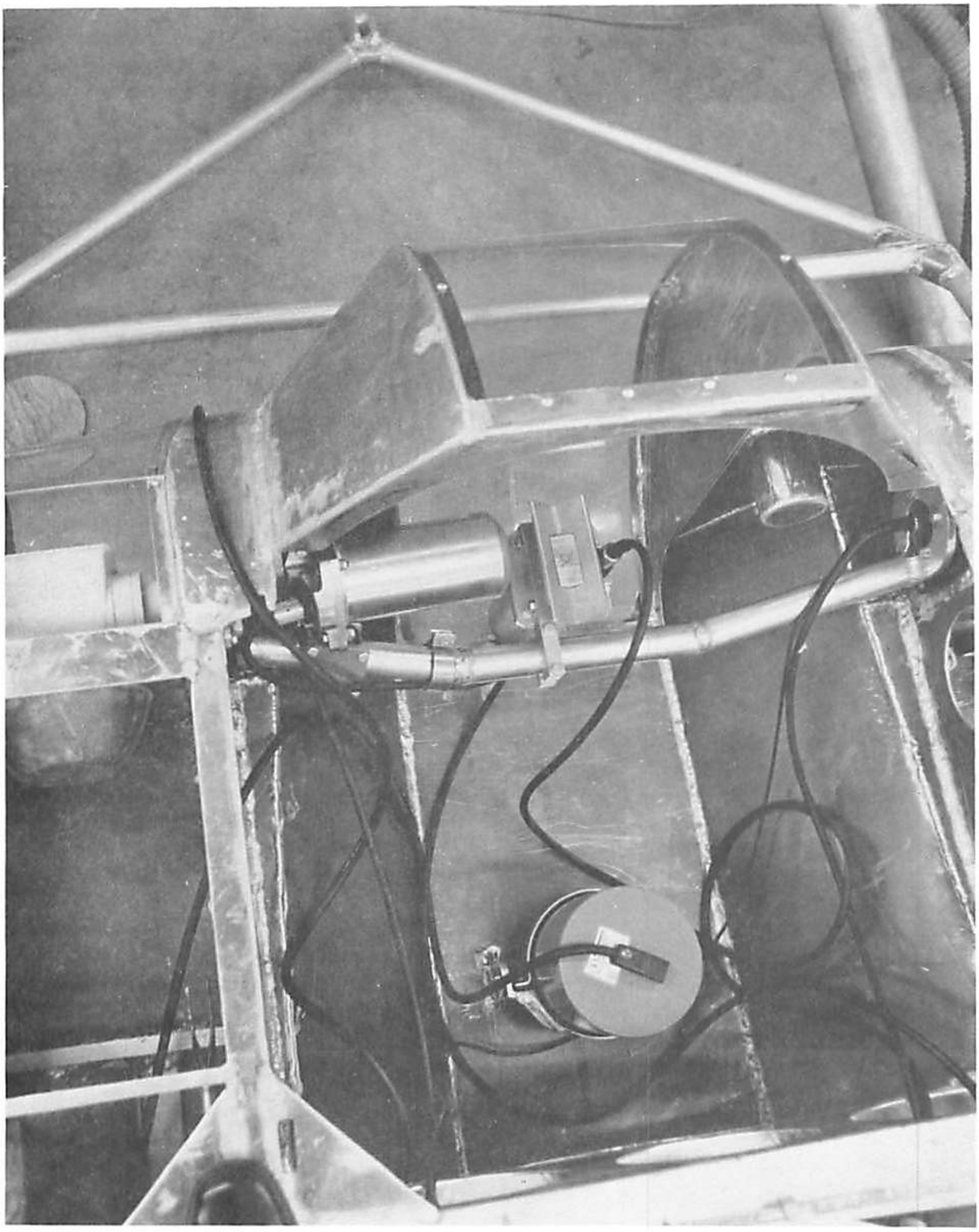


Figure 3. Interior view of RUFAS II vehicle. The pan and tilt mechanism, the strobe light, and one of the thallium-iodide lights can be seen. The TV camera has been removed.

vehicle so that side lobe reflections will not jam the system. The operator readouts of both sonars used analog meters. Both a light and an alarm tone are used to alert the operator when the vehicle is too close to the bottom or an obstacle is detected ahead of the vehicle by the forward looking sonar.

1.2.5 Vehicle Control System

The vehicle is controlled by the two vanes in the stern (Figure 4) which are manipulated by the control servo. This servo uses two motors, one for climb-dive, the other for roll. The climb-dive motor moves the vanes up and down together. The roll motor drives the vanes through a differential gear which will cause one vane to move up and the other to move down. The operator has two options in the control of the vehicle. In one, he can set in a particular vane angle and in the other he can set in a desired height above bottom. In the first case, the input signal is nulled by feedback from the vane position and in the latter case, the feedback is provided by the down looking sonar.

1.2.6 Operator's Consoles

There are two operator's consoles in the tow vessel (Figure 5). One console is for the vehicle operator. This console has readouts of vehicle roll and pitch, port and starboard vane angles, a live TV picture, and the sonar readouts. It is also equipped with the vehicle controls and alarms. The second console is for the data operator. The TV picture at

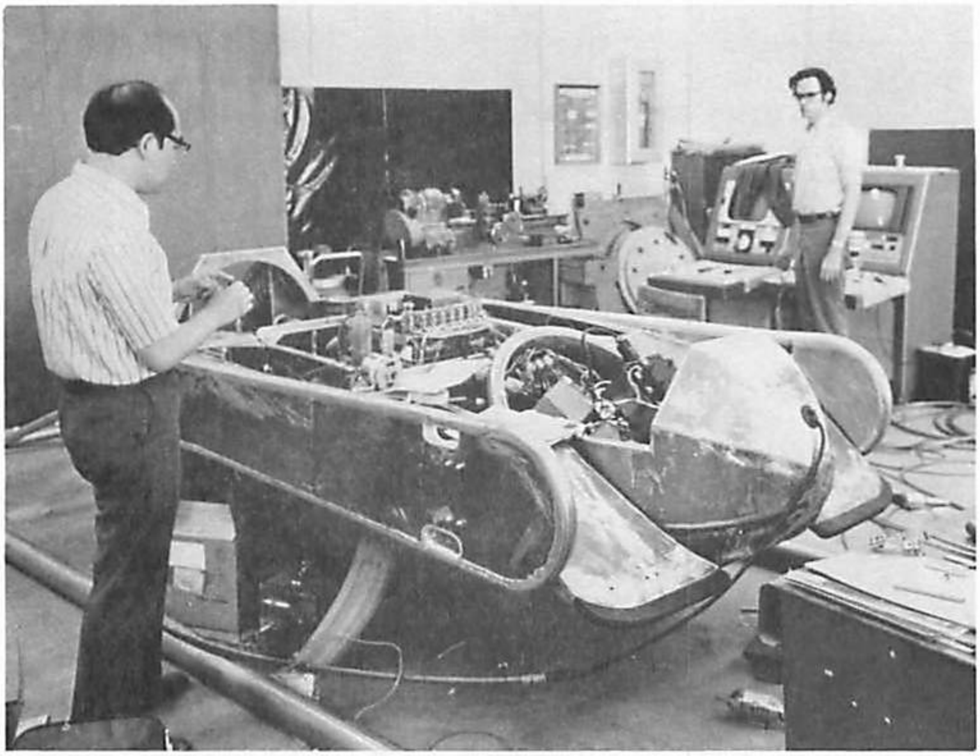


Figure 4. View of the RUFAS II vehicle from the rear with hatches and sphere covers removed. The rubber edged control vanes can be seen in this picture.

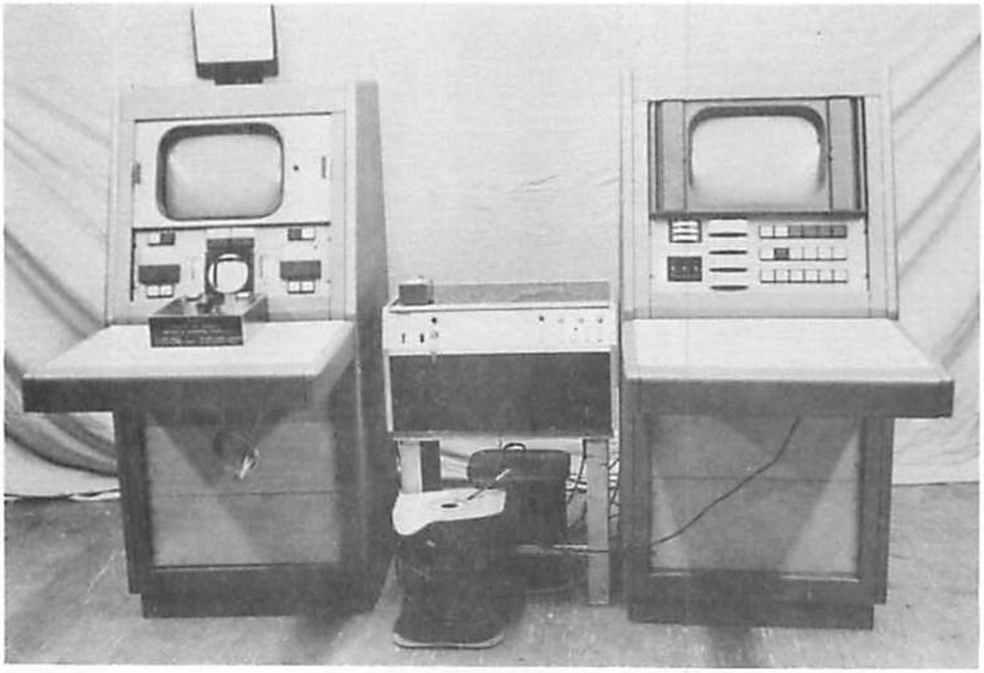


Figure 5. Operator's consoles and video tape recorder.

this console can be live or from the video tape recorder. This operator will operate the TV system and the data camera systems. He will also monitor the electrical power meters and operate the video tape recorder.

1.2.7 Telemetry System

The RUFAS vehicle is connected to the consoles and tow vessel through the tow/electrical cable. This double-armored, steel-jacketed cable contains four power conductors, an RG 59 coaxial cable, and a small, twisted pair of communications wires. Three phase, 60 cycle, power is supplied to RUFAS through the four power conductors. A variable transformer is supplied to the data operator's console so that adjustment may be made to compensate for voltage drop in cables of different lengths or generator voltage levels.

The signals transmitted over the twisted pair are two simultaneous audio tones generated by phase lock-loop circuitry in response to operator switch functions. These tones are decoded by a phase lock-loop receiver on RUFAS to activate motors and relays on the vehicle. This system can provide up to sixteen commands to the vehicle including emergency vane control signals.

The television signal is transmitted baseband over the RG 59 coax. The primary up and down link telemetry signals are frequency multiplexed and transmitted over the same coax with the TV signals. The down link telemetry uses a carrier frequency of 25 MH_z and the up link system a frequency of 29 MH_z. Filters isolate the TV and telemetry systems.

2. RUFAS II MECHANICAL DESIGN

RUFAS II is laid out around the mechanical and electrical requirements of a vehicle to support the instrumentation for bottom and mid-water surveillance down to 400 fathoms and speeds to four knots. Control and monitoring is from a ship which tows the vehicle by means of a combined electrical and tow cable.

The basic sensory instruments for surveillance are a TV camera and a film camera. The vehicle could also be adapted to carry a side looking sonar, if desired. The TV camera is monitored in real time aboard the ship. The film camera records on 35mm movie film which is carried aboard the vehicle until the end of the run and retrieved aboard the tow ship.

It is desired to be able to control the path of the surveillance instruments and maintain them in an observing relationship to features of interest for an extended period of time. The most critical of these requirements is ocean bottom observation, which determines the vehicle requirements. The vehicle must be able to follow the bottom and maintain any desired separation by manual or automatic control. Second-level sensory instrumentation provides the necessary inputs for this function. Down looking and forward looking sonar indicate the distance from the bottom or forward obstructions. Sensors of vehicle attitude and control surface position are integrated with the control circuitry to provide the proper dynamic response of the vehicle.

2.1 Hull Configuration

The response of the vehicle to manual or automatic control inputs is accomplished by hydrodynamic means. Vertical manueverability requires vertical forces of considerable magnitude combined with a relatively small drag. This is accomplished by making the whole vehicle of an approximately symetrical hydrofoil shape. Roll and pitch changes are provided by moveable fins at the trailing edge. To prevent restraint of maneuvering by the tow cable, a hinged tow yoke is provided. This straddles the vehicle and pivots at approximately the hydrodynamic center.

2.2 Component Lay Out

The lay out of components within the free flooding hydrodynamic envelope gives first priority to the basic sensors. The TV camera has its own pressure housing and can be located in a flooded compartment. It is desired to aim the TV camera independently of the vehicle heading. A tilt of 60 degrees above and below the centerline and pan of 30 degrees right or left are provided by remote control from the towing ship. These requirements necessitate placing the TV camera behind a curved window in the extreme front of the vehicle. Lighting is also required at the depths intended. Flood lights for the TV are placed as far as practicable from the camera in the front corners to reduce backscatter from particulate matter in the water. The two floodlights are arranged to follow the tilting motion of the TV camera. They are protected behind windows in the leading edge.

2.3 Data Camera and Electronic Housing

The film camera does not have its own pressure housing and is placed in the aft pressure sphere. The sphere is hinged on its lateral axis to permit on-deck adjustment of the fore and aft aim of the camera. Normally, the camera is turned about 45^{o} forward of vertical to photograph the bottom in the spot illuminated by a down-pointed strobe light mounted in the forward belly. Retrieval and loading of film takes place on the deck of the ship and requires opening of the aft pressure sphere. Hinged hatches on the streamline floodable shell provide access to the pressure spheres and other equipment. A long window in the belly maintains the streamline form of the flooded envelope but permits photographing through it.

Another identical pressure sphere in the center of the vehicle encloses electronic components. These titanium spheres were originally designed for internal pressure use and were obtained from government surplus. To adapt them for easy access to the interiors, they were split in half, provided with ring seals, and bolting flanges with mounting brackets. Plexiglas pressure windows were installed for the film camera.

2.4 Control Servo Housing

A third main pressure vessel of cylindrical shape is mounted in the forward compartment to house the servo mechanism that operates the control surfaces. Push-pull rods run from arms on the ends of the cylinder through an adjustable-ratio link to arms on the control surfaces. The control surfaces, one on each side, are independently operated. A special mechanism employing differential gears enables one electric motor to control roll only. Another electric motor controls pitch only.

2.5 Safety Features

A system of skids is provided to protect the vehicle from bottom contact and damage in launching, retrieving, and handling aboard ship or ashore. They are longer than the vehicle and curve up at the front in the manner of sled runners. They also are placed farther out than the width of the vehicle for protection against side impact. Fiberglass spring legs attach the skids to the vehicle. These are designed to absorb vertical and horizontal impact.

Should the vehicle entangle with an obstruction, the cable attachment at the tow yoke is designed to break loose at a relatively small force. The cable passes over the vehicle to a stronger attachment at the rear which will pull the vehicle end-over-end to tumble free over the obstruction.

3. VEHICLE CONTROL SYSTEM

3.1 Vehicle Control by Vane Positioning

Left and right control vanes at the rear of the vehicle govern the positioning of the vehicle. When the vehicle is in motion, the position of the vanes is the dominating factor in determining the position of the vehicle. The effectiveness of the vanes is approximately proportional to the square of the towing speed. In addition to vane position, vehicle position is influenced by towing speed, towing cable length, vehicle depth, and ocean currents in the flight path.

The various vehicle control systems control only vane position; since the vehicle is very responsive to vane control, a tightly controlled flight path is obtainable through vane position control.

3.1.1 Control Vane Angle Definitions

Figure 6 schematically represents the position of the control vanes with respect to the vehicle plane. The vehicle plane is a plane passing through the axis of rotation of the control vanes and parallel to a plane tangent to both skids, i.e. if the vehicle is resting on a flat surface, then the vehicle plane is parallel to this flat surface.

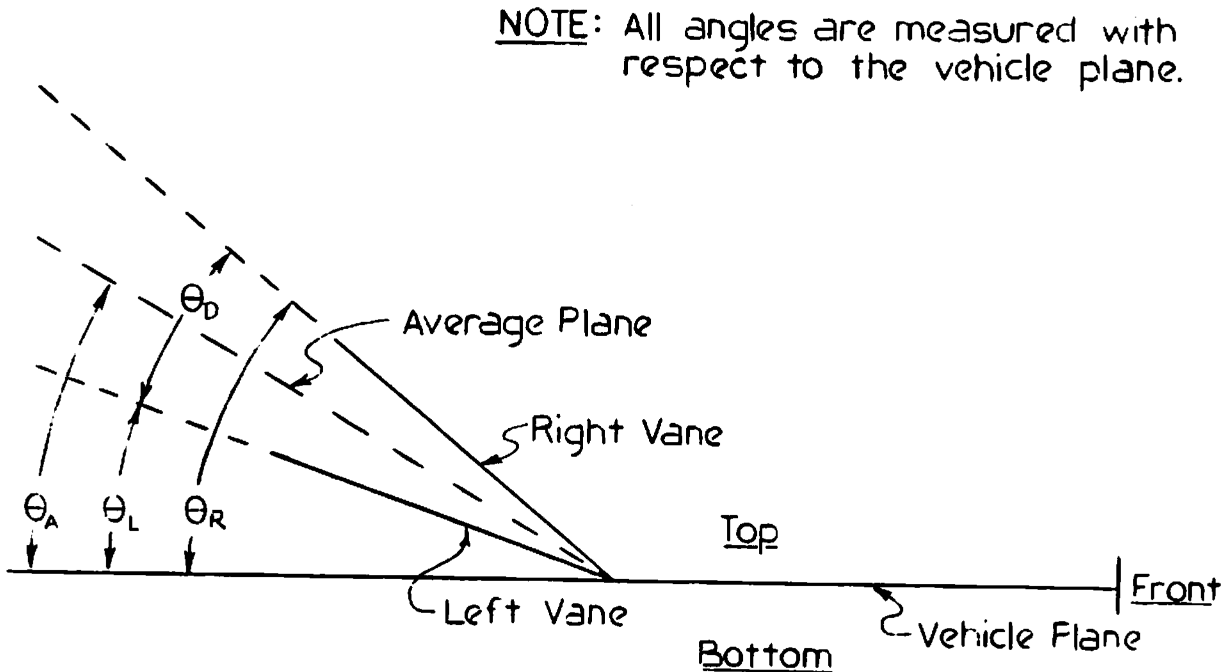
All angles are measured with respect to the vehicle plane; angles above this plane are positive and below are negative. θ_L is the angle of the left control vane and θ_R the angle of the right control vane. θ_D is the angle between the vanes, i.e. $\theta_D = \theta_R - \theta_L$. Note that if $\theta_D > 0$, the right vane is above the left vane, if $\theta_D = 0$, the right and left vane are in the same plane, and if $\theta_D < 0$, the left vane is above the right vane.

The average plane is defined as the plane which bisects the angle between the control vanes. The average plane angle is given by $\theta_A = \frac{\theta_R + \theta_L}{2}$. Note that if $\theta_A > 0$, the average plane is above the vehicle plane, if $\theta_A = 0$, the average plane is in the vehicle plane, and if $\theta_A < 0$, the average plane is below the vehicle plane.

3.1.2 Effects of Control Vanes

When $\theta_D = 0$ and $\theta_A = 0$, the control vanes exert no upward or downward force on the rear of the vehicle.

When $\theta_D = 0$ and $\theta_A > 0$ (i.e. control vanes up), the control vanes exert a downward (with respect to the vehicle plane) force on the rear of the vehicle giving the vehicle a tendency to rotate in an upward path whose radius of curvature is related to θ_A.



The average plane is the plane which bisects the angle between the control vanes (θ_D).

The average plane angle is given by $\theta_A = \dfrac{\theta_R + \theta_L}{2}$.

If $\theta_A > 0$, the average plane is above the vehicle plane.

If $\theta_A = 0$, the average plane is in the vehicle plane.

If $\theta_A < 0$, the average plane is below the vehicle plane.

If $\theta_D = \theta_R - \theta_L > 0$, the right vane is above the left vane.

If $\theta_D = 0$, the right vane and left vane are in the same plane.

If $\theta_D < 0$, the left vane is above the right vane.

Figure 6. Schematic Diagram of Control Vane Position.

When $\theta_D = 0$ and $\theta_A < 0$, (i.e. control vanes down), the control vanes exert an upward force on the rear. In a similar manner, this causes a tendency for the vehicle to rotate in a downward path. The path of rotation is limited among other things by cable weight, cable length, angle of towing cable and cross currents.

The upward vertical component of force due the towing cable must be offset by a downward force from the vanes in order for a horizontal flight path to be maintained. The result is that θ_A is greater than zero (average plane is above the vehicle) causing the vehicle to fly with its rear up from the flight path.

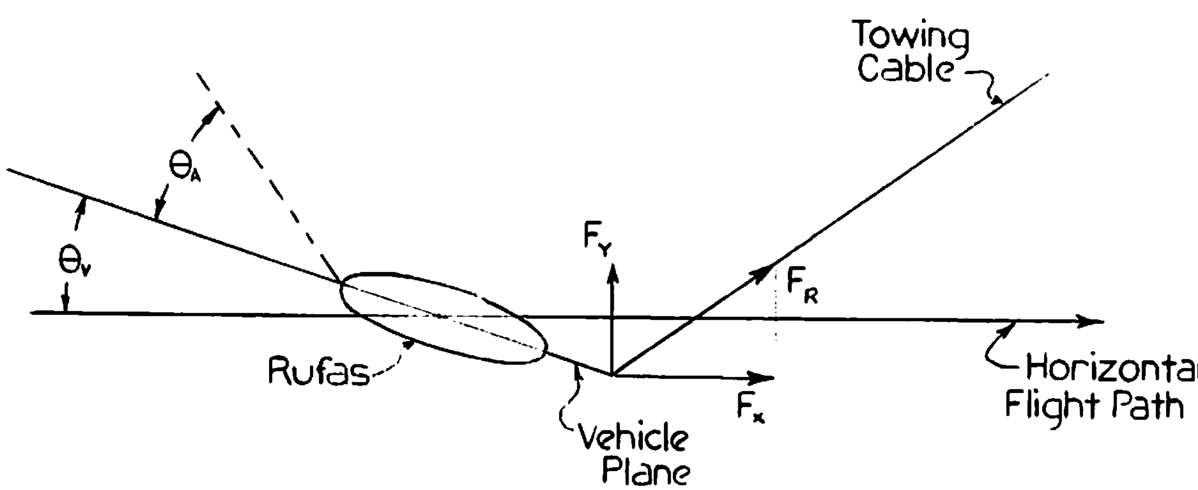


Figure 7. Normal flight condition of vehicle. The vehicle is flying at a tilt to offset the vertical component of the towing force F_y.

Among other factors, θ_A depends on towing speed, cable length, and depth of flight. The amount of θ_A required for a level flight under a given set of conditions may be set manually by the flight commander or adjusted by the automatic flight control system.

If twisting moments (caused by cross currents, towing cable, etc.) about the vehicle's longitudinal axis are neglected and if $\theta_A = 0$, then the vehicle should have no tendency to roll.

If $\theta_D > 0$ (right vane is above the left vane), there is a downward force on the rear right and an upward force on the rear left of the vehicle producing a roll right maneuver and in a similar manner, if $\theta_D < 0$ (left vane is above the right vane), there is a downward force on the rear left and an upward force on the rear right producing a roll left maneuver.

In flight, there will be twisting moments about the vehicle's longitudinal axis caused by such factors as ocean cross currents, cable torque and vehicle imbalance. In order to produce a counter moment to maintain a roll free flight, θ_D will normally not be zero. The amount of θ_D required for a roll free flight may be set manually by the operator or adjusted automatically by the stabilized roll control system.

It is evident that, for a level, roll free flight $\theta_A > 0$ (vanes up) and in general $\theta_D \neq 0$ (some counter roll exists.) The amount of θ_A and θ_D required depends upon variable factors such as towing speed, cable length, depth of flight, buoyancy of vehicle,

vehicle imbalance, and ocean currents. Each set of conditions requires set values of θ_A and θ_D. These two parameters may be set either manually by the operator or adjusted by the automatic flight control system.

3.2 Flight Control System

There are three climb-dive flight control systems which control the parameter θ_A. One of the following three systems can be selected and used at the operator's option:

1. Bang Bang Climb-Dive
2. Proportional Climb-Dive Angle Control
3. Automatic Terrain-Following Control

Also, there are three roll control systems which control the parameter θ_D. Only one of the following three systems can be selected and used at a time.

1. Bang Bang Roll
2. Proportional Roll Angle Control
3. Roll Stabilizer

The Bang Bang Roll and Bang Bang Climb-Dive System is a fast acting, backup system whose control signals (consisting of either a fully on signal or a completely off signal) are transmitted to the motor amplifier on a pair of twisted wires. These signals are completely independent of the downlink telemetry system. (See Section 4)

The command signals from the mother ship for the remaining four control systems are transmitted to the vehicle via the downlink telemetry on a single coax cable. Unlike the two state on-off signals of the Bang Bang system signals, these signals are fully proportional.

Relays switch the motor amplifier input (through the electronic limit switches) from the bang bang control signals to the proportional telemetry derived control signals. The motor amplifier input is always connected to either the bang bang control signals or the proportional telemetry derived control signals.

3.3 Control System Components

The major control system components are the motor, motor amplifier, vane position feedback pots, mechanical limit switches, and the electronic limit switches. These components of the control system are common to all of the control systems. However, there are two sets of these components, one for the roll control system (controlling θ_D) and one for the climb-dive control system (controlling θ_A).

3.3.1 The Motor

Two identical, twenty-eight volt D.C. motors are used to drive the gear train and mechanical mechanism to properly position the vanes. These motors have constant field current and are armature controlled by a motor amplifier. The motors provide a bidirectional rotation to the gear train.

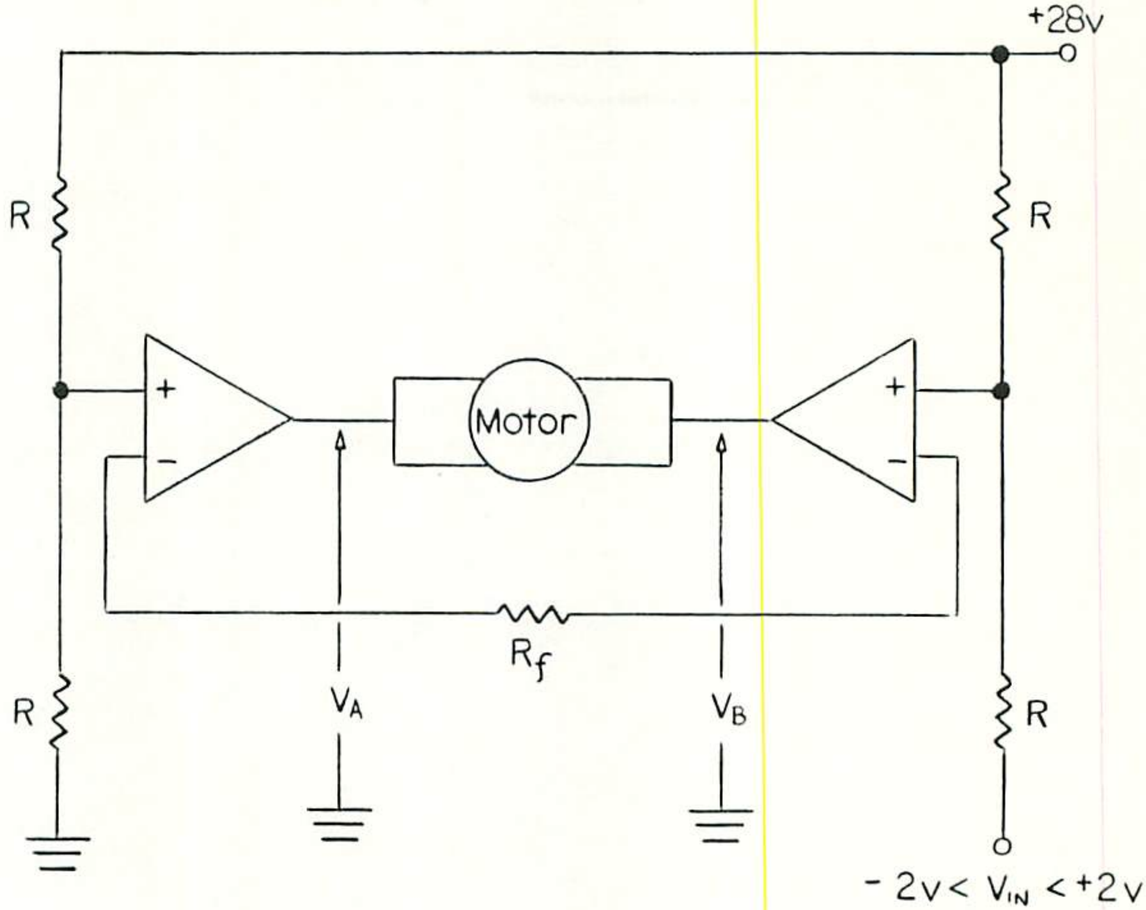


Figure 8. Block Diagram of Motor Amplifier.

3.3.2 The Motor Amplifier

Figure 8 gives the block diagram of the motor amplifier. Note that the amplifier is a power bridge with the motor "floating off ground." If V_{in} = 0 volts, the bridge is balanced, $V_A = V_B$ with no current flowing through the motor, hence, the motor is at a standstill. If $V_{in} > 0$ $V_B > V_A$ and the motor rotates. If $V_{in} < 0$ the motor rotates in the opposite direction. The range of allowable inputs for linear operation is -2 volts $< V_{in} < +2$ volts. The output voltage $(V_A - V_B)$ to input voltage gain (V_{in}) is approximately 12 volts per volt. If the input is open circuited, then V_{in} is effectively + 28 volts $V_B > V_A$ and the motor rotates. V_{in} must be zero (i.e. grounded) for the motor to stop.

Bidirectional motor rotation from a single polarity power supply (+28 volts) is achieved using a bridge configuration.

Refer to the motor amplifier schematic diagram (IET 73-003). The actual amplifier consists of 12 output transistors (6 on each side) in a complimentary symmetry, Darlington connected configuration. This allows nearly twice the power supply voltage swing across the motor (-28 volts to +28 volts) and a maximum current of 10 amperes (electronically current limited).

3.3.3 Vane Position Feedback Pots

Vane position is sensed by a potentiometer mounted on the vane drive shaft. As shown in Figure 9, a constant current is forced into the vane pot to develop an output voltage directly proportional to vane position (the constant current technique requires only a single wire, in addition to ground).

The vane position is used in the electronic limit switches, Roll Angle Control System, Climb-Dive Angle Control System, Roll Stabilizer Control System, Automatic Terrain Following Control System, and is telemetered uplink to the operator as a visual readout.

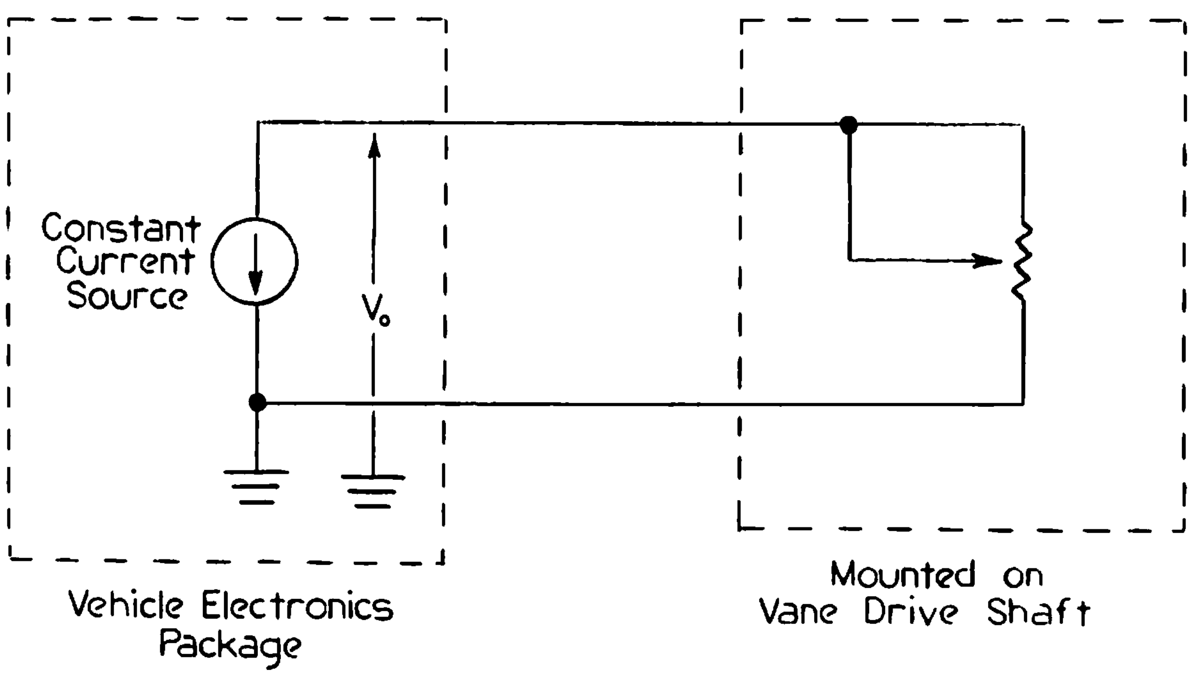


Figure 9. Vane position feedback pot system.

3.3.4 The Pitch Sensing and Roll Sensing Pendulum Pots

The angle that the vehicle plane makes with the horizon is sensed and measured by a pendulum pot. Also, another pendulum pot measures the roll angle of the vehicle.

The pitch and roll angle is sent to the operator's console as a visual readout of the vehicle position.

The uplink data transmission system requires a positive offset voltage on the pendulum pot which must be removed to provide a voltage swing about zero. See Figure 10.

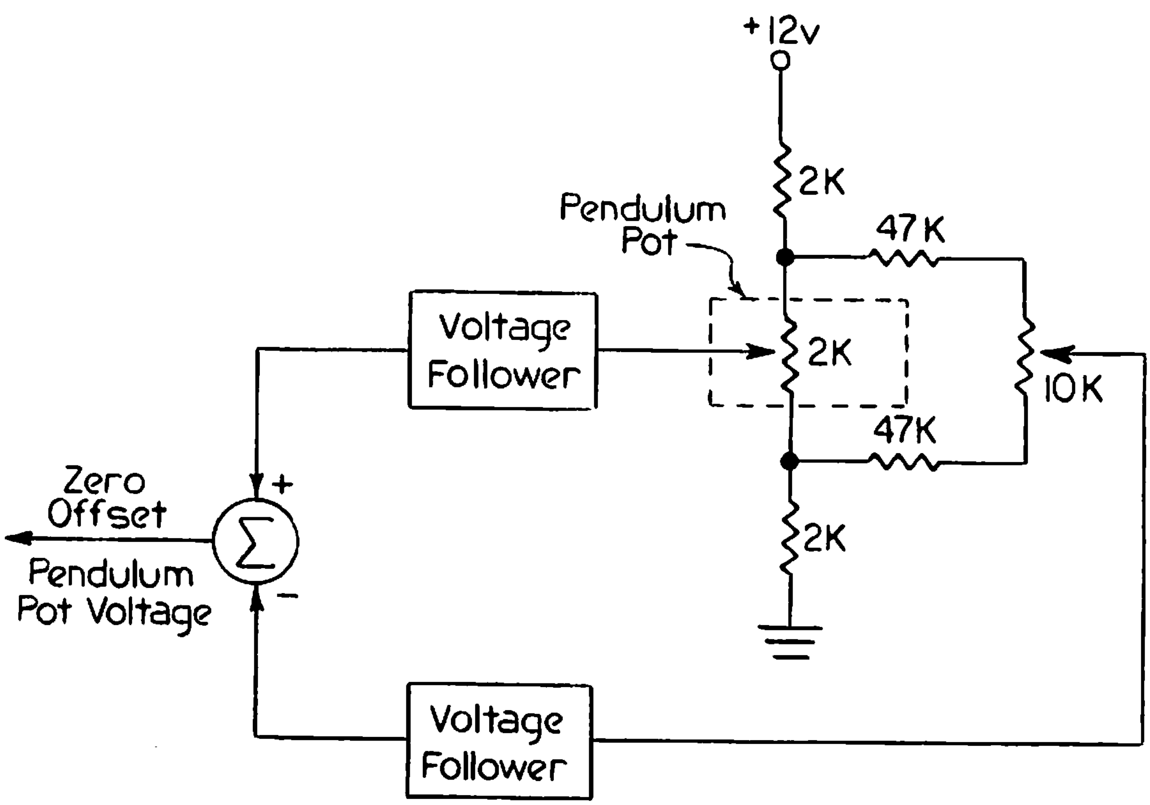


Figure 10. Method of removing the offset voltage of pendulum pot.

The pendulum pot output voltage is very highly amplified necessitating a zero offset voltage and also an extremely stable method of providing the zero offset. Figure 10 shows how this is achieved. Note that any variation in voltage across the pendulum pot is cancelled in the difference amplifier (this automatically compensates for resistance aging and power supply variations).

The vehicle roll angle is a feedback signal in the Roll Stabilizer Control System and the vehicle pitch angle is a feedback signal in the Terrain-Following Control System.

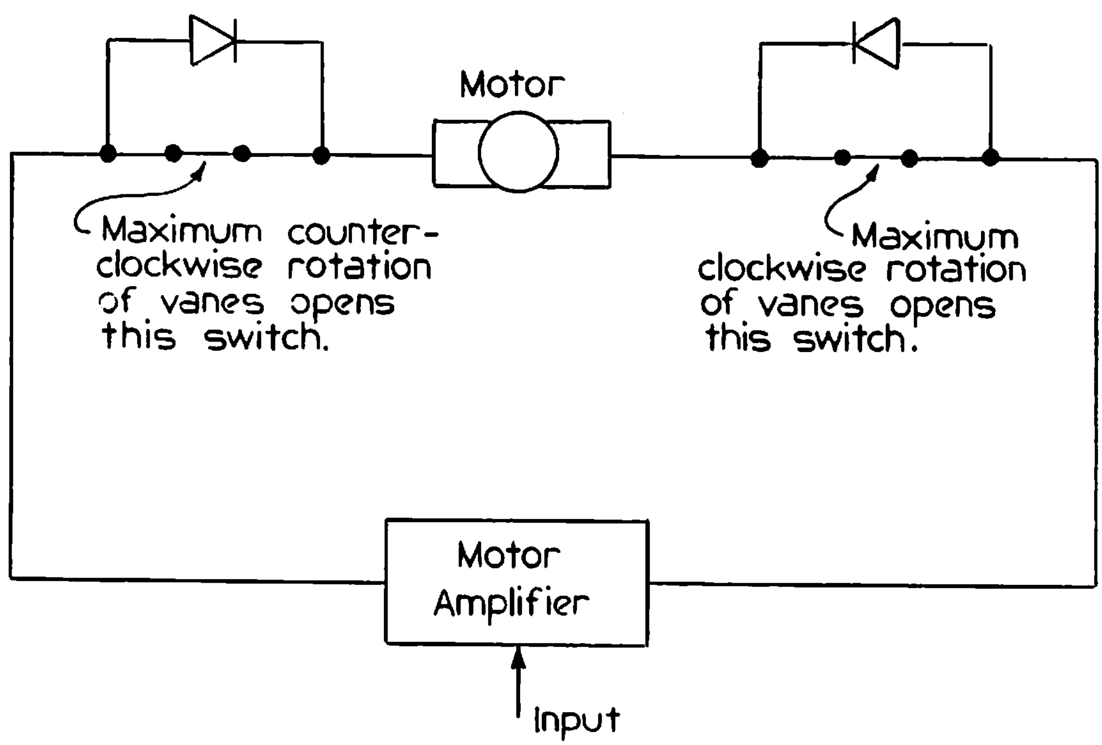


Figure 11. Mechanical Limit Switch Block Diagram.

3.3.5 Mechanical Limit Switches

Figure 11 shows a block diagram of the Mechanical Limit Switch System. The limit switches are opened by a cam mounted on the output vane shaft when the vanes reach a predetermined rotation (i.e. just before a mechanical stop occurs). With the switch opened, the motor cannot drive the vanes into an undesired region, however, a diode across the limit switch allows current to flow in the opposite direction so reverse vane travel is possible. This system, in addition to the electronic limit switch, protects the gear system, mechanical linkage, motor and motor amplifier from damage by not allowing a mechanical stop to occur.

3.3.6 Electronic Limit Switches

The mechanical limit switches limits the output current to the motor. The Electronic Limit Switch System is an analog to the mechanical limit switches but limits the drive signal at the input of the motor amplifier.

Refer to Figure 12. Normally, the vanes are within operating limits and the output of the comparators keep the FET switches closed. This then, puts the two ideal diodes in parallel and the control signal has a direct path to the motor amplifier, giving normal control.

The high comparator detects when the vanes reach an upper limit and turns off the associated FET switch, preventing further vane travel in that direction. However, a reverse travel input signal can be applied through the remaining closed FET switch. When the vanes reach a lower limit, the lower comparator turns off its associated FET switch, thus preventing further vane travel. Reverse travel is possible through the remaining closed FET switch.

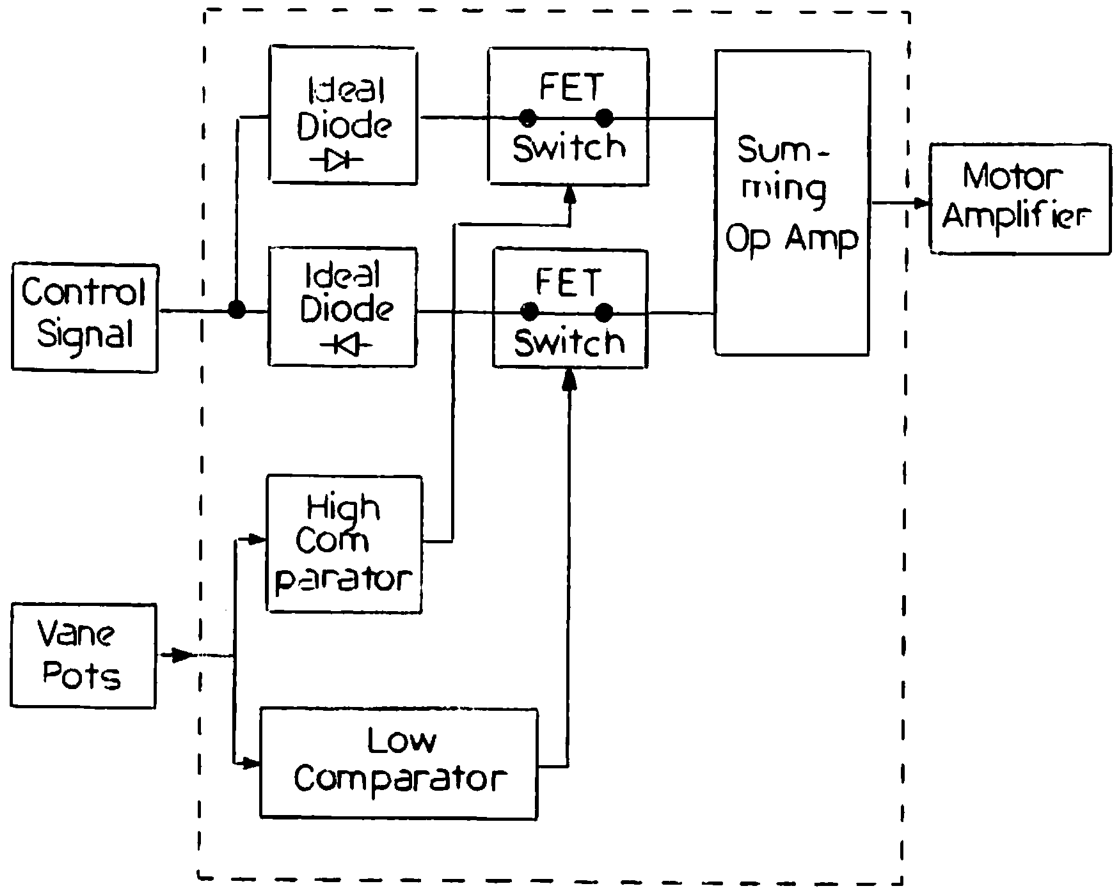


Figure 12. Electronic Limit Switch System.

3.4 Bang Bang Climb-Dive and Bang Bang Roll

The Bang Bang Climb-Dive System controls θ_A whereas, the Bang Bang Roll System controls θ_D, otherwise the two control systems operate in an identical manner and, hence, only the climb-dive system will be described.

To climb, the operator presses the Bang Bang Climb button, which applies the maximum input voltage to the motor amplifier (Figure 13). The vane position feedback pots provides the operator with a visual readout of the vane position. Vane angle travel is proportional to the time that the button is held down.

When the button is released the motor amplifier input is grounded, stopping the drive motor and holding the control vanes at a fixed angle.

An inflection point in the climb trajectory is initiated by pressing the Bang Bang Dive button. This removes the motor amplifier input from ground and applies a reverse polarity maximum input voltage which drives the vanes in the opposite direction of travel.

Note two things: First, if the vehicle is in any of the other climb-dive control systems and the Bang Bang Climb (or Dive) button is pressed, the Bang Bang Climb Control System automatically assumes command. Once in the Bang Bang Control Mode, the motor amplifier input is grounded when the control button is released.

Secondly, the operator must manually fly the vehicle in the Bang Bang Mode solely by visually gathering information from the Flight Control Console Instrument Panel. The available information are vane angle, vehicle angular position, height above bottom, depth below surface, range of climb or dive (inferred from height, depth, vane angle, vehicle angle information).

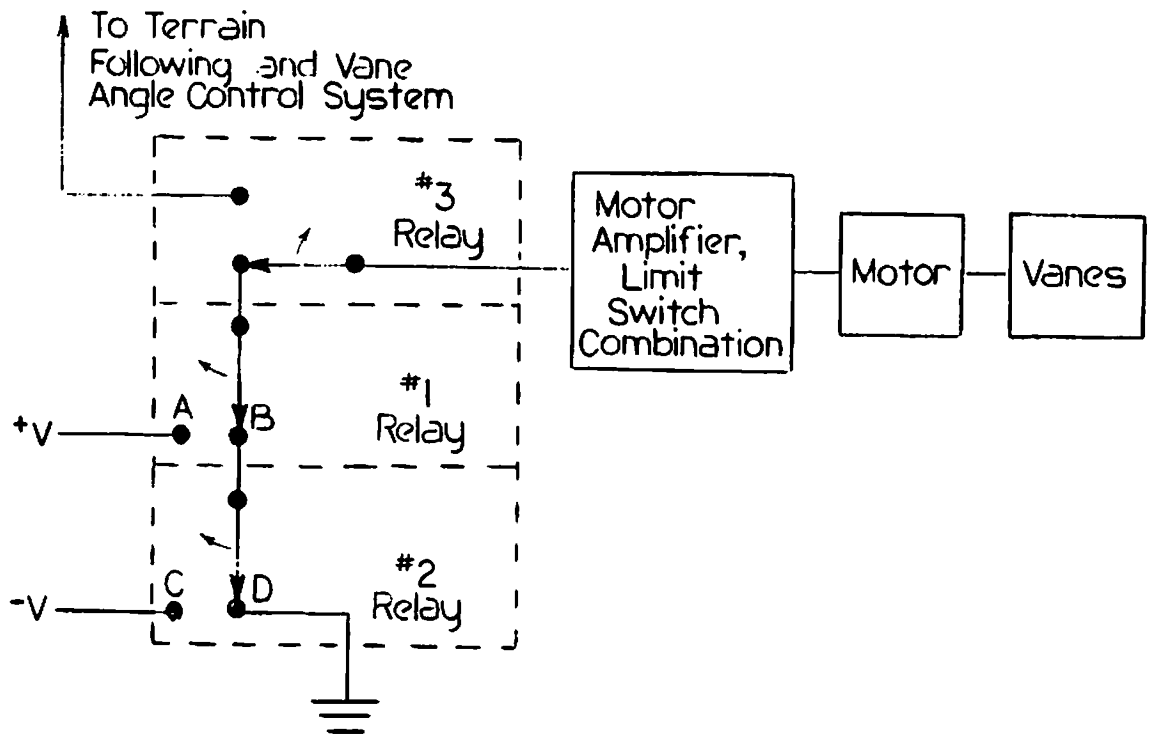


Figure 13. Bang Bang Control System Interconnection.

Relay #3 is the control system transfer relay. It is properly set when the desired control system is selected.

Relay #1 switches to position A when a Bang Bang Climb command is given.

Relay #2 switches to position C when a Bang Bang Dive command is given.

Note that when no command is given relay #1 assumes position B and relay #2 assumes position D grounding the motor amplifier input and stopping the motor.

3.5 Proportional Climb-Dive Angle Control and Proportional Roll Angle Control Systems

The Proportional Climb-Dive Angle Control System controls θ_A, whereas, the Proportional Roll Angle Control System controls θ_D. Other than this fundamental difference, the two systems (from a system concept) are identical in nature. In fact, these two systems can be compared to the Bang Bang Control System since they both determine the angles θ_A and θ_D. The basic difference between the Bang Bang Control System and the Proportional Angle Control System is that in order to obtain a given angle, say θ_{1A}, the Bang Bang Control button must be held down for a time t_1, where as, in the Proportional Angle Control System, the Flight Commander sets the Proportional Angle control to θ_{1A} and the vanes travel until the angle θ_{1A} is reached. Both systems produce θ_{1A} as a final result in the almost same amount of time due to the high system gain.

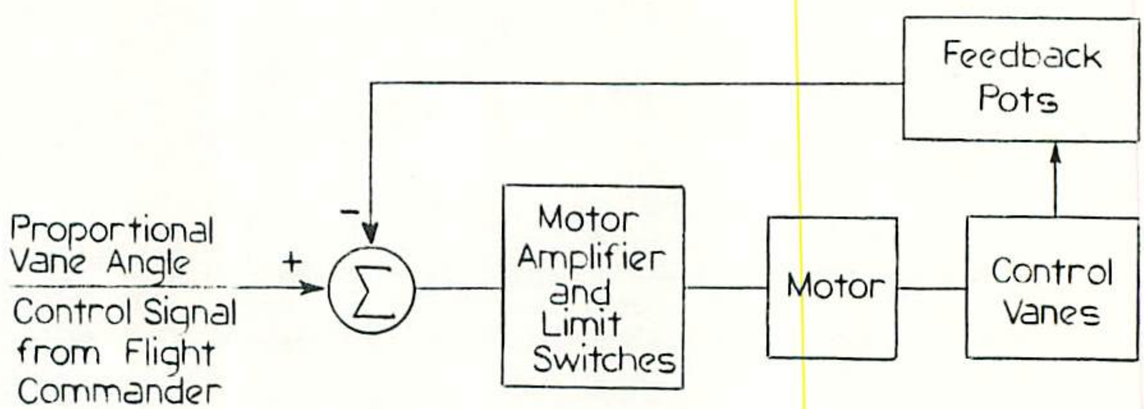


Figure 14. Proportional Vane Angle Control System Block Diagram.

The Proportional Angle Control System (Figure 14) is a feedback control system allowing a precise selection of vane angle.

Vane angle position is fed back and compared against the desired vane angle. When the actual vane angle equals the desired angle the motor amplifier input signal is zero and the vanes stop moving.

3.6 Roll Stabilizer

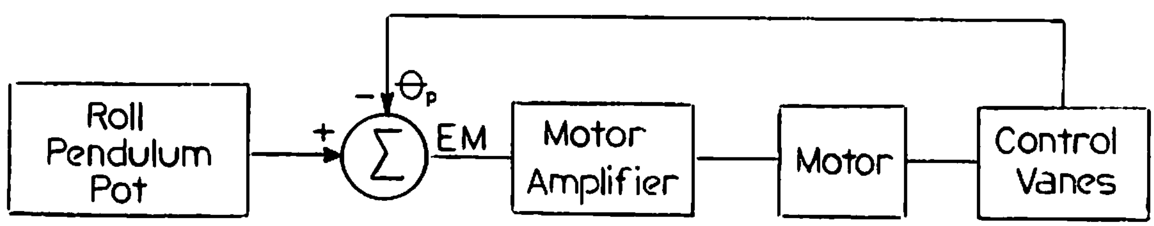


Figure 15. Roll Stabilizer Diagram

The Roll Stabilizer System maintains a level vehicle flight against underwater cross currents and imbalance due to the cable and vehicle.

A pendulum pot is positioned to give zero signal voltage output when the vehicle is in a level flight condition. The pendulum pot is mounted to sense roll maneuvers, i.e. rotation about the vehicle longitudal axis and produces a signal voltage proportional to the amount of rotation.

Clockwise rotation produces a signal voltage of one polarity while counter-clockwise rotation produces a signal voltage of the opposite polarity.

If the Roll Stabilizer is in operation and an undesired right roll occurs (for example, a clockwise rotation about vehicle longitudal axis), the output of the roll pendulum pot causes the motor to drive the left vane up and the right vane down (i.e. $\theta < 0$) producing a voltage output from the control vanes which is proportional to θ_D. This control vane voltage is then summed with the roll pendulum pot voltage in such a way to produce a zero output voltage when the two voltages are equal. Hence, when the two output voltages are equal the motor amplifier input is zero and the motor stops causing the control vanes to stop. Thus, the amount of vehicle rotation determines the angle between the vanes, i.e. θ_D and hence, the rate of counter-rotation produced by the vanes.

Summarizing, if an undesired roll occurs with the roll stabilizer in operation (which is the normal mode of operation) a different vane angle (θ_D) proportional to the amount of undesired roll produces a counter rotation tending to maintain a level flight condition.

3.7 Automatic Terrain-Following Control System

The Automatic Terrain-Following Control System maintains a desired vehicle height above bottom (as selected by the operator) following the gradual contours of the ocean floor. The ranges of operation in this mode are from 5 to 200 feet. The Manual Proportional or the Bang Bang Climb-Dive system must be used between 20 and 50 feet.

The normal flight procedure is to fly down to the approximate desired height or to within the control range using the Bang Bang Climb-Dive or Manual Proportional Control System and then switch into the Terrain-Following Mode.

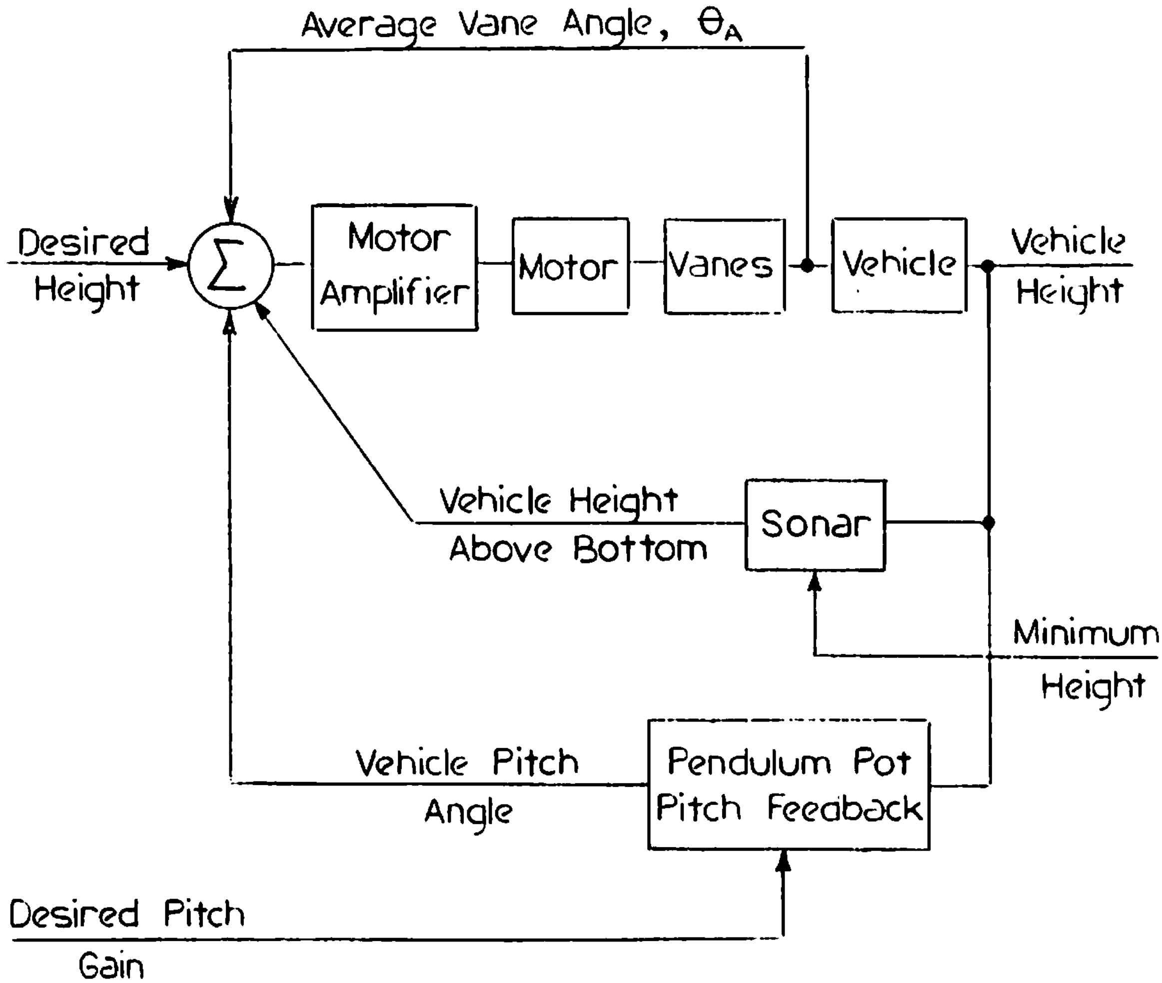


Figure 16
Automatic Terrain-Following Control System Block Diagram

Referring to Figure 16, the basic control system consists of the desired height input (as dictated by the operator) summed against the actual vehicle height (as provided by the sonar). The result is used to control the vane angle θ_A (through the motor amplifier and motor) which positions the vehicle to the proper height. Normally, the sonar provides new vehicle height information once every second.

To prevent the vehicle from bottoming out onto the ocean floor, a minimum height feature is included. A diode referenced fixed voltage is summed with the sonar input providing a minimum sonar signal output. The minimum height is preset to approximately 5 feet above bottom but increases with towing speed giving a desirable increased safety factor with increased tow speeds.

To damp the vehicle response, two additional feedback loops are used. Considerable damping is provided by feeding back the average vane angle θ_A and summing with the desired height and actual vehicle height. However, this still provides less than critical damping due to the relatively slow rate of change of the control vanes. Anticipatory feedback from a pendulum pot mounted to give the vehicle pitch angle (i.e., the derivative of the vehicle position) is used to provide the additional damping required for critically damping and overdamping the vehicle response.

Four discrete levels of pitch gains can be selected by the operator by a four-position rotatory switch on the Flight Control Panel. This allows the vehicle response to be varied from very overdamped to slightly underdamped.

4. TELEMETRY SYSTEM

It is necessary for the RUFAS operators onboard the towing ship to monitor a number of vehicle parameters. They also must provide the RUFAS vehicle and instruments with certain commands. The variety of information generated on RUFAS for up-transmission plus the commands down to RUFAS dictate that a telemetry system be used. These requirements coupled with cable constraints resulted in the use of a frequency multiplexed system so that telemetry signal shares a single RG-59 coax cable with the television video. A second downlink communication system was added to provide operator control of RUFAS in the event of some failure of the primary telemetry system. This added system is a Phase Lock Loop Tone Control System and has a separate transmission path over a small pair of cummunications wires.

4.1 Phase Lock Loop System

The phase lock loop transmitter (IET 73-009) consists of two oscillators which produce two simultaneous frequencies when a switch is closed. The oscillators are Signetics NE 566 integrated circuits. The frequency of oscillation, f_0, for the NE 566 circuit may be changed by any one of three methods: by changing an external resistor between pin 6 and 8 of the IC; by controlling the voltage at pin 5 of the IC; or by changing the value of a capacitor connected between pin 7 of the IC and ground. Since the frequency generation in this case is a switching function from one frequency to another, the first method is used.

The VCO operating frequency is determined by:

$$fo = \frac{2}{RC}\left(1 - \frac{V5}{V8}\right)$$

Where V8 and V5 are the voltages at pins 8 and 5 of the IC respectively.

C is a 4747 Pfd temperature stable 1% capacitor. The resistor R is selected by the control switches. These resistors are temperature stable 1% resistors. The values of R for one of the VCO are 2.67K, 3.67K, 4.67K, and 5.67K. The resistance values of the other VCO range from 7.5K to 13.5K in 2K steps. The switches are arranged to form a four by four matrix or 16 separate switch functions.

The outputs of both VCO's are summed by an operation amplifier and transmitted to the RUFAS vehicle on a pair of small communications wires in the tow cable.

The phase lock loop receiver (IET 73-010) uses eight Signetics NE 567 tone decoder circuits. The 567 tone and frequency decoder is a highly stable phase locked loop with synchronous lock detection and power output circuitry. Its primary function is to drive a load whenever a sustained frequency within its detection bandwidth is present at the input. The bandwidth and center frequency are independently determined by means of external capacitors and resistors. The center operating frequency is given by:

$$f_0 = 1.1/RC$$

Where R is the resistance between pins 5 and 6 of the 567 IC and C is the capacitance between pin 6 and ground. C is a 17000 Pfd temperature stable 1% capacitor. The frequency selecting resistor R varies from 2.67K to 13.5K and exactly corresponds to the resistor selected for the transmitter oscillator. When an in-band signal is present, the output transistor of the IC saturates; its collector voltage being less than 1 volt at full output current.

Four N7402 Quadruple 2-input position NOR gates are used to provide 16 AND gates for the outputs of the phase-locked loop circuits. The circuits are connected so that 16 functions can be controlled by the switches on the operator console.

4.2 RF Telemetry Systems

Two additional telemetry systems are used in the RUFAS system. There is an uplink telemetry system to provide data to the operators of the control vanes and two sonar readouts. The sonars provide information on the sled's height above the sea bed and the clearance ahead. In addition one spare channel is provided for uplink data transmission. A downlink command telemetry system is used which is almost identical to the uplink system. Both the uplink and downlink systems use parts of the Heathkit model GDA-405-D 8 channel digital proportional radio control system.

4.2.1 RF Telemetry Encoder

A block diagram of the downlink telemetry system is shown in Figure 17. The transmitter produces a crystal-controlled, rf carrier that is modulated by on-off carrier keying. The carrier is turned off for 350 microseconds by a monostable (one shot) multivibrator in the encoder.

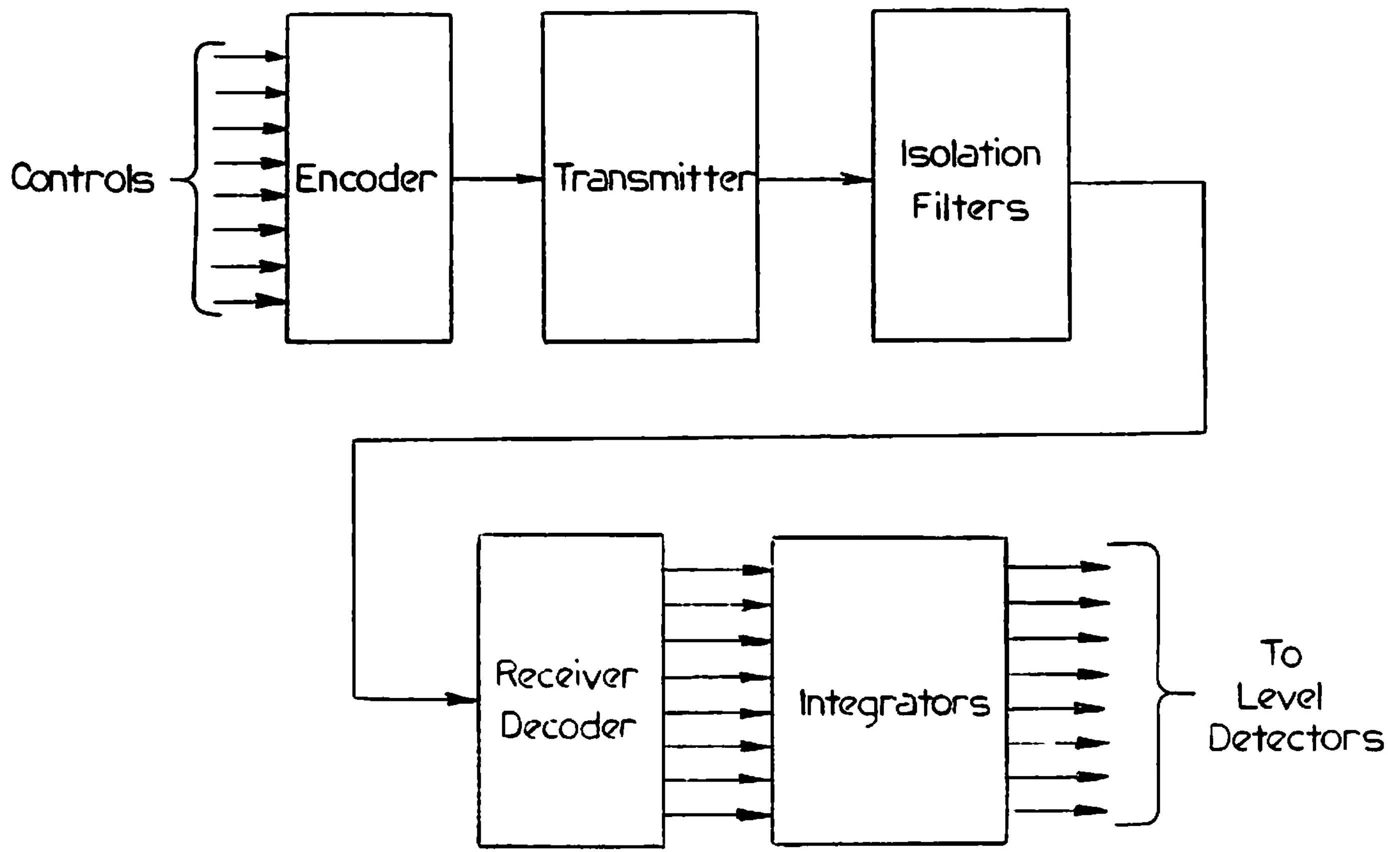


Figure 17
Block Diagram of Downlink RF Telemetry System

It is then turned off for a period of 1000 to 2000 microseconds (depending on the input control) then off again for another 350 microseconds and so forth. After the ninth 350 microseconds off pulse, a 5000 microsecond synch pause is produced by the encoder and the process is repeated. This is illustrated by the waveforms in Figure 18. The first waveform shows a frame of nine pulses that is repeated every 17,000 microseconds in a continuous train. After every ninth pulse there is a 5000 microsecond pause before the start of the next pulse. Each off pulse is 350 microseconds wide and there are 1500 microseconds from the start of a pulse to the start of the next pulse.

The second waveform shows that the time difference between two pulses may be increased or decreased by as much as 500 microseconds by changing the input to the encoder. It is this time difference that determines the output of the receiver on the channel in question. These time changes are produced by either a change in voltage or a change in resistance at the input to the encoder. When an input to the encoder is changed the time interval of that channel is changed. The second waveform in Figure 18 illustrates an increase in the time interval of channel #2 when the channel #2 encoder input is changed. All other channels remain the same. The 5000 microsecond pause after the ninth pulse in each frame is the synch pause. This pause synchronizes the receiver's decoder circuit with the transmitter signal.

A detailed description of the operation of the encoder and transmitter circuit is found in the Heathkit Assembly Manual (Heath Part No. 595-1406) for the model GDA-405-D 8 channel digital proportional radio control transmitter.

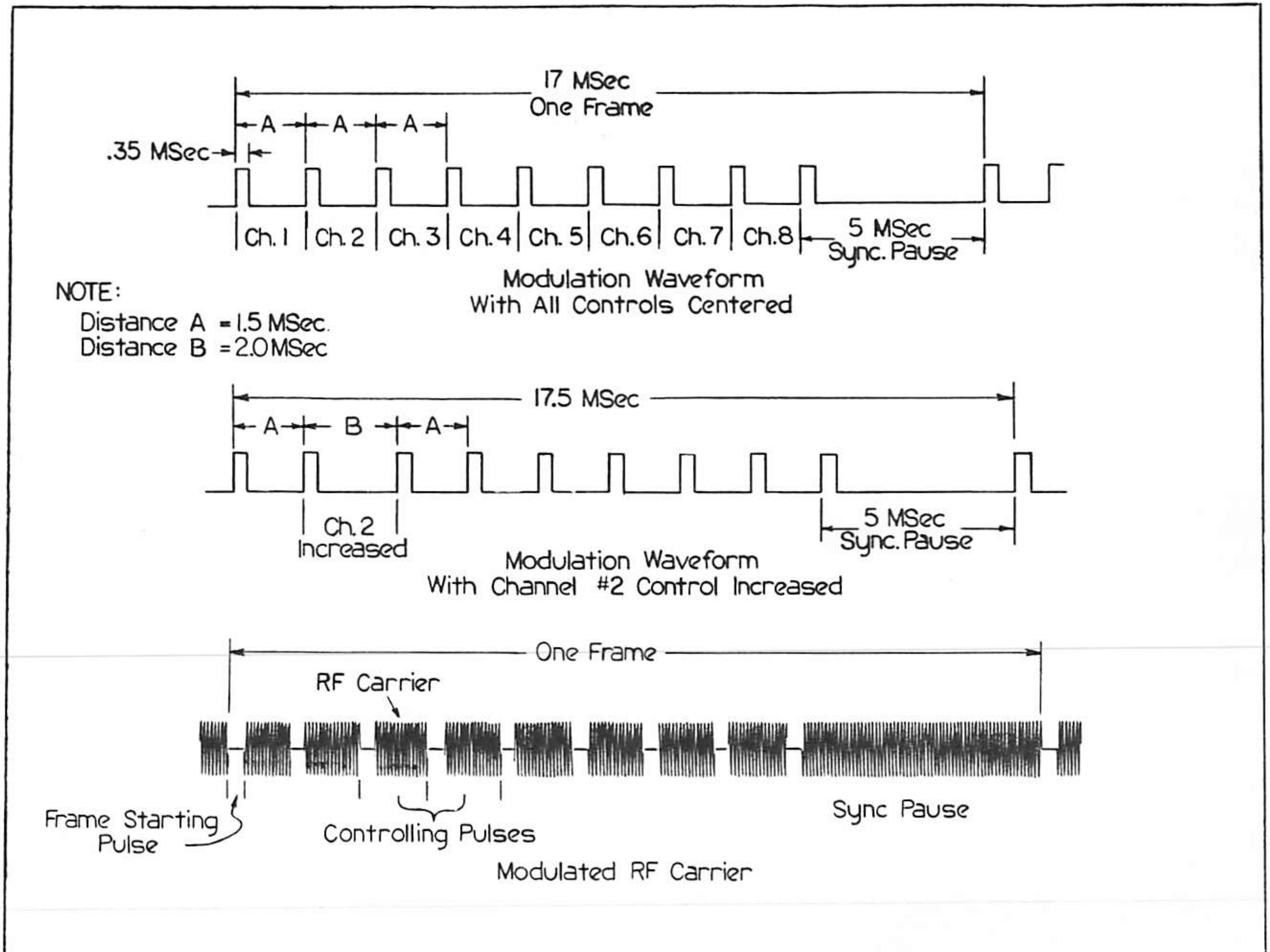


Figure 18. Telemetry Waveforms

4.2.1.1 Encoder Accessory Circuits

The switching of channels by the encoder is accomplished by the shifting of a single bit in the encoder-decoder IC. This bit is entered into the IC by the sudden application of power to the IC circuit charging the 0.047μF capacitor on pin 2 of the IC through the 47K resistor between pins 2 and 6 of the IC. If the voltage is applied gradually (as from the build up from a regulated power supply) the bit is not entered into the IC properly. The voltage level sense, time delay switch circuit (IET73-019) is used to delay the application of power to the IC until the output of the regulator is at a 5 volt level.

If a system transient or some other cause loads more than one bit into the encoder-decoder IC, the effect is the activation of more than one channel control and the resulting loss of synchronization of the telemetery pulse train. The "One" eliminator circuit senses the presence of more than one bit in the IC and causes the power to be removed from the IC until the bits are eliminated. The voltage level sense, time delay switch then reapplies power to the IC and correctly loads a single bit.

4.2.2 RF Transmitter and Receiver.

The transmitter produces a crystal-controlled rf carrier that is modulated by on-off carrier keying. This keying is accomplished by the encoder turning off the dc power to the rf oscillator during the off pulse time. This rf signal is routed through the appropriate filters and the RG59 coaxial cable to the 8-channel digital proportional receiver Heathkit Model GDA-405-2.

The receiver circuits amplify and detect the rf carrier to produce the pulse modulated waveform. The pulses are shaped and amplified for proper triggering of the decoder integrated circuit.

The frequency of operation of the rf telemetery system has been modified to provide separation of the uplink and downlink rf signals by use of filters. The uplink telemetry system uses a carrier frequency of 29.195MHz, and the downlink carrier is crystal controlled at 25.195MHz.

A detailed theory of operation and circuit description of the receiver-decoder is provided in the Heathkit Assembly Manual for the Model GDA-405-2 receiver.

4.2.3 Pulse Width Demodulator

The eight outputs of the receiver-decoder are positive pulses as shown in Figure 19. The information is contained in the width of the positive pulse which varies from one to two milliseconds as the input to the channel in question is changed from one extreme to the other. This pulse width (time) is converted to a voltage by the integration of the pulse in the pulse width demodulator (IET73-203). The pulse after being amplified to the proper level is applied to the conventional integrator which charges the feedback capacitor for as long as the pulse is applied. After the pulse is over the capacitor holds the output of the integrator at the level which corresponds to the pulse width. The capacitor must be discharged before the information can be updated. This is accomplished by using the leading edge of each incoming pulse to trigger the FET in parallel with the integration capacitor. This resets the integrator so that each incoming pulse updates the data.

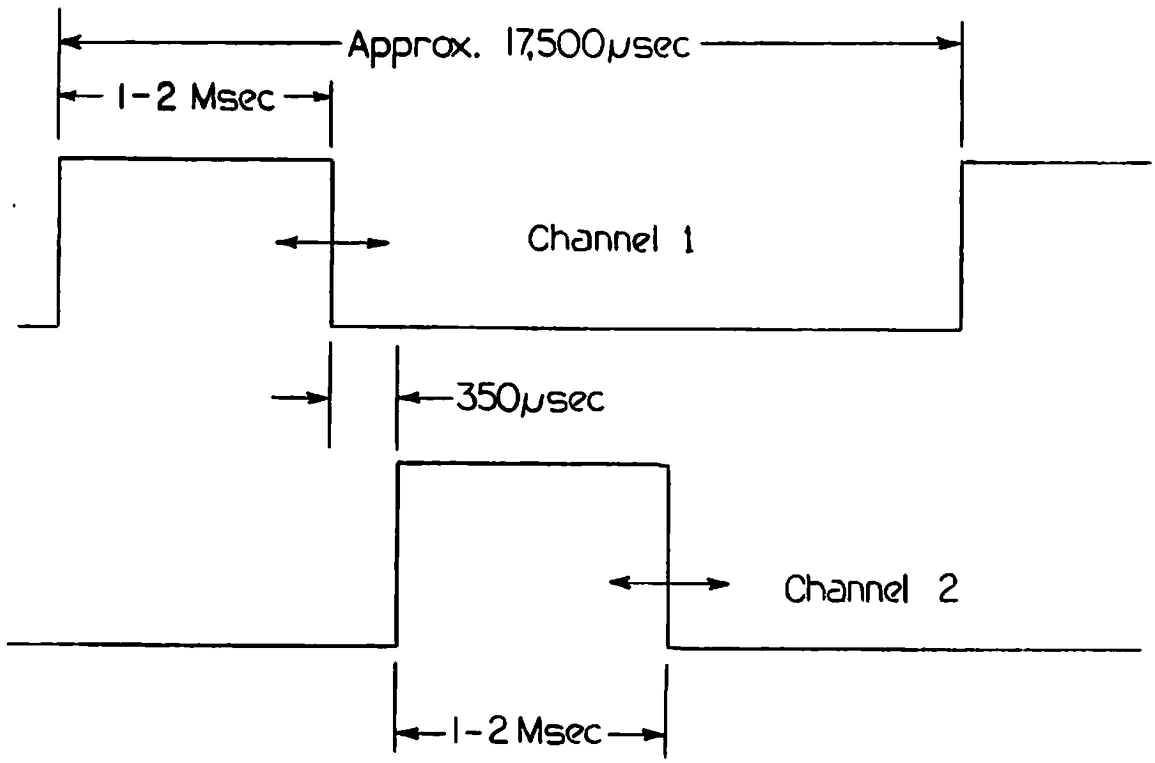


Figure 19 Two of the eight outputs of the receiver-decoder

4.2.4 The Linearizer

The output of the integrator circuit is a dc voltage which is updated approximately 60 times each second. This dc voltage should be a faithful reproduction of the input to encoder. However, the system has some small nonlinearites which are too large not to correct when the voltage is used for data readout.

In these cases the output of the integrator is fed to the linearizer circuit (IET 73-202) which corrects the system nonlinearity by providing an equal and opposite nonlinearity. This is accomplished by making the gain of the input operational amplifier a function of the input voltage. The outputs of the linearizer circuits are fed to the data readout meters.

4.2.5 The Level Detectors

Some telemetry channels are used to allow the operator to turn certain RUFAS functions on and off. This is accomplished by switching resistance values at the input of the encoder (see Section 4.2.1) which varies the pulse widths for the channel in question. This in turn is converted into a dc voltage out of the integrator.

The magnitude of this dc voltage depends on the position of the control switches on the operator's consoles.

The level detectors and decoder circuits (IET 73-011 and IET 73-012) are used to sense the magnitude of the dc voltage and turn relays or electronic switches on or off when the input voltage level crosses a set threshold.

The detector circuits are conventional operational comparator circuits set so that the output of the op-amp goes low when the input goes above the level set by the input resistors and the negative reference voltage input. The outputs of the op-amps for the level detectors on the channel in question are decoded using transistor "AND" and "OR" circuits to turn appropriate relays and switches on or off as required.

4.2.6 Pulse Width Modulator

The data which is transmitted from RUFAS to the operator's console originates as either a change in resistance or a change in voltage. The resistance changes come from the pendulum pots which are used to sense the vehicle pitch and roll and the pressure transducer which is used to sense the vehicle depth. The voltage changes come from the D/A converters on the output of the forward and down looking sonars and from the flight control system to indicate the port and starboard vane positions.

The pulse width for a telemetry channel is normally controlled by switching a resistance value for that channel. The timing capacitor for the encoder multivibrator charges through this resistance so the pulse widths is directly proportional to the resistance (See Section 5.2.1).

In the case of the uplink telemetry, the system transducers which provide a change in resistance are outside the range of resistance required to give the proper pulse width. The resistance to pulse width modulator circuit (IET 73-005) converts the change in transducer resistance to a change in current from the current source. The current source is switched on by the encoder IC switching to that channel position. In a similar manner, the system outputs which are voltages are used in the voltage to pulse width modulator circuit to control the magnitude of a current source.

5. SONARS

Two, Heathkit Model M1-101 digital depth sounders are used in the RUFAS system. The transducer for the forward looking sonar is pendulum-mounted in the nose of the vehicle so that it can be used to measure the horizontal clearance ahead of RUFAS. The transducer for the down looking sonar is mounted in the belly of RUFAS approximately in line with the tow yoke connection. This allows the vehicle to pivot without changing the vertical distance from the transducer to the seafloor appreciably. This transducer was initially mounted in the stern of the vehicle to provide maximum separation of transducer. However, tow tank

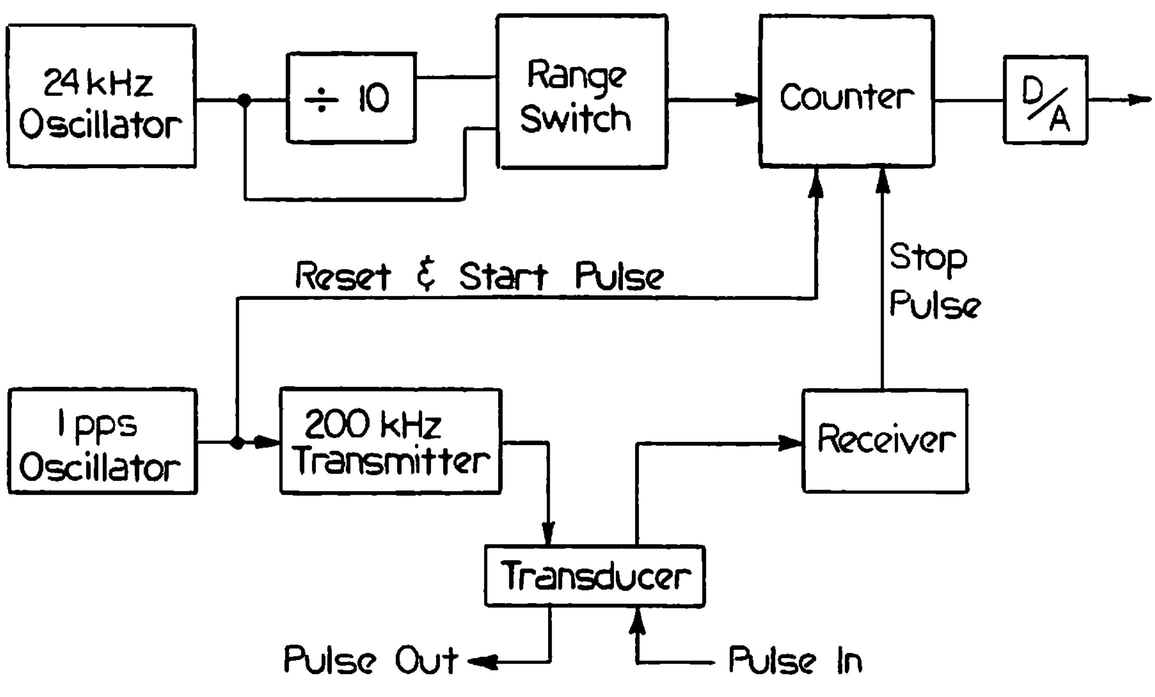


Figure 20. Depth Sounder Operation

testing of the vehicle showed this arrangement to lead to instability in the Automatic Terrain-Following Control System.

Figure 20 is a simplified illustration of the operation of the depth sounder. The Heathkit Depth Sounder contains a 24 KHz oscillator, a 200 KHz transmitter, a counter, and a one (1) pulse per second oscillator. The 1PPS oscillator triggers the 200 KHz transmitter, zeros the counter, and allows the counter to start counting the 24 KHz oscillations. In the 200 foot range the range switch allows the BCD counter to count the 2.4 KHz oscillations from the divide by 10 circuit. In the 20 foot range, the range switch directs the counter to count the 24 KHz oscillations. Thus, one count in the 200 foot range corresponds to one foot and one count in the 20 foot range corresponds to one tenth of one foot. The counter continues counting until turned off by the receiver. The receiver turns off the counter when an echo pulse is detected by the transducer or when the 200th oscillations is counted.

If no echo pulse is received before the count reaches 200, the sonar will automatically change range. Therefore, if the sonar is in the 20 foot range and no echo is detected, the sonar changes to the 200 foot range. In the 200 foot range, the receiver cannot turn off the counter until at least 20 oscillations have been counted. Thus, if the depth is less than 20 feet, no echo will be received to turn off the counter and the sonar will change to the 20 foot range.

Detailed circuit descriptions and theory of operation for these sonars is provided in the Heathkit Assembly Manual for the Model M1-101-1 Digital Depth Sounder (Heath Part No. 595-1325-01).

5.1 Down Looking Sonar

The down looking sonar is a digital depth sounder which has been modified by replacing the digital decoders and display tubes with a Burr Brown Model DAC20-12U-BCD Digital to Analog Converter. The analog output of the DAC is transmitted over the uplink telemetry system (Section 4.2) to provide a meter readout of the vehicle height above the ocean bottom. It is also used directly in the terrain-following automatic control system. (see Section 3).

The analog output voltage is the same for the 20 foot range as the 200 foot range i.e., the output of the DAC is the same if the input is 15 feet on the 20 foot range as it is if the input is 150 feet on the 200 foot range. This makes it necessary to transmit the range information to the operator. The information is provided as a light on the Height-Above-Bottom Meter.

5.2 Forward Looking Sonar

The forward looking sonar is used to provide warning to the operator of obstruction in the path ahead of RUFAS, so that he can maneuver the vehicle to avoid collisions. The Heathkit Model M1-101 Digital Depth Sounder is modified to accomplish this objective.

A N7476 flip-flop has been added to hold the 200th count so that the clearance ahead readout meter will read full scale if no echo is detected by the sonar receiver. This flip-flop is set by the 200th count which turns the counter off. It is cleared by the 1PPS oscillator at the beginning of the next sounding period.

This sonar is locked into the 200 foot range by holding the RANGE GATE flip-flop in the 200 foot range position. This prevents the switching to the 20 foot range when no echo is received.

In order to prevent "ground clutter" from giving a false indication, the counter gate is held open until after the 80th count. The effect of this is to ignore returns from less than 80 feet.

6. OPERATING PROCEDURES

The RUFAS II system can be operated in either a bottom survey mode or in a mid-water mode. The underwater, remotely-controlled, instrument platform (sled) is towed by a surface ship at speeds from one to five knots.

The mission of a particular survey will determine the operating procedure to satisfy mission objectives. In bottom survey modes, the towing speed will be reduced so that the operator can interpret the TV pictures. The vehicle height above bottom will depend on water clarity and towing speed. In some operations the TV picture and video tape will be the primary data. In others, photographs of the bottom will be required. This requires the chief scientist for a particular mission to develop operating procedures to accomplish his mission objectives.

6.1 Installation and Hook-Up

1. Install the RUFAS control consoles in an air-conditioned environment. Tie or bolt down the consoles and video tape recorder. Install the interconnecting cable between consoles.

2. Install the interconnecting cable from the RUFAS console to the

eight slip rings on the slip ring winch. The wires should be connected to the slip ring in the following order:

#1 AC voltage phase A ------------- 3 parallel green wires

#2 AC voltage phase B ------------- 3 parallel red wires

#3 AC voltage phase C ------------- 2 parallel black wires

#4 AC neutral --------------------- 3 parallel white wires

#5 RF shield ---------------------- coax shield

#6 RF signal ---------------------- coax center conductor

#7 Phase Lock Loop Signal ground -- small black conductor

#8 Phase Lock Loop Signal --------- small white conductor

NOTE

A three phase variable transformer is provided in the data operators console to adjust the line voltage provided to the RUFAS vehicle to 120/208 volts. The maximum rating of this transformer is 500 volts. The voltage is adjusted with the RUFAS POWER and CONSOLE POWER switches on but the power to the RUFAS vehicle disconnected by the manual 3 phase power switch in the lower left hand corner of the data operators console control panel. A voltmeter is provided on the transformer to aid in the adjustment. It should be set to approximately 120 volts.

3. Connect the consoles and video tape recorder to a source of 120 volt, 60 Hz, single phase power. Connect the console main power input to a source of 3 phase, four wire, 60 Hz, power of at least 120/208 volts.

4. Install the tow/electrical cable on the slip ring winch. The electrical core of this cable should be attached to the slip rings in exactly the same order and manner as the interconnecting cable from the consoles was installed. Inspect and clean the slip rings if needed.

CAUTION:

Do not connect the electronic sphere penetrator number 4 (IET 73-123) or camera sphere penetrator number 2 (IET 73-124) until it can be verified with a voltmeter that AC power has been properly connected through the slip ring cable assembly.

5. Install the tow/electrical cable on the RUFAS vehicle and connect the cables to the sphere penetrators.

6.2 Pre-Launch Checks for Data and Flight Operators

Figures 21, 22, and 23 show the location of data and flight operators controls and instruments. The illuminated switches are "on" when the light behind the switch is illuminated.

1. With S-1 "OFF" turn S8 and S9 "ON". Verify the voltmeters V_A, V_B, and V_C read approximately 120 volts. Verify all other switches are "OFF". Turn both TV monitors "ON".

2. Turn S-1 "ON". This applies 3 phase, 60 Hz, 120.208 volts to RUFAS. I_C and I_N should read about 0.5 amperes. I_A and I_B should be approximately zero.

3. Verify the operation of the television system. Operate the focus, tilt, and pan controls. These are momentary switches and will operate for as long as the switch is held in or the limit is reached on RUFAS. Verify the video tape recorder operation.

CAUTION:

The TV camera must not be pointed at the sun at any time or permanent damage will result. After the above test the camera should be left pointing so that the sun will not directly strike the lense.

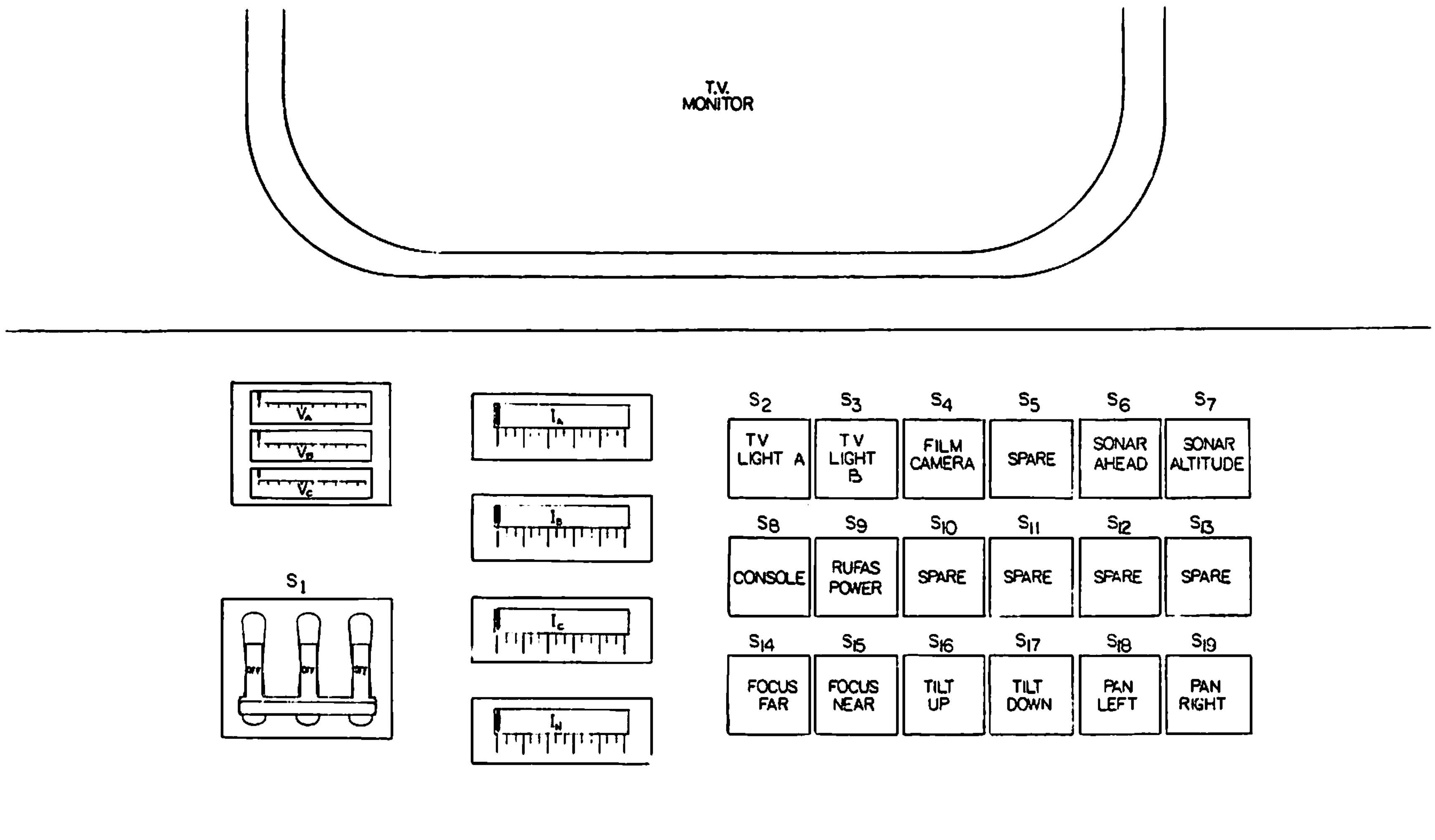


FIGURE 21 : DATA OPERATOR'S CONSOLE

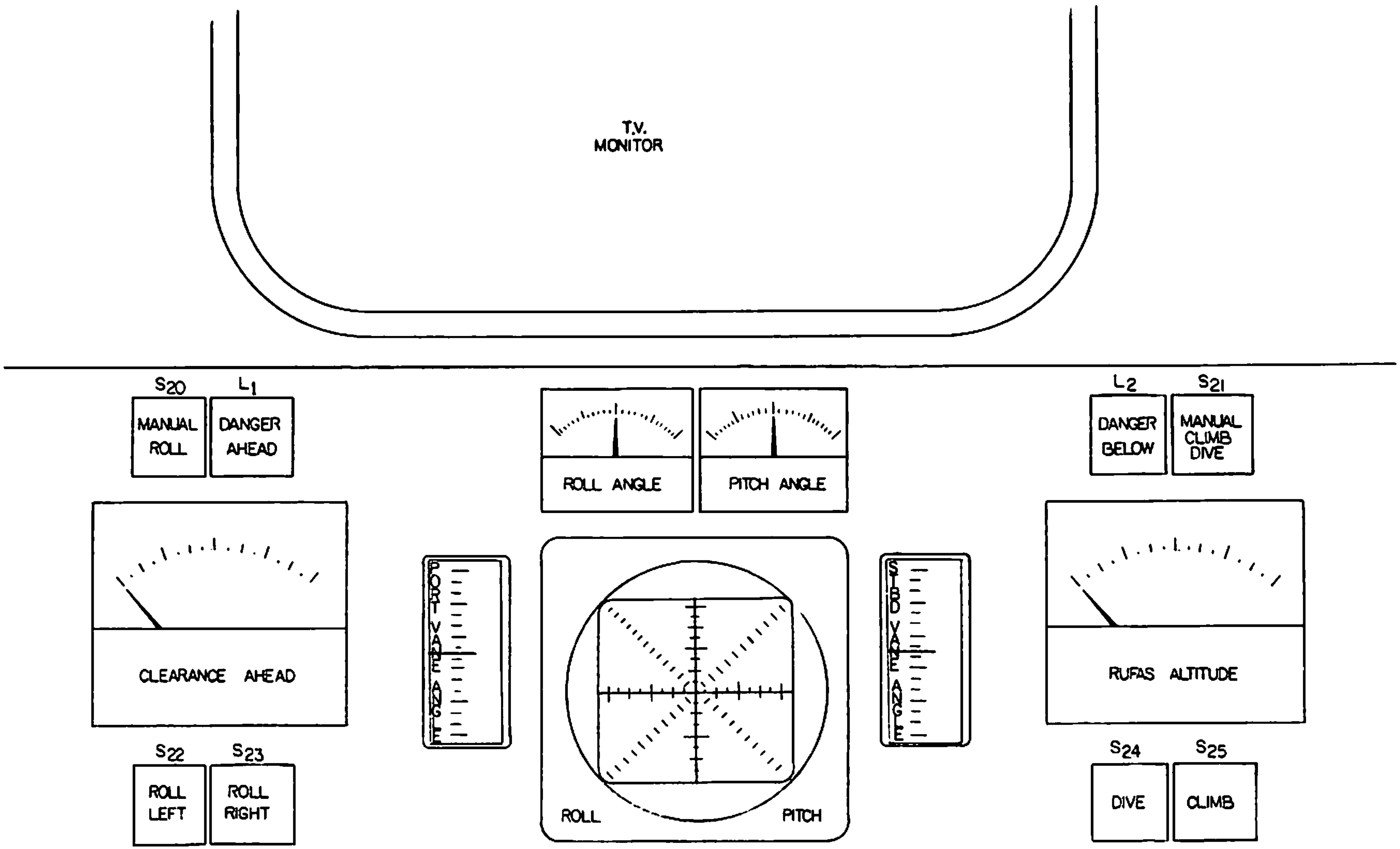


FIGURE 22: FLIGHT OPERATOR'S CONSOLE

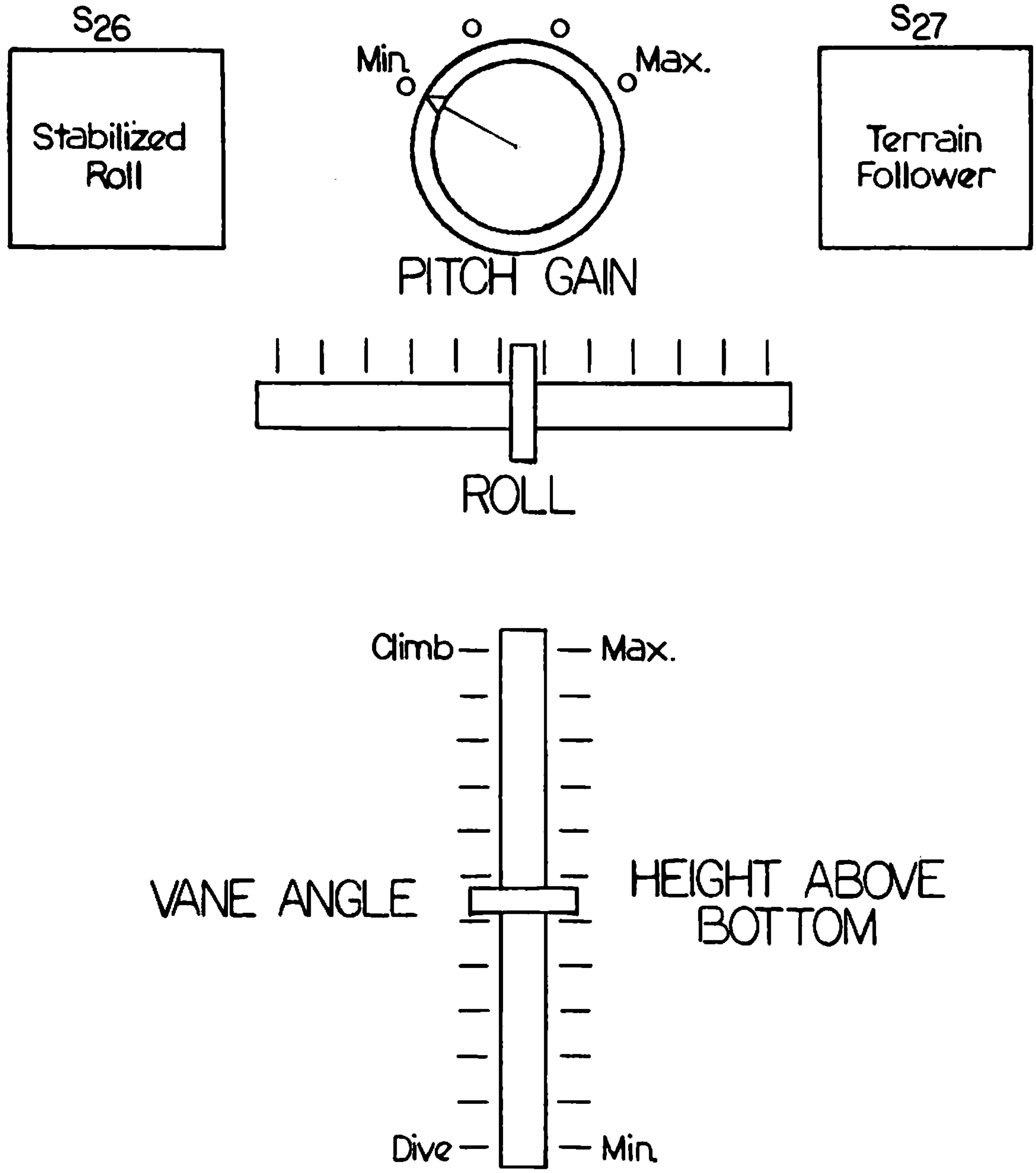


FIGURE 23: FLIGHT OPERATORS CONTROL BOX

4. Verify the operation of the Bang Bang Roll (S22 and S23) and Bang Bang Climb-Dive switches (S24 and S25). Depressing S24 or S25 will illuminate S21 and cause the vanes to move up for as long as the climb button is held in or down for as long as the dive button is held in. The vane angle meters show the position of the control vanes. Depressing S22 or S23 will illuminate S20 and cause the vanes to move in opposite direction. Use the Roll switches to set both vane angle meters to the same reading and the Climb-Dive switches to set both vanes to the zero position.

5. Lift slightly one end of the sled and monitor the Pitch Angle Meters. The cross neddle instrument horizontal neddle should move up and down with the nose of the sled. It has a full scale deflection of approximately 8 degrees and is about 8 times more sensitive than the small Pitch Angle Meter.

6. Lift slightly one side of the sled and monitor the Roll Angle Meters as above.

7. If this pre-launch check is being performed at sea, the roll and pitch of the ship will make steps 5 and 6 unnecessary.

8. Verify that momentarily depressing S20 turns off its indicator light and transfers roll control to the control on the Flight Operators control box. When the control is moved to the left the port vane moves up and the starboard vane moves down. When the control is moved to the right the opposite reaction occurs. Both vanes should be at about the same position when the control is centered.

9. Turn "ON" S26. The vanes should move to compensate for the pitch of the ship. If onshore, this can be checked by lifting one side of the sled. Turn S26 "OFF" and use S22 and S23 to set the vanes to the same angle.

10. Verify that momentarily depressing S21 turns off its indicator light and transfers pitch control to the control on the flight operators control box. The control vanes should follow the position of the control.

11. Position the Vane Angle Control to the maximum dive position. Turn "ON" S27 and verify that the vanes move to a climb position. Turn "OFF" S27 and position the control vanes to zero with S24 and S25.

12. Verify the operation of the sonars by turning S6 and S7 "ON". The reading will be eratic when RUFAS is not in the water but the readout meters will indicate that the units are operating. Turn S6 and S7 "OFF".

CAUTION:

The thallium iodide TV lights will be destroyed if operated out of water for more than 90 seconds. In checking these lights, an observer should be stationed where the operation can be verified as soon as power is applied and power removed immediately after his verification. The lights will burn for about 30 seconds after the switch is turned off because of the delay circuit. S1 is an emergency switch and removes all power with no delay.

13. Turn S2 "ON". Turn S3 "ON". Verify TV light operation. Turn S2 "OFF". Turn S3 "OFF". The currents I_A, I_B, and I_N will vary in the three to five amphere range when the lights are striking and will drop to approximately zero about 30 seconds after the switches are turned off.

14. Verify the operation of the film camera and strobe by turning S4 "ON". The strobe will fire at the rate set by the camera intervalometer. Turn S4 "OFF".

15. Turn "OFF" S1, S9, and S8. This completes the pre-launch check of the operator controls and instruments.

6.3 Pre-Launch Checks of Vehicle

1. Inspect and tighten all mechanical and electrical cable connections.

2. Inspect the inside of the electronic sphere. Insure that inside cable connections are correctly made.

3. Clean, inspect and grease the O-ring and seal the electronics sphere.

4. Remove camera from camera sphere and load the film magazine. Refer to the data camera operating manual for detailed information.

5. Insure that the intervalometer switch is left in the "PULSE" position and the interval is greater than 9 seconds.

6. Verify that the sphere camera window is clean and clear.

7. Replace the camera in the sphere and check its operation from the console. (see Section 6.2)

8. Insure that inside cable connections are secure.

9. Clean, inspect, and grease the O-ring. Seal the camera sphere.

10. Verify that the lense cover is removed from the TV camera if launch is to proceed. Otherwise verify that it is in place.

11. Replace the hatches and tie down the hatch handles.

12. This completes the pre-launch checks of the vehicle.

6.4 Operation

The procedure for placing the sled into the water and removing it from the water will vary according to the configuration of the ship. In general, the sled is lowered into the water with power on and lights out and cool. The winch operator then pays out line as the flight operator flys the sled to the desired depth or height above the bottom. Normally the stabilized roll circuits are turned on as soon as the vehicle is launched. However the terrain follower circuit cannot be used until the RUFAS vehicle is manually flown into the operational range of the down looking sonar. That is, the down looking sonar should switch from the 200 foot range to the 20 foot range before the terrain follower is turned on. The flight operator should be careful to fly the RUFAS vehicle into the terrain follower range at a relatively low angle. If the vehicle enters the terrain follower mode at an extreme angle with a high rate of descent, the vehicle may strike the ocean bottom before the automatic control circuits can respond.

When the vehicle has reached the operational depth and control has been transferred to the automatic control circuits, the vehicle should fly itself except for emergency situations. The flight operator should monitor his TV picture, the sonar readouts and the ships sonar readout. Tests have shown that the terrain following circuits can fly the vehicle over contours which vary up to 25^{o}. In the event steeper angles are encountered the flight operator must manually maneuver the vehicle over or around them.

After completion of a transect or observation tow, the RUFAS vehicle should be brought to an altitude 10-12 fathoms above the bottom. At this point the towing vessel should be slowed down and recovery initiated. During recovery the flight operator can fly the vehicle up as the winch operator brings in the tow cable. The TV camera can be tilted up so that the RUFAS vehicle can be kept below the surface until most of the cable has been winched in. When the vehicle is ready to be lifted from the water the TV should be tilted down to prevent damage from the sun and the control vanes should be put in a level or dive position.

APPENDIX

Engineering Drawings

The engineering drawings which follow are provided for maintenance purposes and to provide the technical reader with details of the electronic design.

The following drawings are provided:

IET73-001............................Ship System Block Diagram

IET73-002............................RUFAS System Block Diagram

IET73-003............................Motor Amplifier System

IET73-004............................Limit Switches

IET73-005............................Pulse Width Modulator Circuits

IET73-006............................Connector Wiring Diagram (Power Buss)

IET73-007............................Floating Signal Buss

IET73-008............................Signal and Control Buss

IET73-009............................Phase Lock Loop Transmitter

IET73-010............................Phase Lock Loop Receiver

IET73-011............................Level Detector and Decoder for On-Off-On Functions

IET73-012............................Level Detector and Decoder for On-Off, On-Off Functions

IET73-013............................Stabilized Roll Circuit

IET73-014............................Flight Controller

IET73-015............................Altitude and Obstacle Warning System

IET73-016............................Meter Scaling Circuit

IET73-017............................Ship Power Distribution

IET73-018............................RUFAS Power Distribution

APPENDIX - Engineering Drawings Continued;

IET73-019............................Accessory Circuits for Encoder Board

IET73-020............................Motor Housing Circuit

IET73-021............................Wiring Diagram for Data Camera

IET73-022............................Relay Connections for Roll Shelf

IET73-023............................Relay Connections for Climb-Dive Shelf

IET73-024............................Encoder

IET73-101............................Level Detector Decoder

IET73-102............................Pressure Transducer

IET73-103............................Turn Off Time Delay Circuit for T.V. Lights

IET73-104............................Turn On Power Delay Circuit

IET73-105............................± 9v Regulator

IET73-106............................Power Distribution for Receiver and Transmitter (On RUFAS)

IET73-107............................LPF-1S at T.V. Monitor

IET73-108............................LPF-1R at T.V. Camera

IET73-109............................BRF-1R at Receiver

IET73-110............................HPF-1R at Receiver

IET73-111............................HPF-2R at Receiver

IET73-112............................Power Buss

IET73-113............................Under 20 ft. Light Indicator

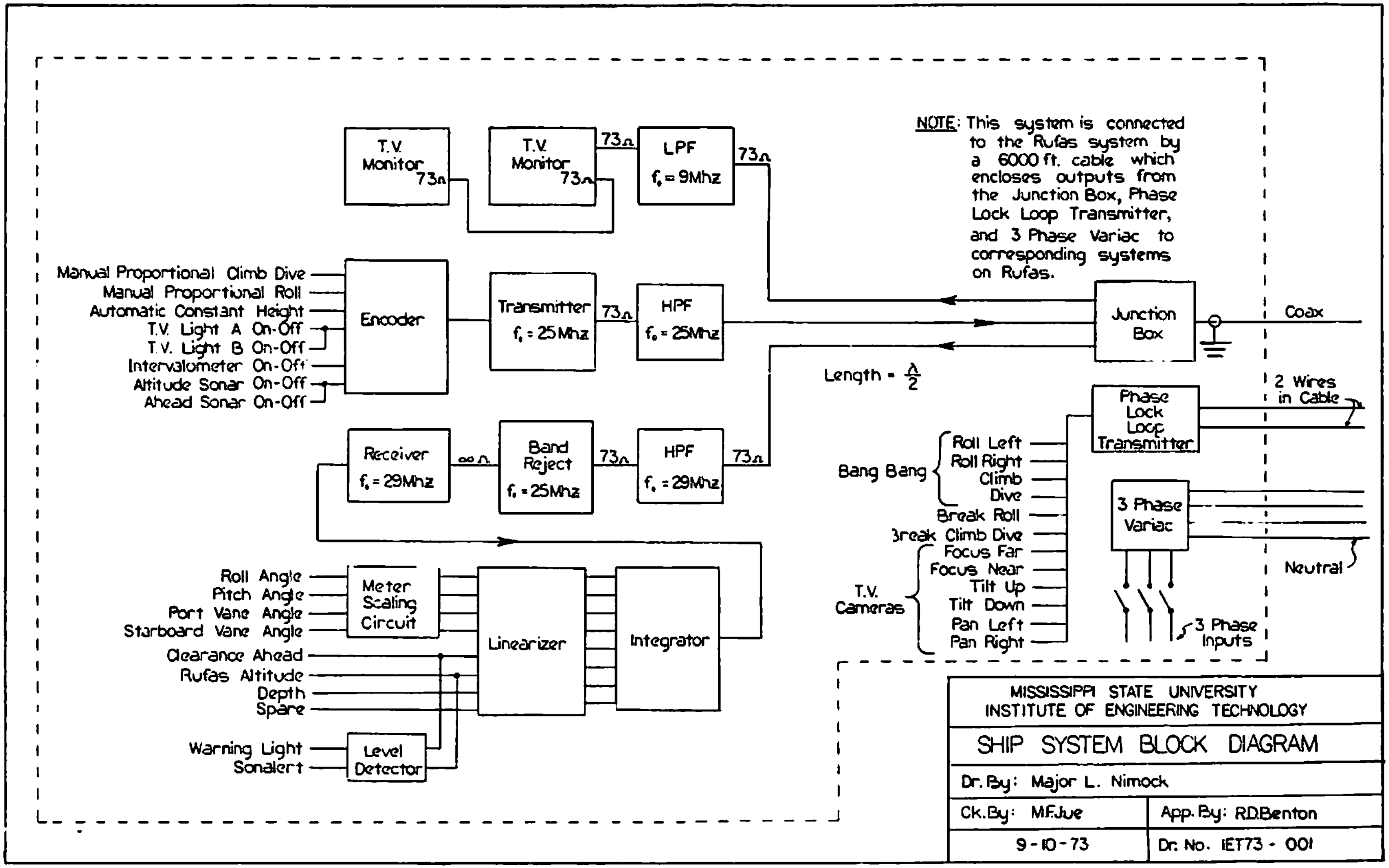
IET73-114............................Light Indicating System for Switching from Bang Bang to Manual Automatic Mode

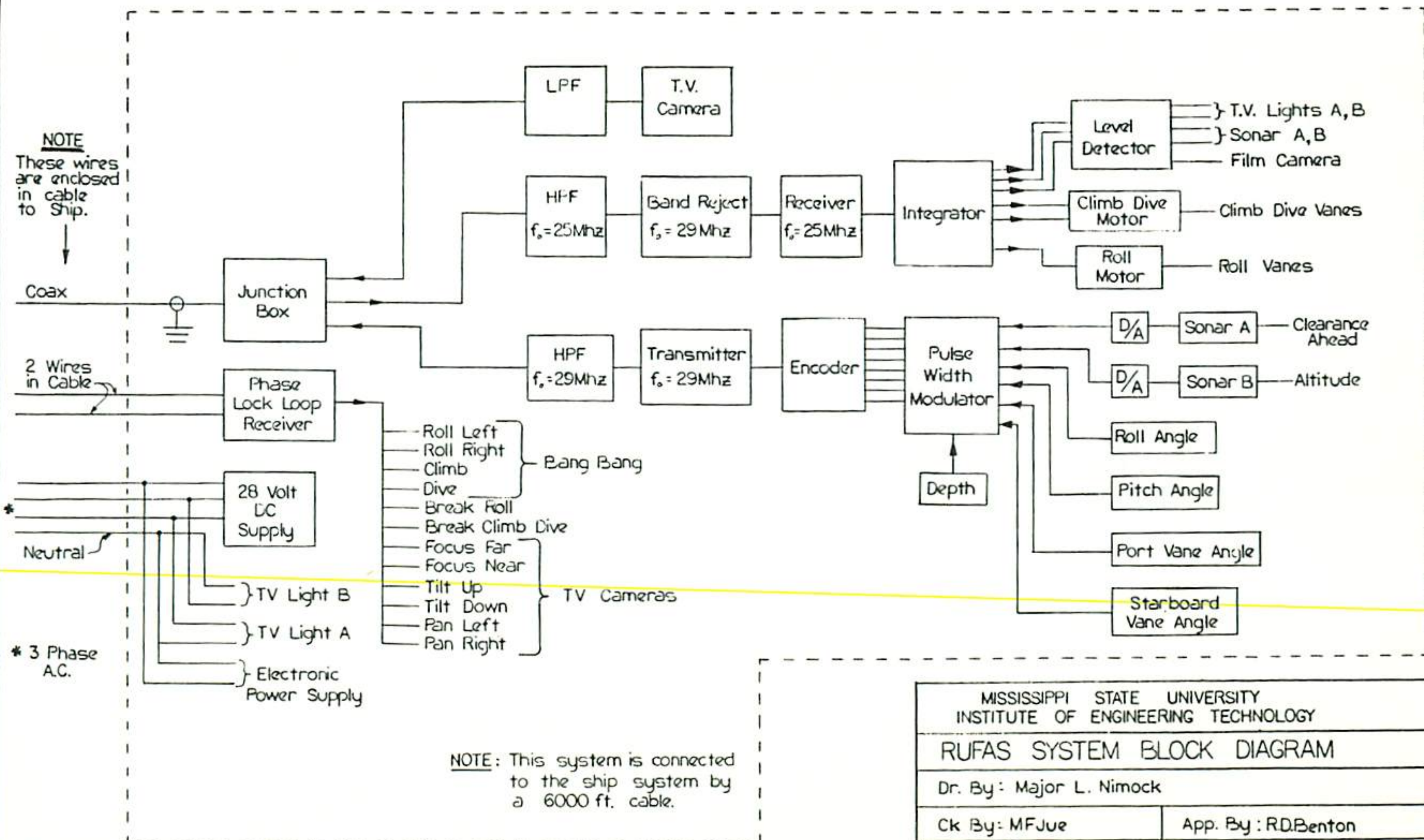
IET73-115............................Modification to T.V. Power Supply (Focus Control)

IET73-116............................Uplink Telemetry Signal Flow

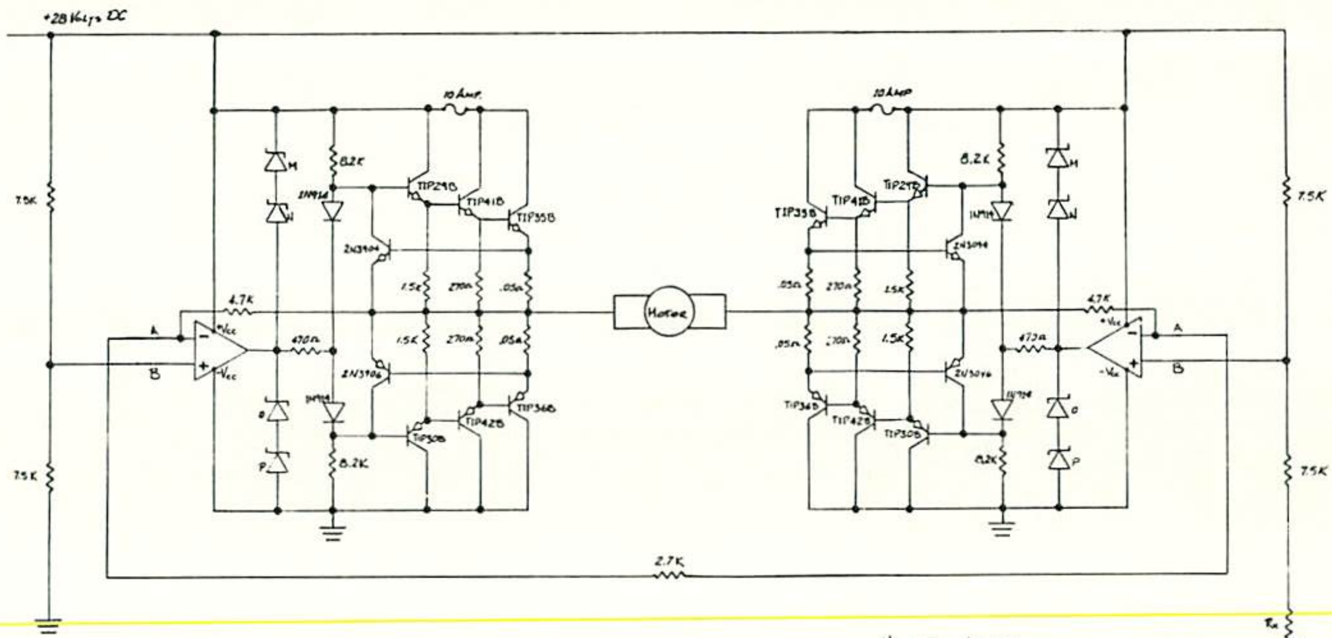
IET73-117............................Downlink Telemetry Signal Flow

APPENDIX - Engineering Drawings Continued;


NOTE: This system is connected to the Rufas system by a 6000 ft. cable which encloses outputs from the Junction Box, Phase Lock Loop Transmitter, and 3 Phase Variac to corresponding systems on Rufas.
T.V. Monitor 73Ω
T.V. Monitor 73Ω
73Ω
LPF f₀ = 9Mhz
73Ω
Manual Proportional Climb Dive
Manual Proportional Roll
Automatic Constant Height
T.V. Light A On-Off
T.V. Light B On-Off
Intervalometer On-Off
Altitude Sonar On-Off
Ahead Sonar On-Off
Encoder
Transmitter f₀ = 25Mhz
73Ω
HPF f₀ = 25Mhz
Junction Box
Coax
Length = λ/2
Receiver f₀ = 29Mhz
∞Ω
Band Reject f₀ = 25Mhz
73Ω
HPF f₀ = 29Mhz
73Ω
Phase Lock Loop Transmitter
2 Wires in Cable
Bang Bang
Roll Left
Roll Right
Climb
Dive
Break Roll
Break Climb Dive
T.V. Cameras
Focus Far
Focus Near
Tilt Up
Tilt Down
Pan Left
Pan Right
3 Phase Variac
Neutral
3 Phase Inputs
Roll Angle
Pitch Angle
Port Vane Angle
Starboard Vane Angle
Clearance Ahead
Rufas Altitude
Depth
Spare
Meter Scaling Circuit
Linearizer
Integrator
Warning Light
Sonalert
Level Detector
MISSISSIPPI STATE UNIVERSITY
INSTITUTE OF ENGINEERING TECHNOLOGY
SHIP SYSTEM BLOCK DIAGRAM
Dr. By: Major L. Nimock
Ck. By: M.F.Jue
App. By: R.D.Benton
9-10-73
Dr. No. IET73 - 001

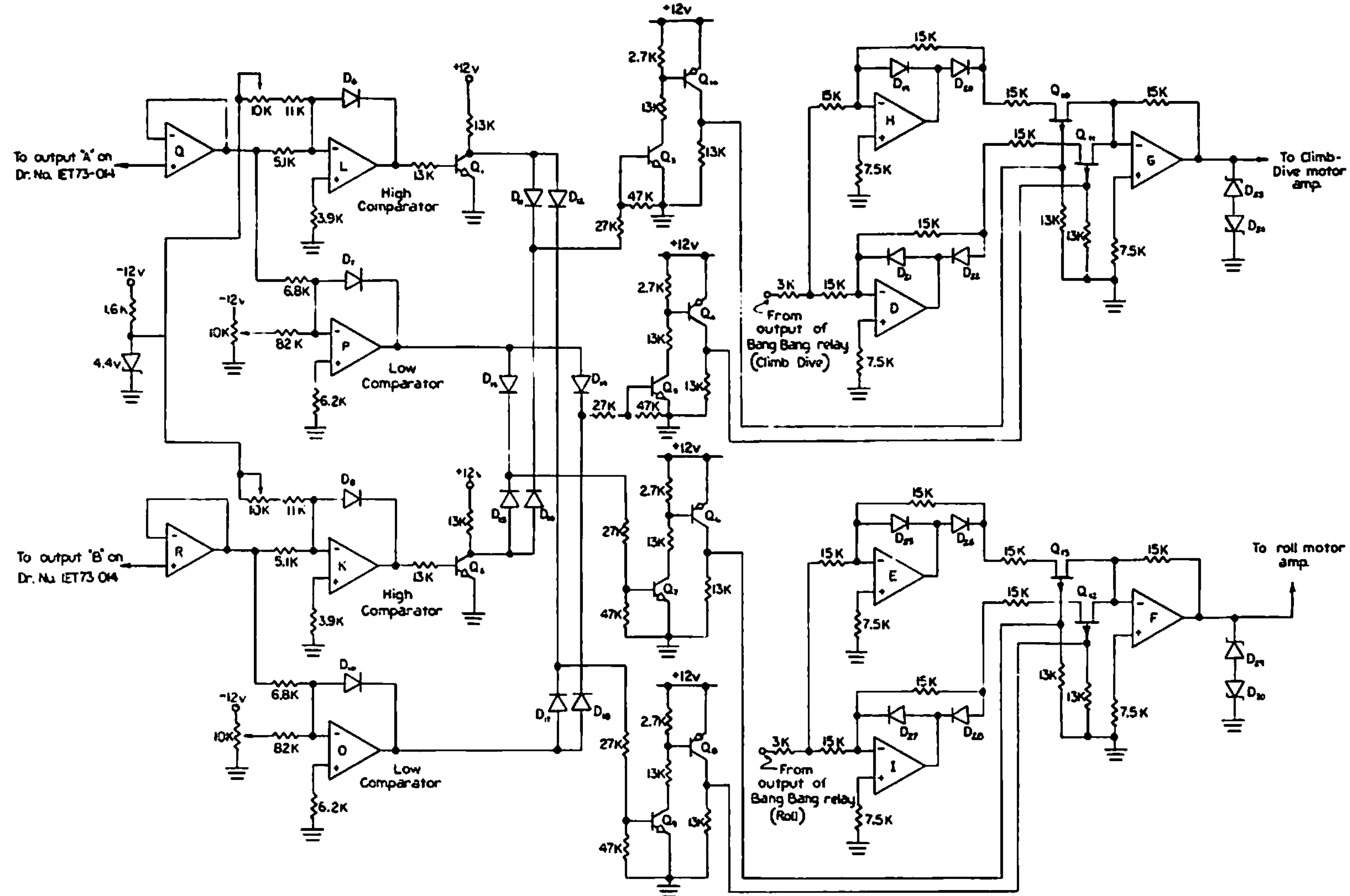


MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
RUFAS SYSTEM BLOCK DIAGRAM	
Dr. By: Major L. Nimock	
Ck By: MFJue	App. By: R.D.Benton
9 10 73	Dr. No. IET73 - 002

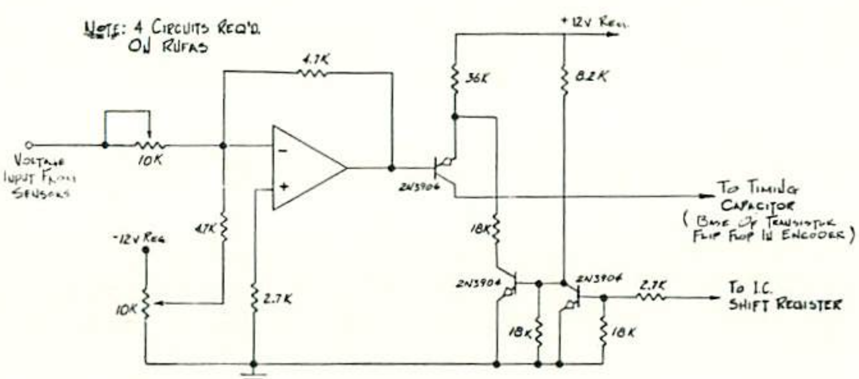


Note: M + N = 31 Volts
O + P = 31 Volts
R_x = 100Ω For Roll Amplifier
R_x = 470Ω For Climb Amplifier
1 Amplifier Required For Climb-Dive
1 Amplifier Required For Roll

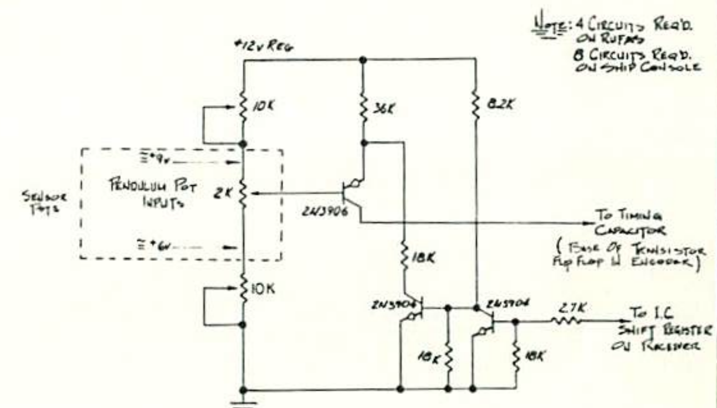
Mississippi State University Institute Of Engineering Technology	
Motor Amplifier System	
Dr. By: Major L. Nimock	
Ck. By: M.F. Joe	App. By: R.D. Benton
9-20-73	Dr. No.: IET73-003



MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
LIMIT SWITCHES	
Dr. By: Major L. Nimock	
Ck. By: M.F.Jue	App. By: R.D.Benton
10-10-73	Dr. No. IET73-004

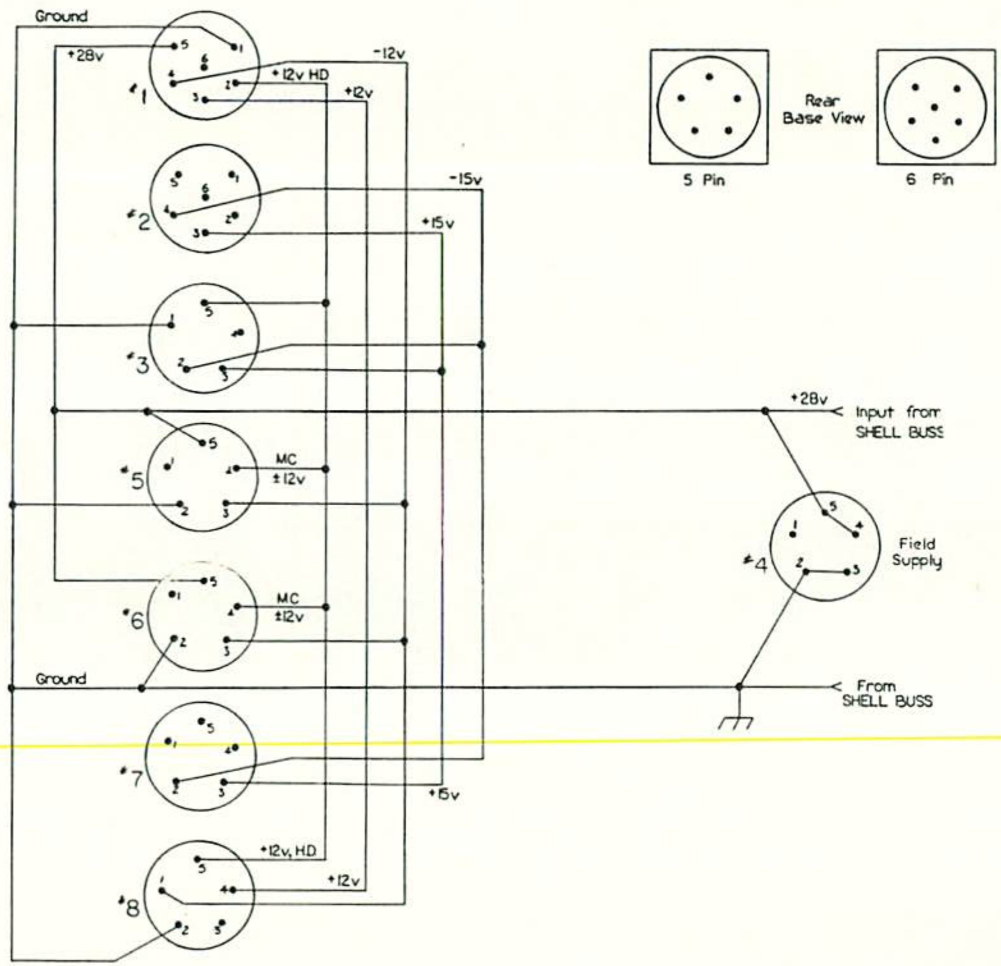


VOLTAGE TO PULSE WIDTH MODULATOR



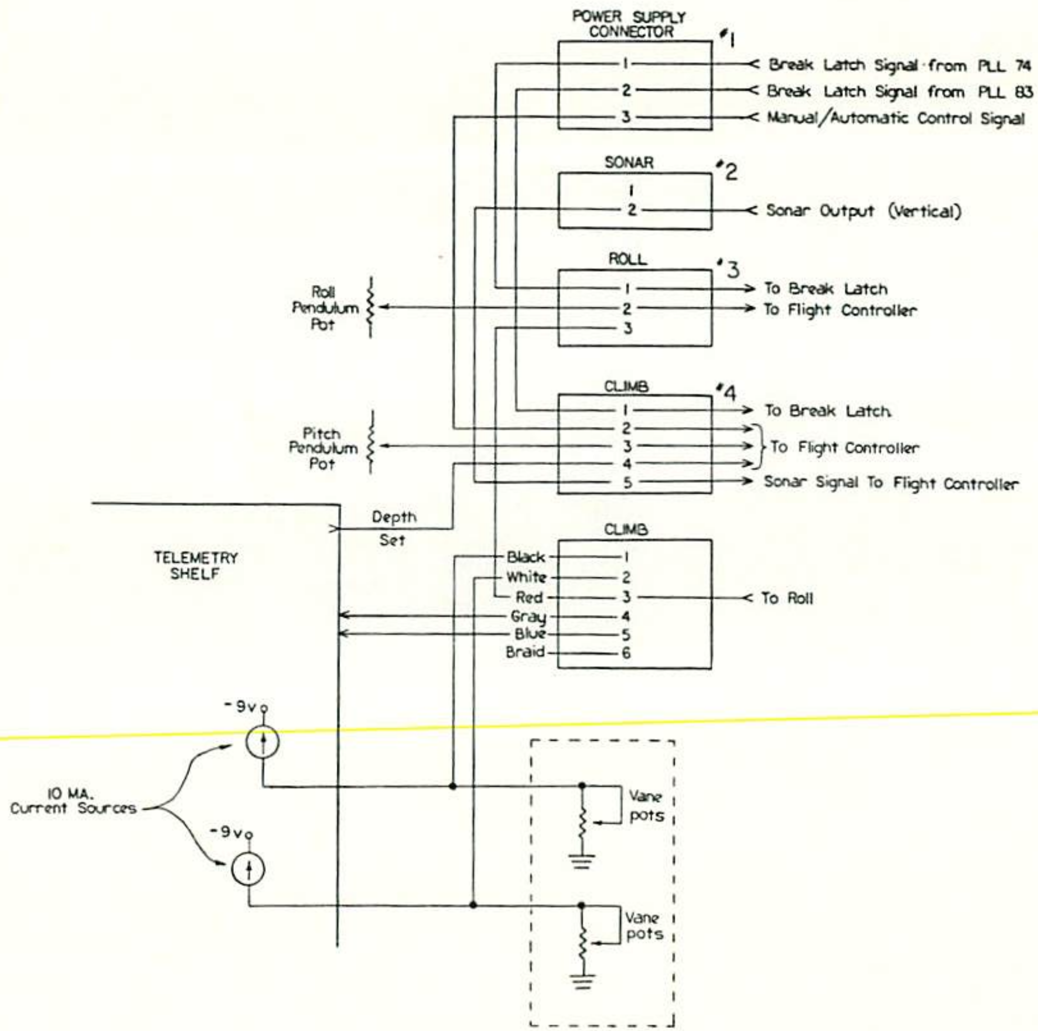
RESISTANCE TO PULSE WIDTH MODULATOR

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
PULSE WIDTH MODULATOR CIRCUITS	
DR. BY: MAJOR L. NIMOCK	
CK. BY: M.F.J.	APP. BY: R.D.B.
9-25-73	DR. NO. IET73-005



NOTE: The lines from Shell Buss should go to Field Supply first, then to other connector.

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
CONNECTOR WIRING DIAGRAM (POWER BUSS)	
Dr. By: Major L. Nimock	
Ck. By: MEJ.	App. By: R.D.B.
11 - 7 - 73	Dr. No. IET73-006

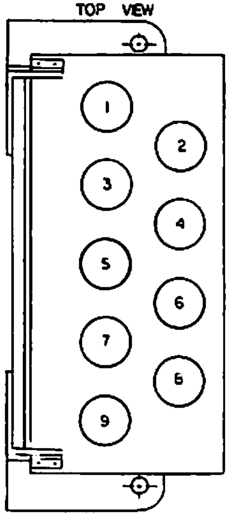


NOTE

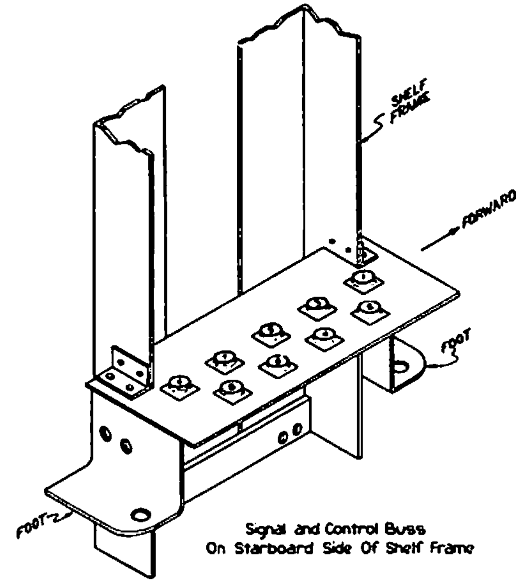
This buss was added after completion of the original S+C buss. The buss is attached to the telemetry shelf as a cable. It is anchored to the shelf frame by nylon cable wraps.

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
FLOATING SIGNAL BUSS	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
11 - 6 - 73	Dr. No. IET73 - 007

TOP VIEW

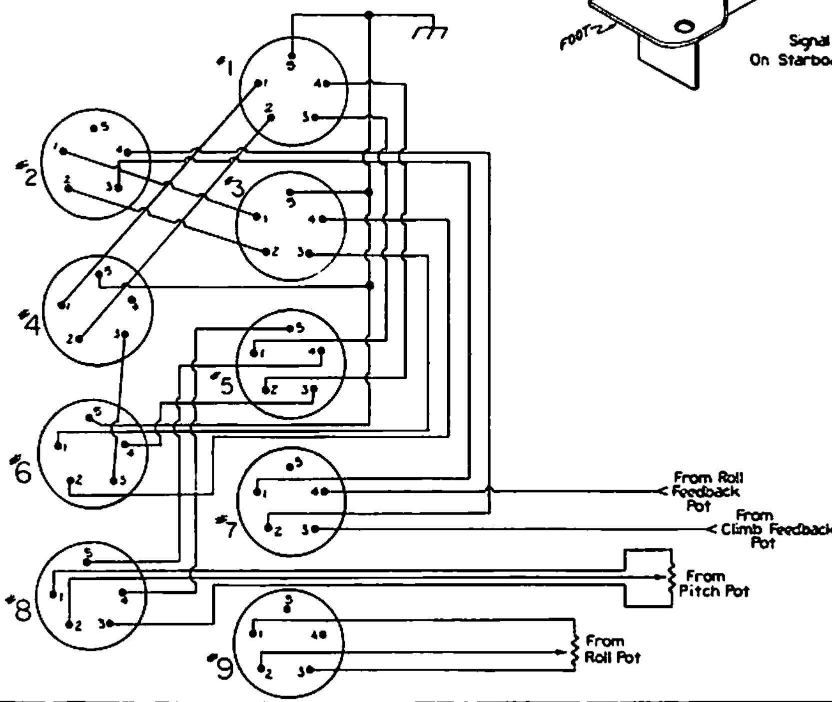


1. } Power Supply Shelf
2. }
3. Sonar Shelf
4. Roll Shelf
5. Climb-Dive Shelf
6. }
7. } Telemetry Shelf
8. }
9. }

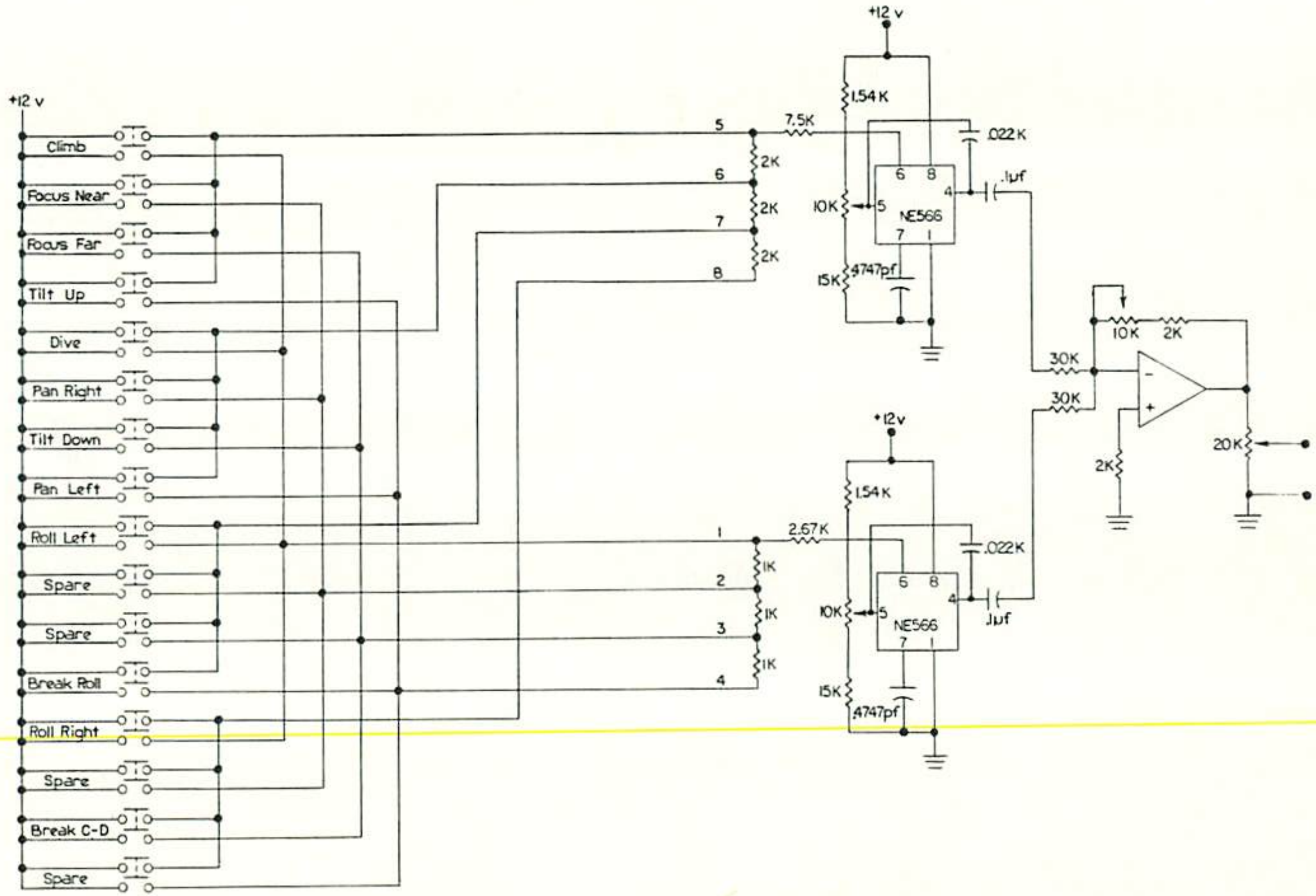


Signal and Control Buss
On Starboard Side Of Shelf Frame

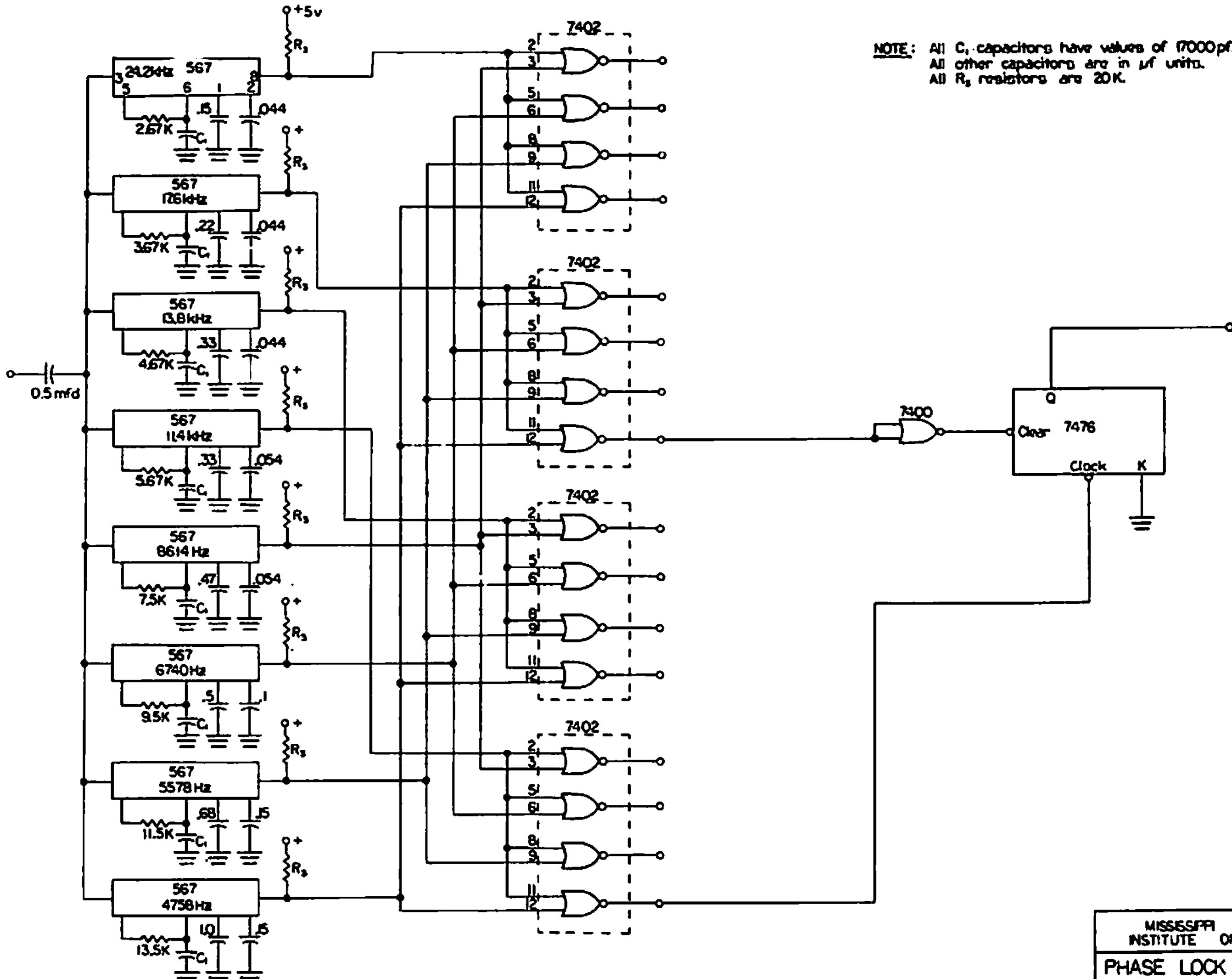
BOTTOM VIEW
(SHOWING WIRING DIAGRAM)



MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
SIGNAL AND CONTROL BUSS	
Dr. By: Major L. Nimock	NOT TO SCALE.
Ck. By: M.F.J.	App. By: RDB.
11-12-73	Dr. No. IET73-008

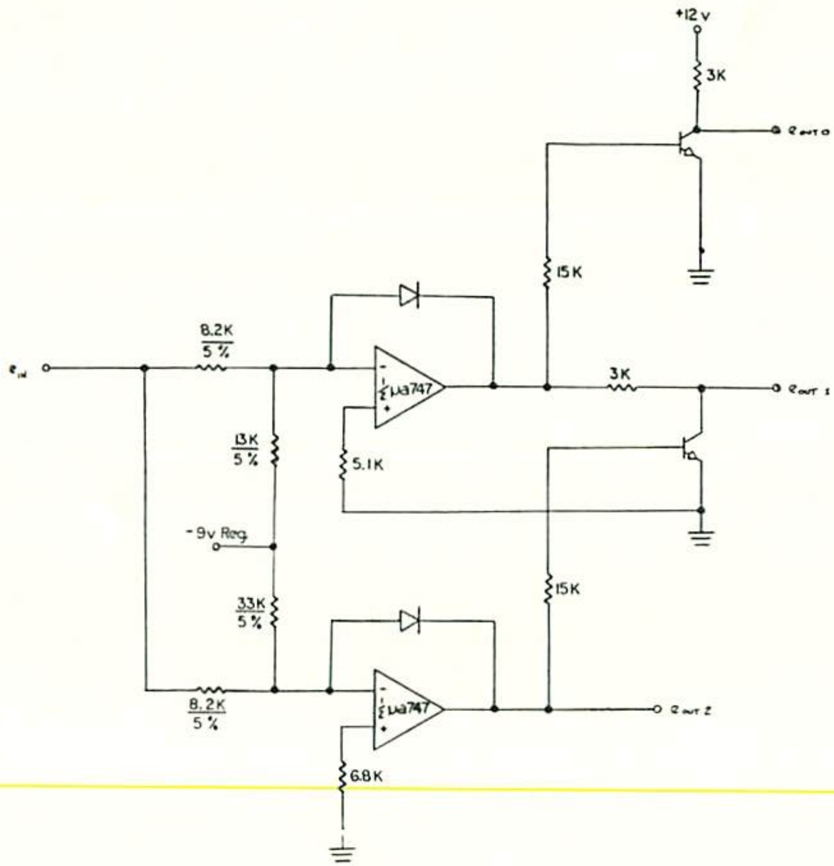


MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
PHASE LOCK LOOP TRANSMITTER	
Dr. By: Major L. Nimock	
Ck By: MFJ	App. By: RDB.
10 - 3 - 73	Dr. No. IET73-009



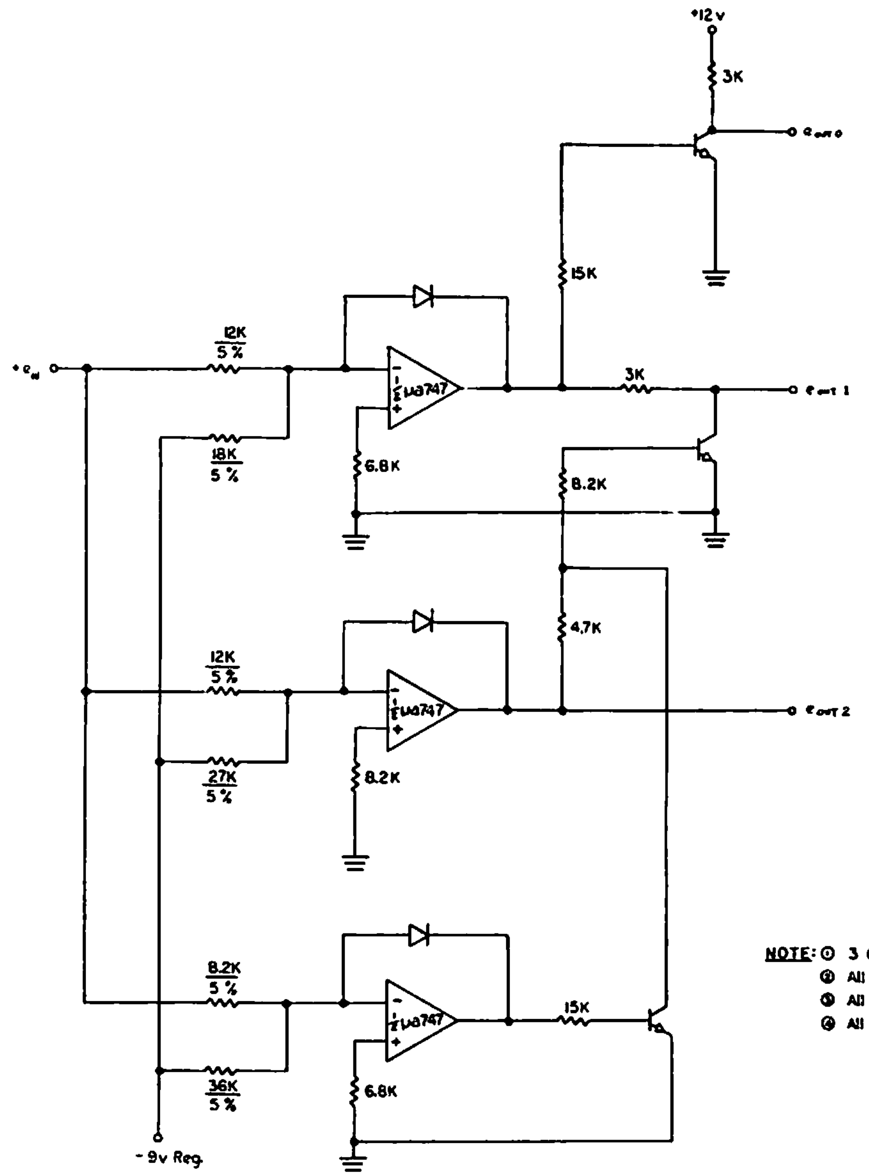
NOTE: All C_1 capacitors have values of 17000pf.
All other capacitors are in μf units.
All R_s resistors are 20K.

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
PHASE LOCK LOOP RECEIVER	
Dr By: Major L. Nimock	
Ck.By: M.F.J.	App.By: R.D.B.
10 – 4 – 73	Dr. No. IET73-010



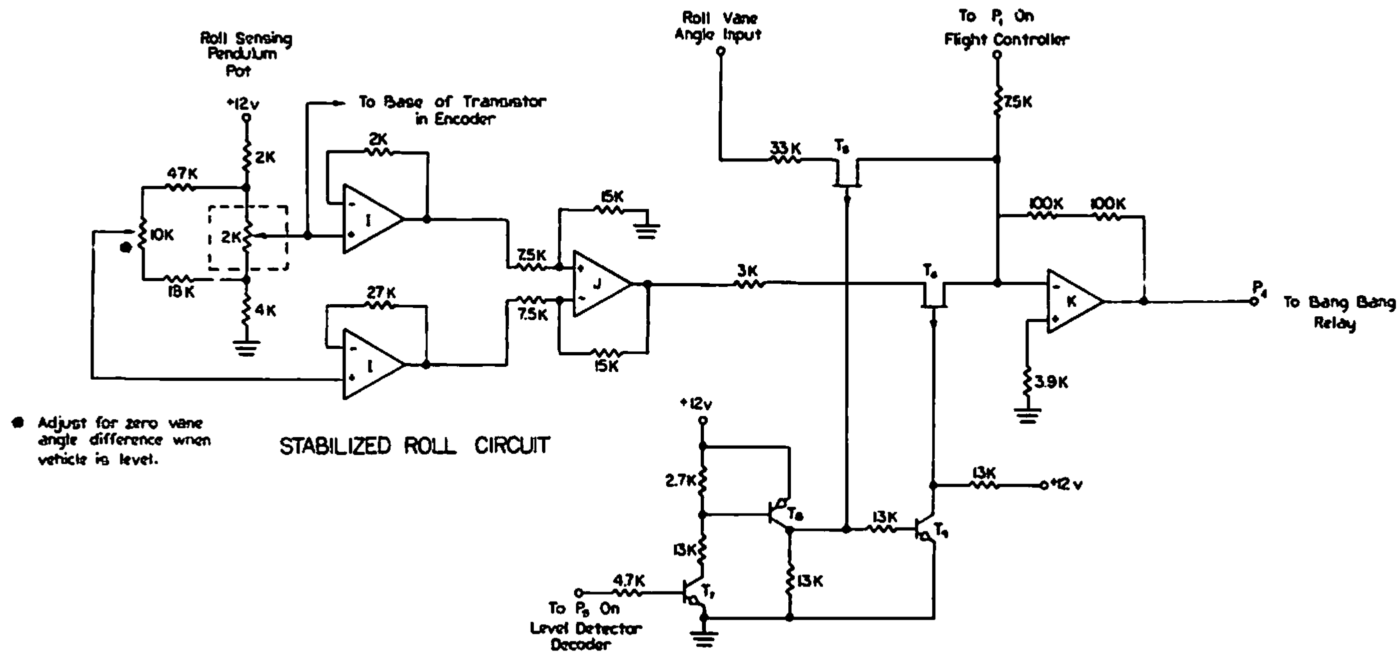
NOTE: ① 3 Circuits required
② All PNP Transistors are 2N3906
③ All NPN Transistors are 2N3904
④ All Diodes are 1N914

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
LEVEL DETECTOR and DECODER for ON-OFF-ON FUNCTIONS	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
10-30-73	Dr. No. IET73-011



NOTE: ① 3 Circuits required
② All PNP Transistors are 2N3906
③ All NPN Transistors are 2N3904
④ All Diodes are IN914

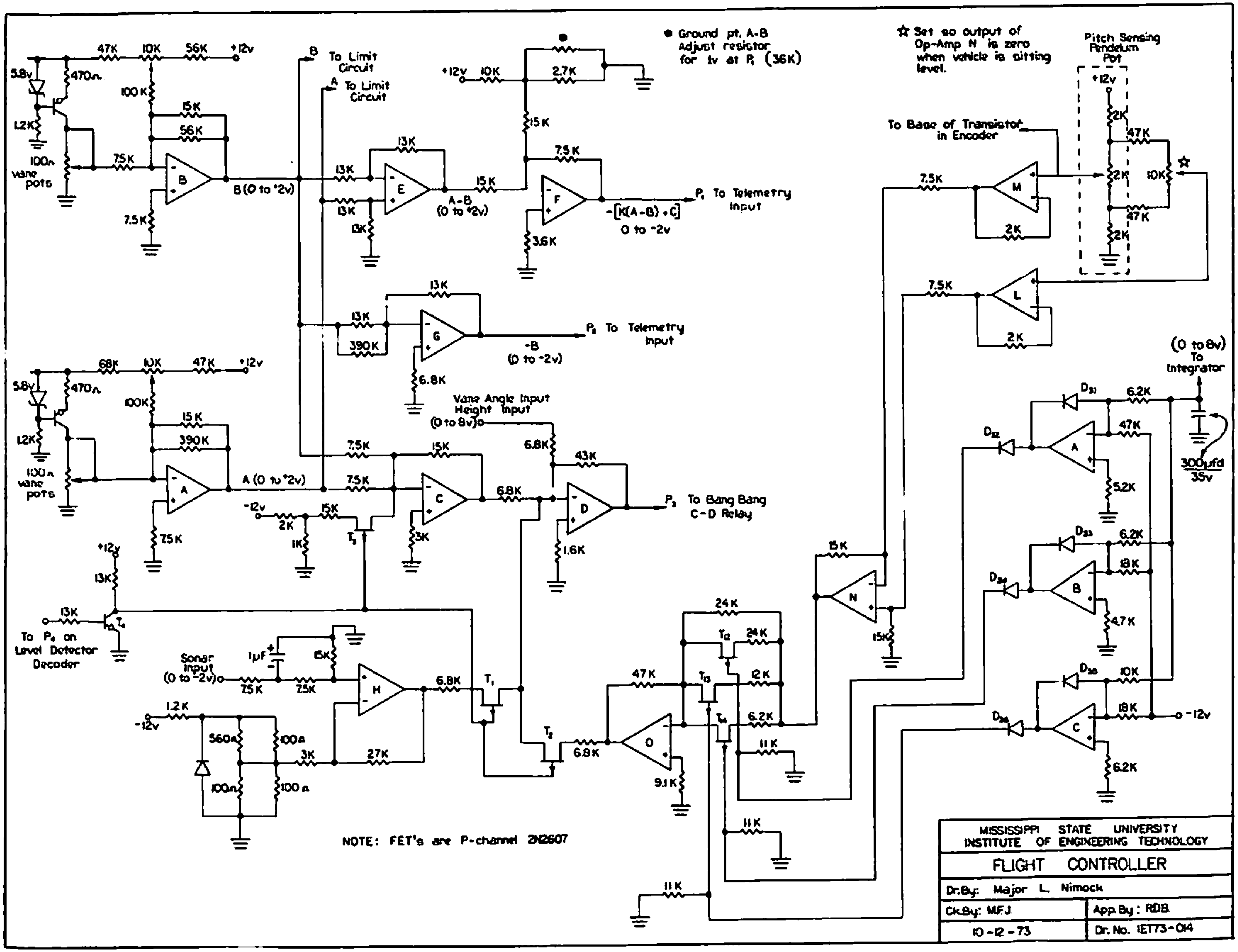
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
LEVEL DETECTOR and DECODER for ON-OFF, ON-OFF FUNCTIONS	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
10 - 30 - 73	Dr. No. IET73-012

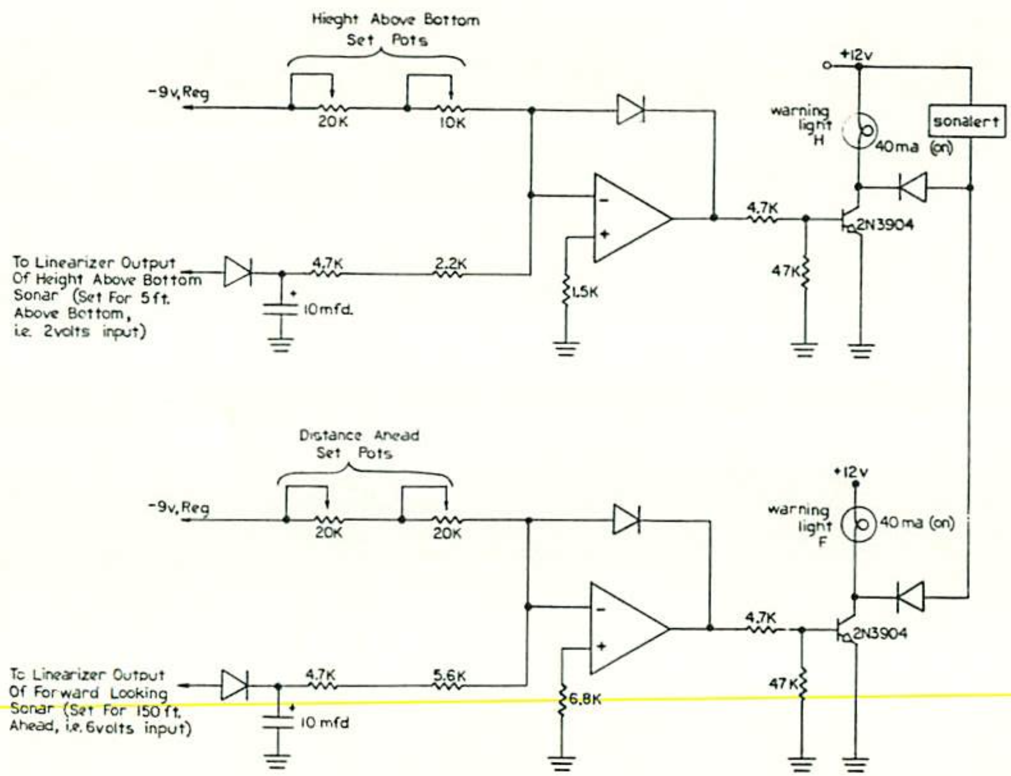


STABILIZED ROLL CIRCUIT

NOTE: FET's are P-channel 2N2607
Transistors are 2N3904

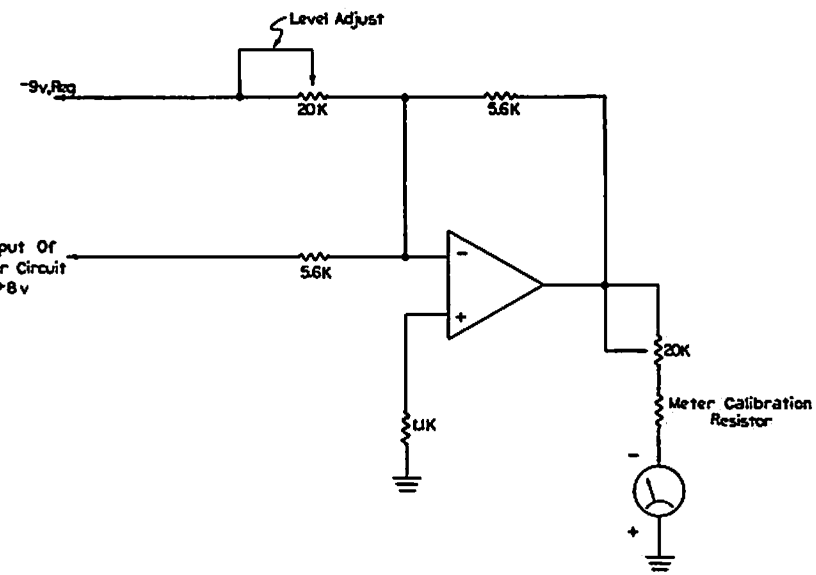
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
STABILIZED ROLL CIRCUIT	
Dr. By: Major L. Nimock	
Ck. By: MFJ	App By: RDB.
10-19-73	Dr. No. IET73-013


● Ground pt. A-B Adjust resistor for 1v at P1 (36K)
☆ Set so output of Op-Amp N is zero when vehicle is sitting level.
Pitch Sensing Pendulum Pot
To Base of Transistor in Encoder
To Limit Circuit
To Limit Circuit
B (0 to +2v)
A-B (0 to +2v)
-[K(A-B)+C] 0 to -2v
P1 To Telemetry Input
-B (0 to -2v)
P2 To Telemetry Input
vane pots
Vane Angle Input Height Input (0 to 8v)
A (0 to +2v)
P3 To Bang Bang C-D Relay
(0 to 8v) To Integrator
300µfd 35v
To P4 on Level Detector Decoder
Sonar Input (0 to -2v)
NOTE: FET's are P-channel 2N2607
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY
FLIGHT CONTROLLER
Dr.By: Major L. Nimock
Ck.By: MFJ
App.By: RDB
10-12-73
Dr. No. IET73-014



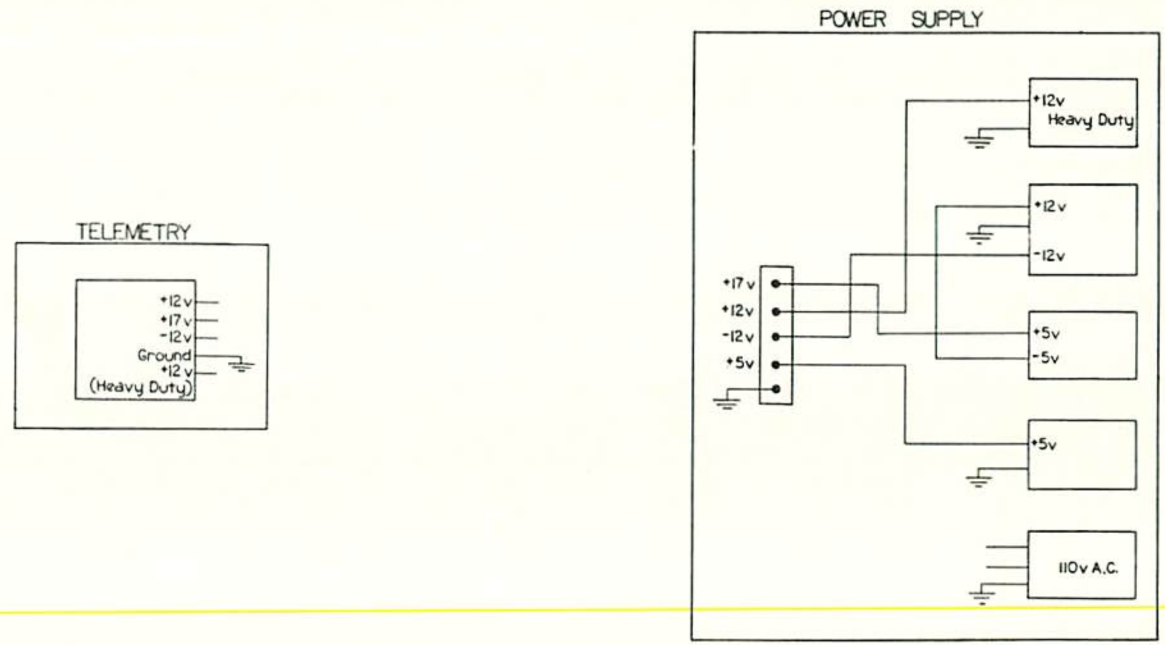
NOTE: All Diodes Are IN914

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
ALTITUDE and OBSTACLE WARNING SYSTEM	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App By: R.D.B.
9-27-73	Dr. No. IET73-015

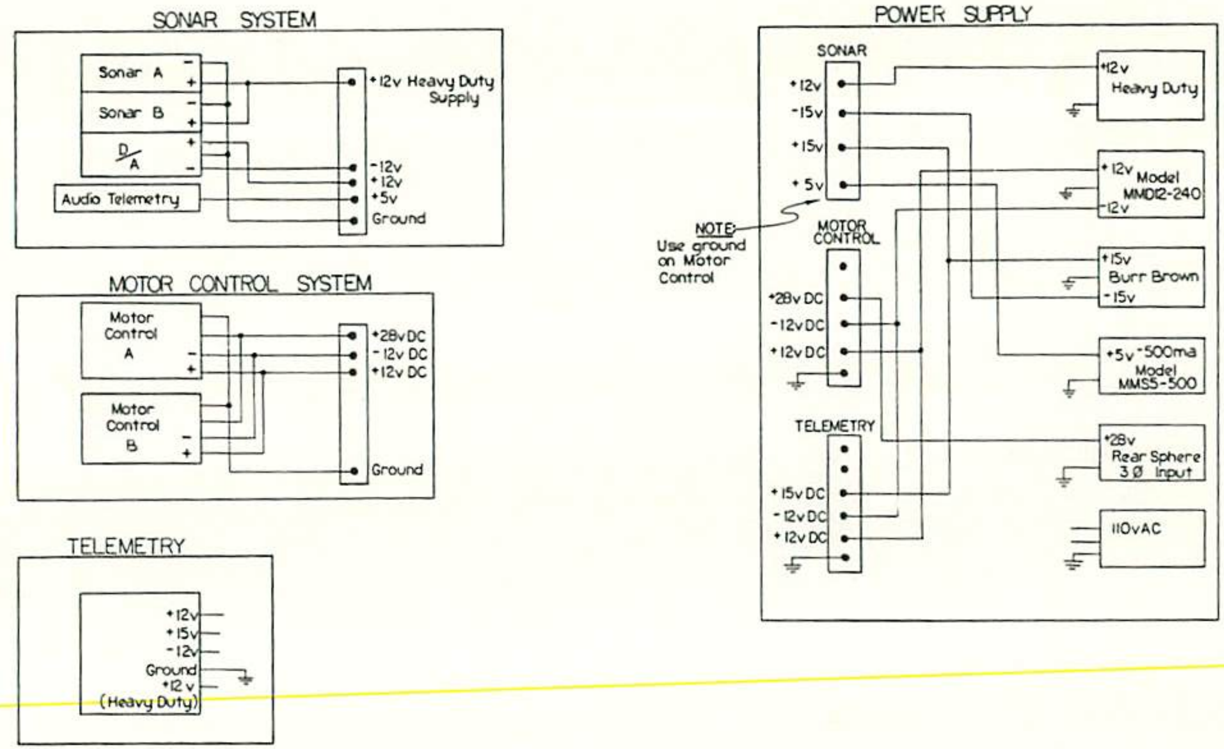


NOTE: 1 Required For Each
Zero Center Reading Meter

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
METER SCALING CIRCUIT	
Dr.By: Major L. Nimock	
Ck.By: M.F.J	App: By: R.D.B.
9-27-73	Dr. No. IET73-016



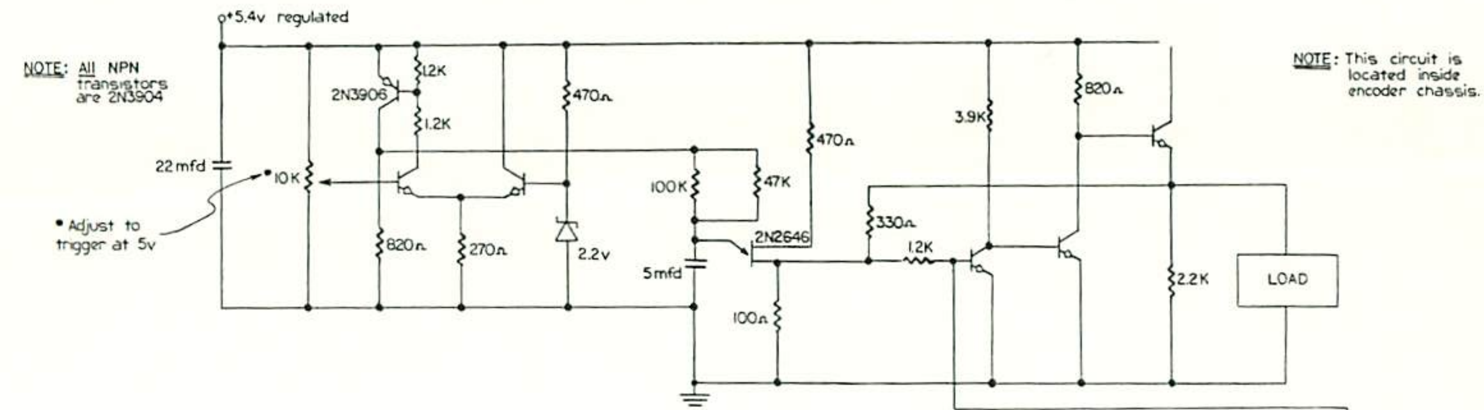
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
SHIP POWER DISTRIBUTION	
Dr. By: Major L. Nimock	
Ck. By: M.F.J	App. By: R.D.B.
11-20-73	Dr. No. IET73-017



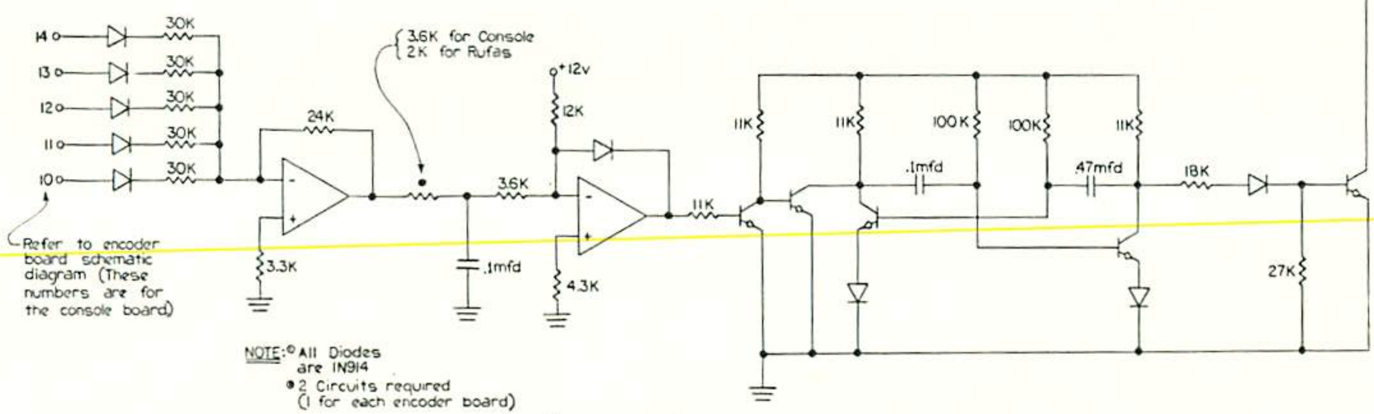
POWER COLOR CODING

Voltage	Color
120 v A.C.	Green
Ground	Black (except for Heavy Current - - - White-Yellow)
+12v	Blue
-12v	Violet
+5v	Yellow-Blue
+15v	Yellow
-15v	White
+28v	White-Green

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
RUFAS POWER DISTRIBUTION	
Dr. By: Major L Nimock	
Ck. By: MFJ	App. By: RDB.
11-19-73	Dr. No. IET73-018



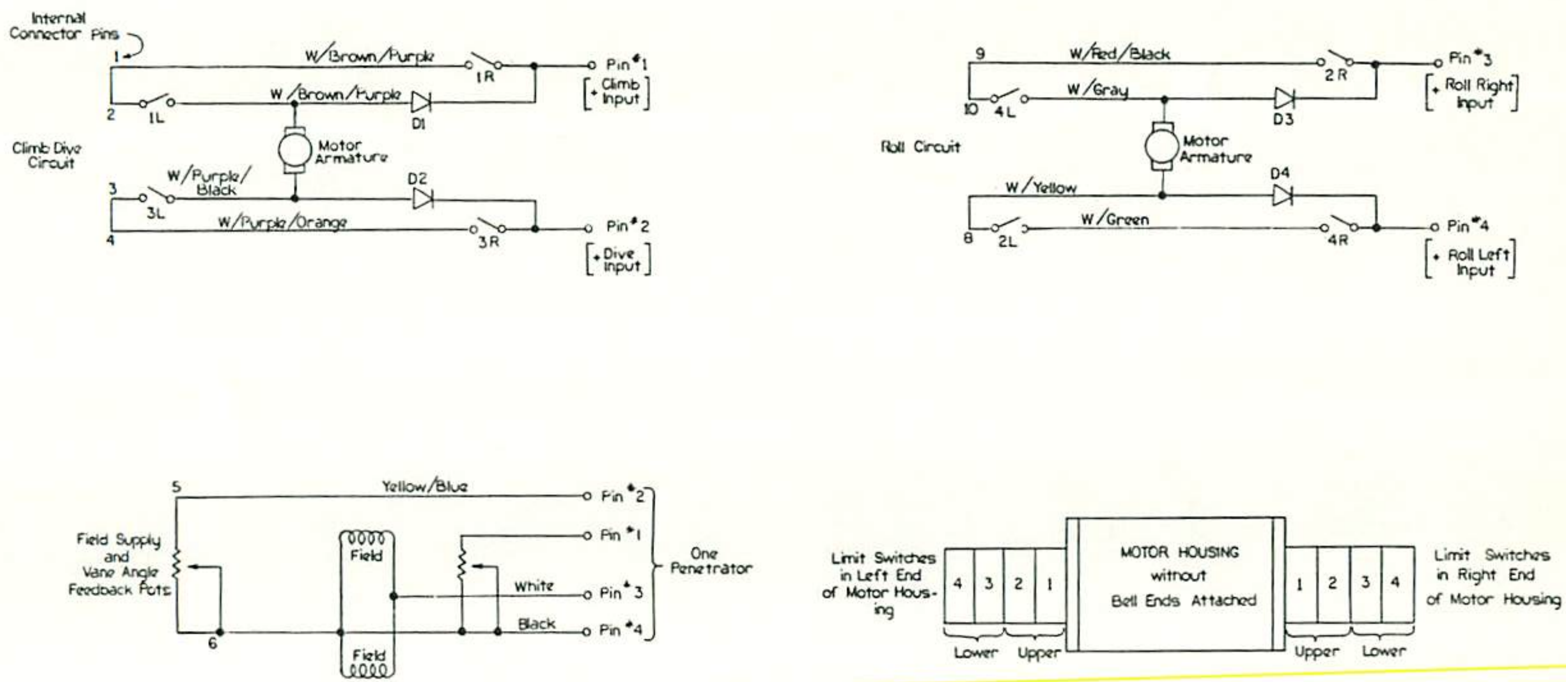
VOLTAGE LEVEL SENSE, TIME DELAY SWITCH FOR TRANSMITTER ENCODER BOARD



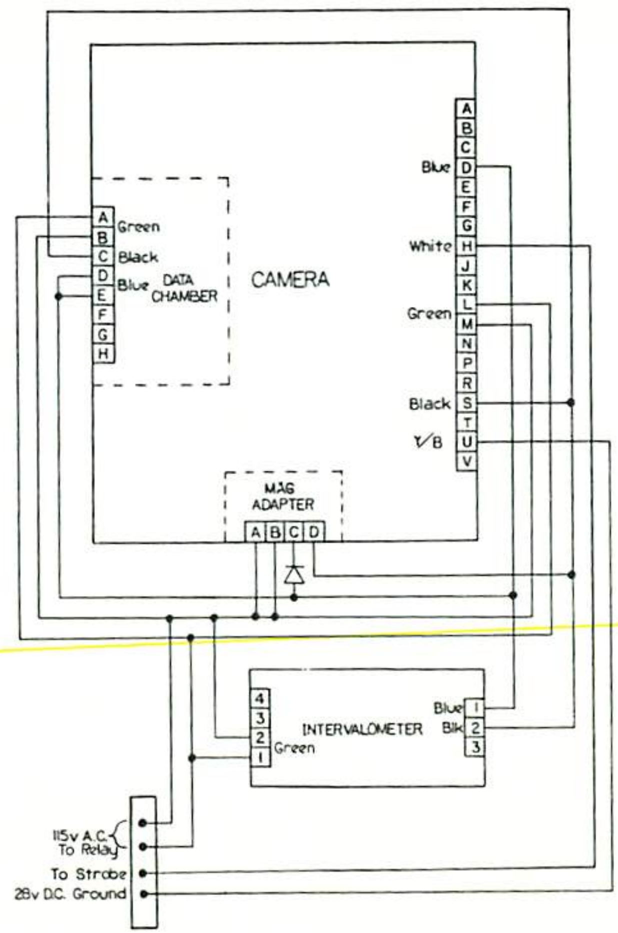
NOTE: ⊙ All Diodes are IN914
⊛ 2 Circuits required (1 for each encoder board)

"ONE" ELIMINATOR CIRCUIT

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
ACCESSORY CIRCUITS for ENCODER BOARD	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
11-30-73	Dr. No. IET73-019

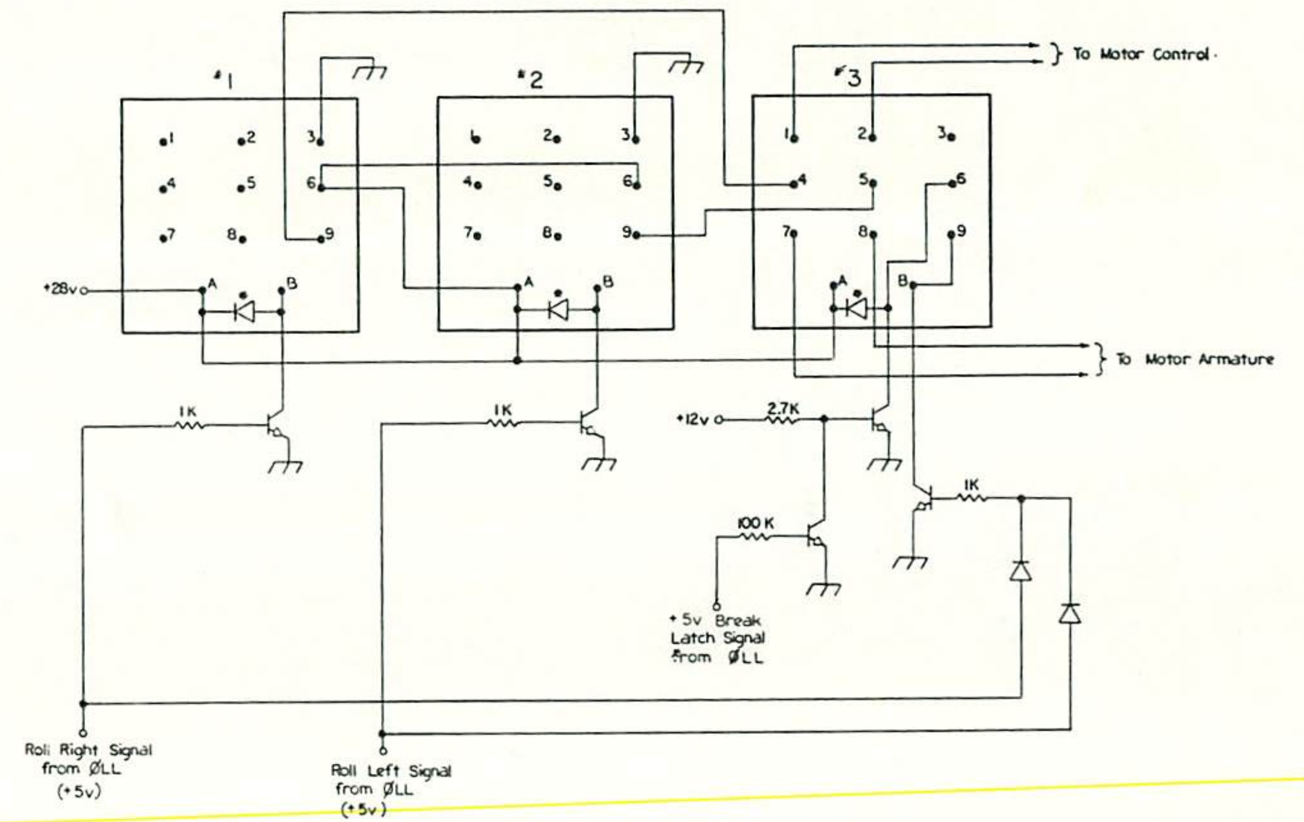


MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
MOTOR HOUSING CIRCUIT	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
12 - 6 - 73	Dr. No. IET73-020



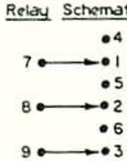
NOTE: Diode is IN4004

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
WIRING DIAGRAM FOR DATA CAMERA	
Dr. By: Major L. Nimock	
Ck. By: MFJ	App.By: RDB.
12-10-73	Dr. No. IET73-021

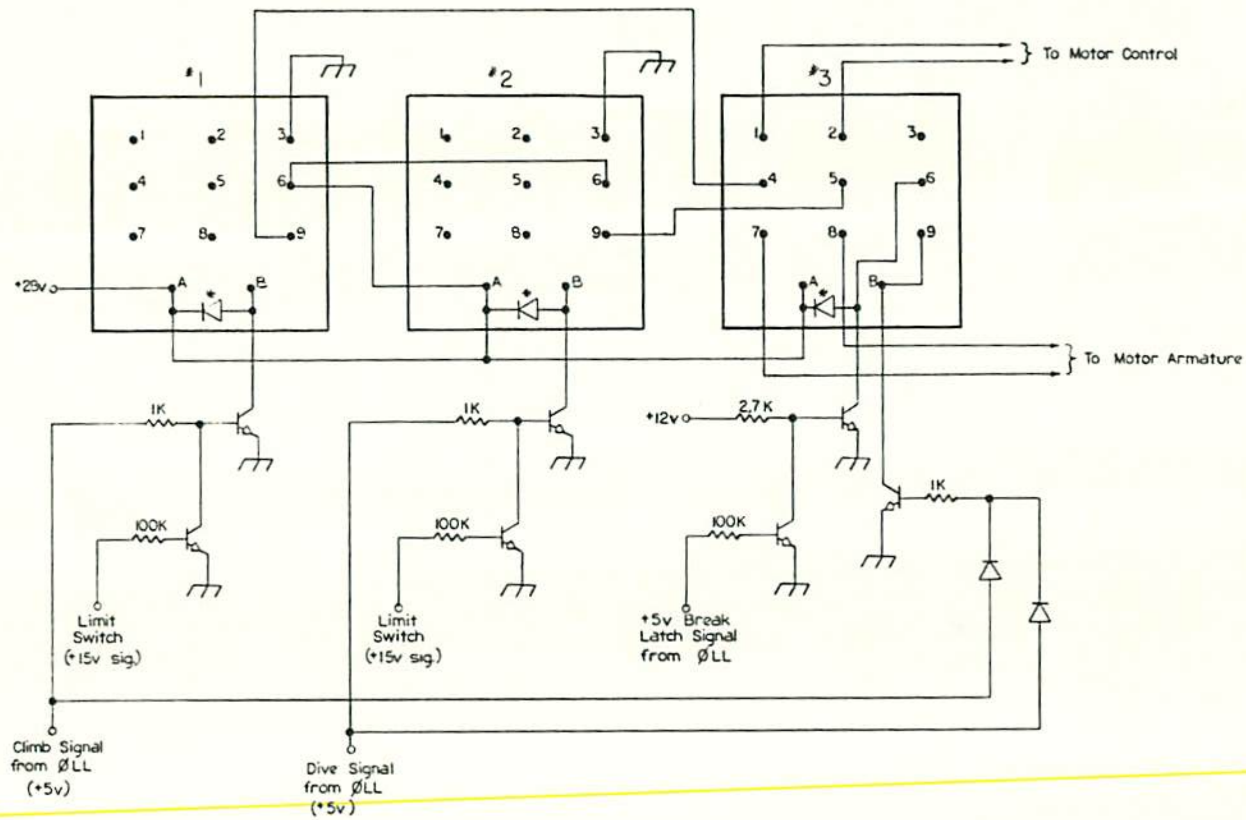


NOTE: All Transistors are 2N3904.
All Diodes are IN914,
except Diodes with * by them.
These Diodes are IN4004.

Relay Schematic

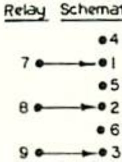


MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
RELAY CONNECTIONS for ROLL SHELF	
Dr. By: Major L. Nimock	
Ck. By: MFJ.	App. By: RDB.
12-14-73	Dr. No. IET73-022

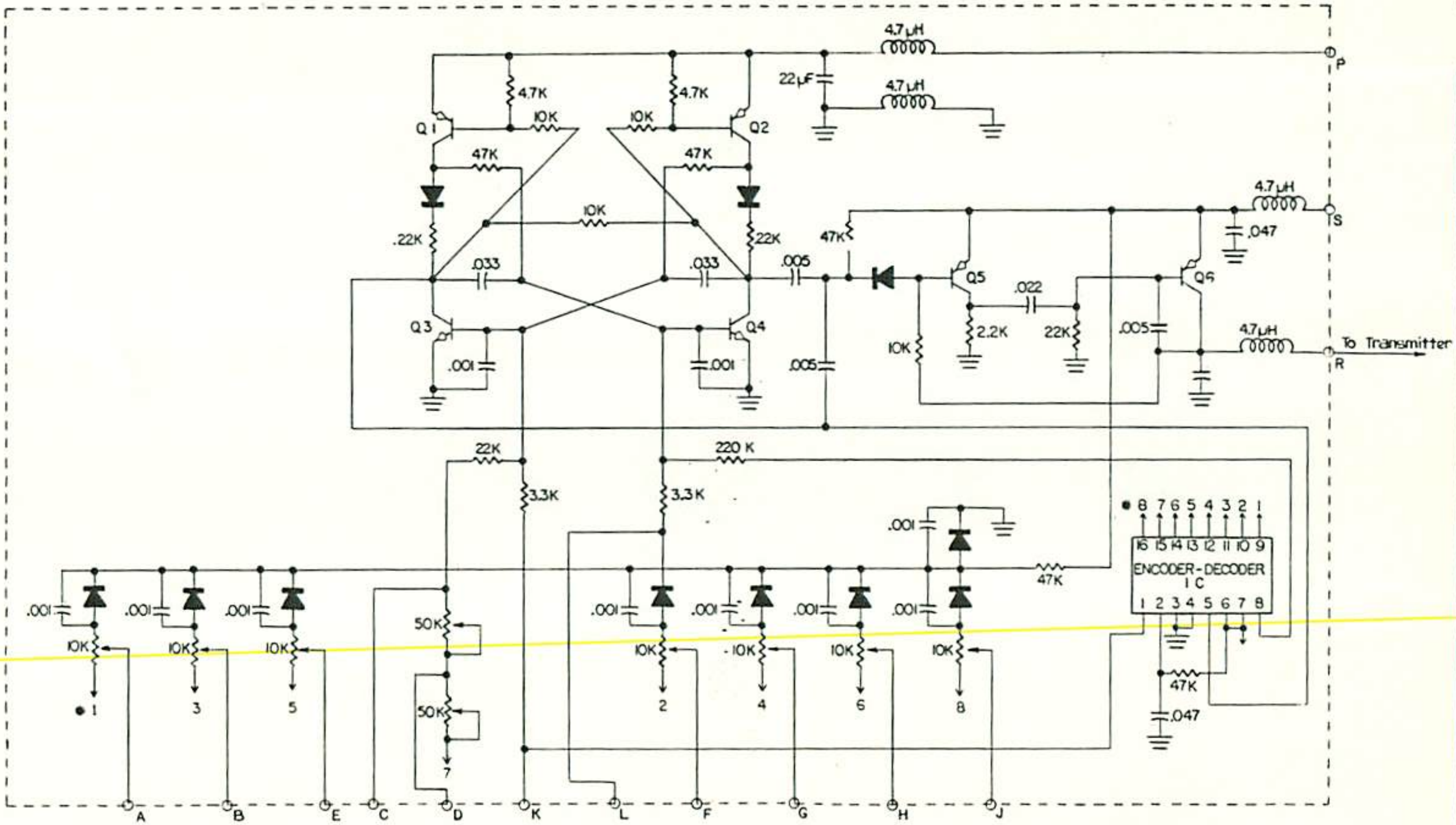


NOTE: All Transistors are 2N3904
All Diodes are IN914
except Diodes with * by them
which are IN4004.

Relay Schematic

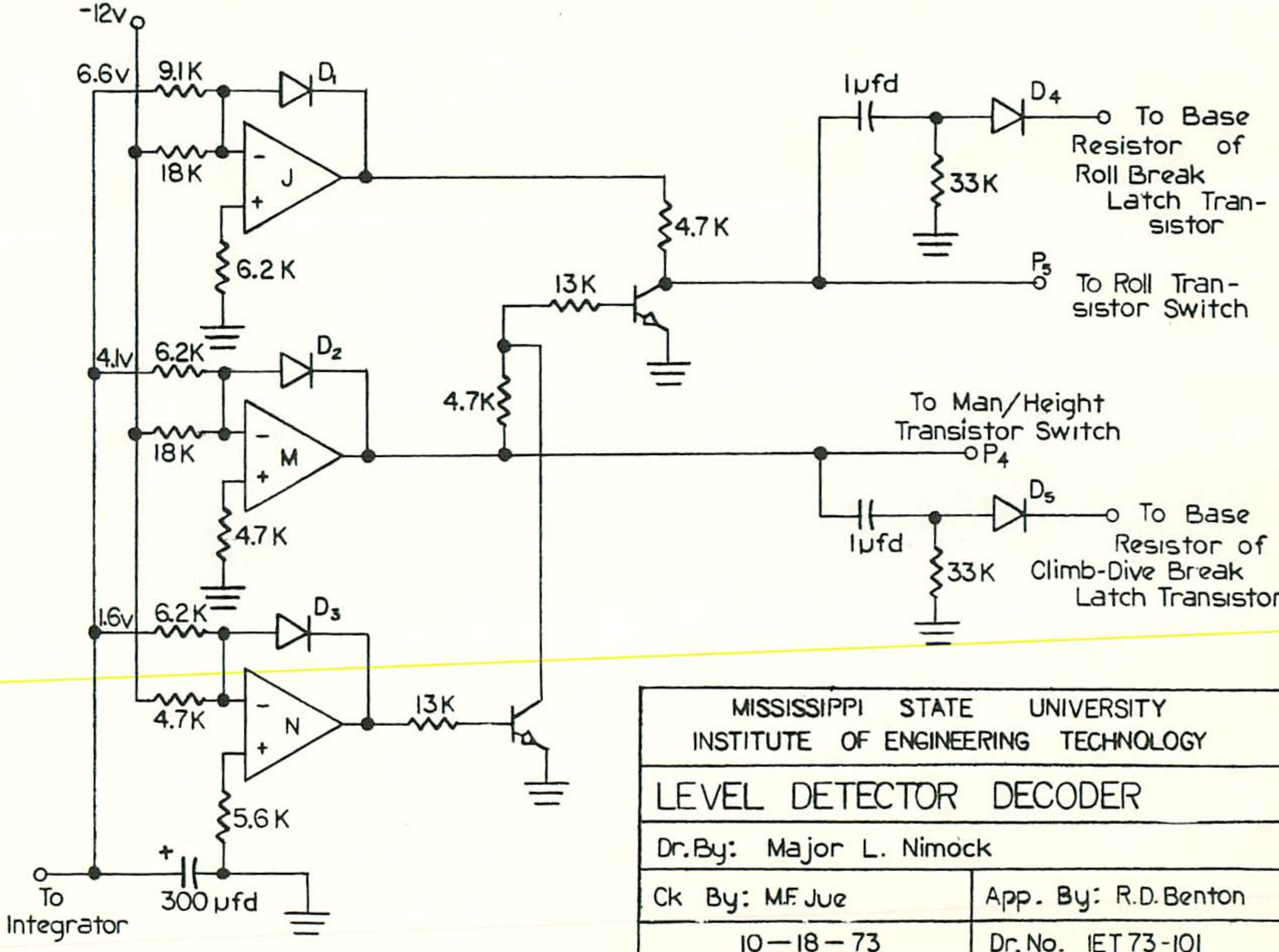


MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
RELAY CONNECTIONS for CLIMB-DIVE SHELF	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
12-14-73	Dr. No. IET73-023



● Number on pots indicates their connection to corresponding number on Encoder-Decoder.

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
ENCODER	
Dr By Major L. Nimock	
Ck By: M.F.J.	App By: R.D.B.
2 - 4 - 74	Dr No. IET73-024

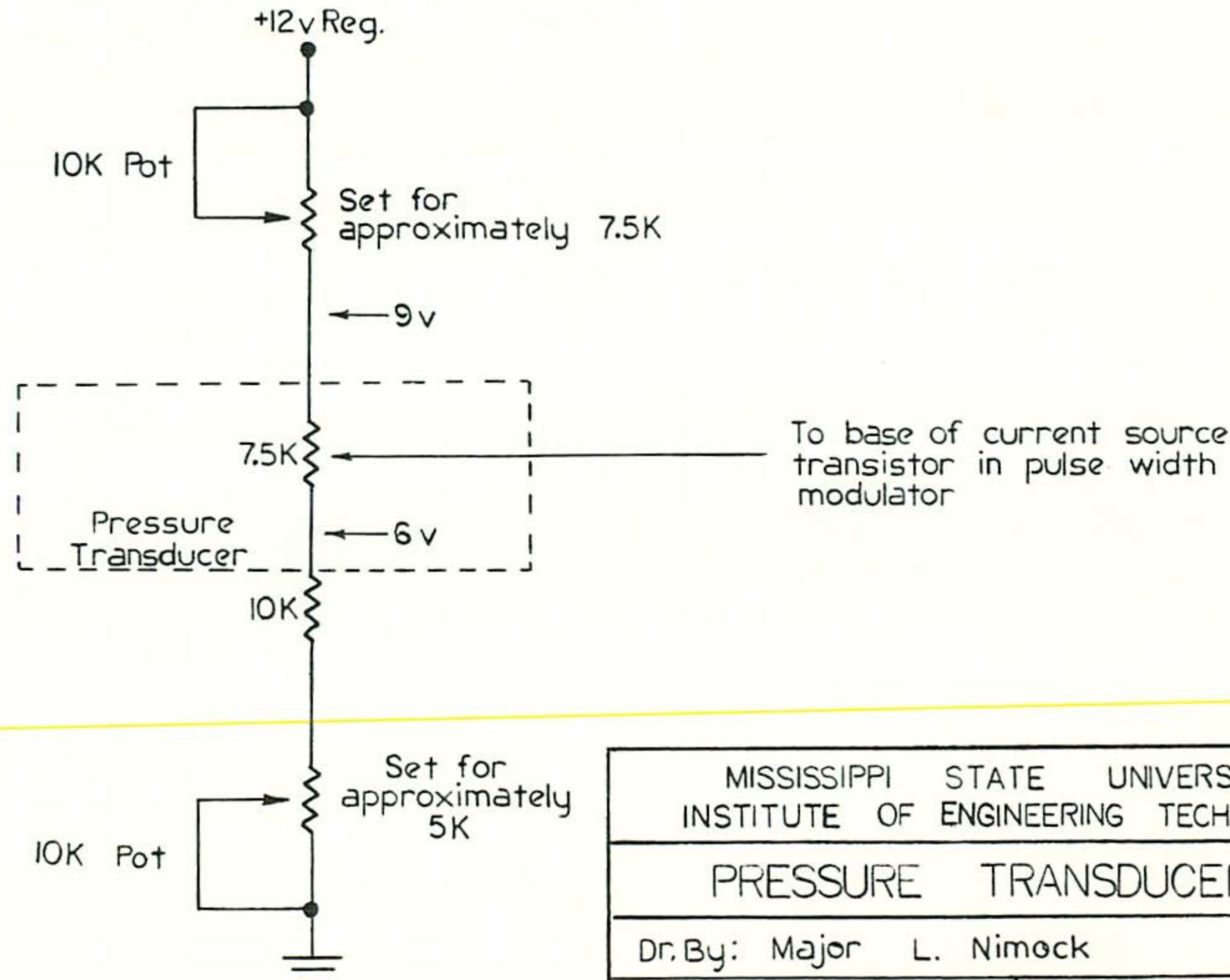


MISSISSIPPI STATE UNIVERSITY
INSTITUTE OF ENGINEERING TECHNOLOGY

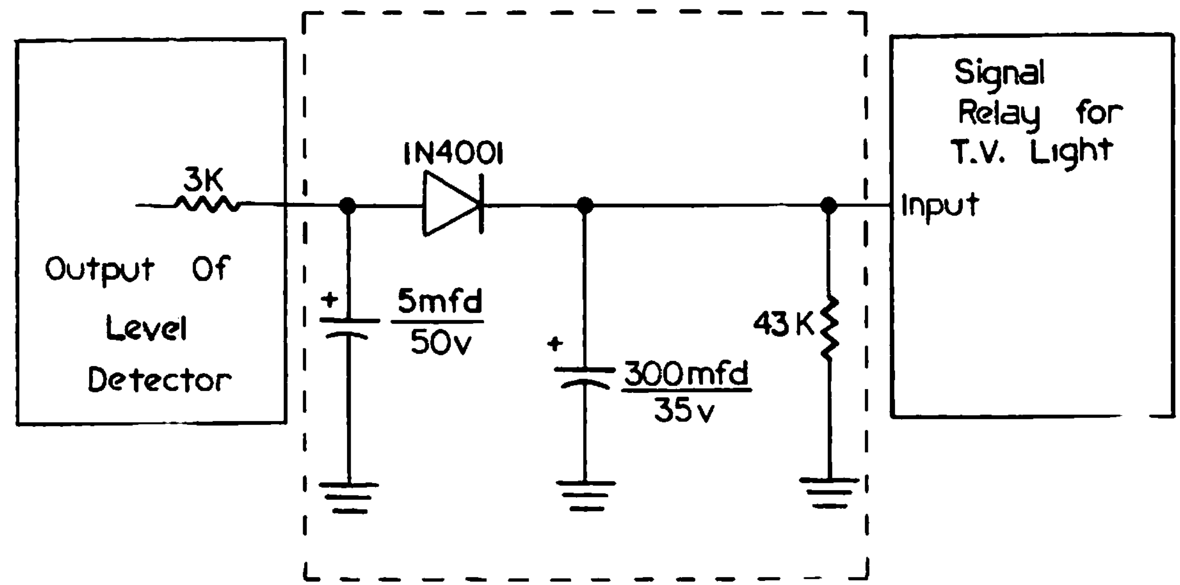
LEVEL DETECTOR DECODER

Dr. By: Major L. Nimock

Ck By: M.F. Jue	App. By: R.D. Benton
10 — 18 — 73	Dr. No. IET 73-101

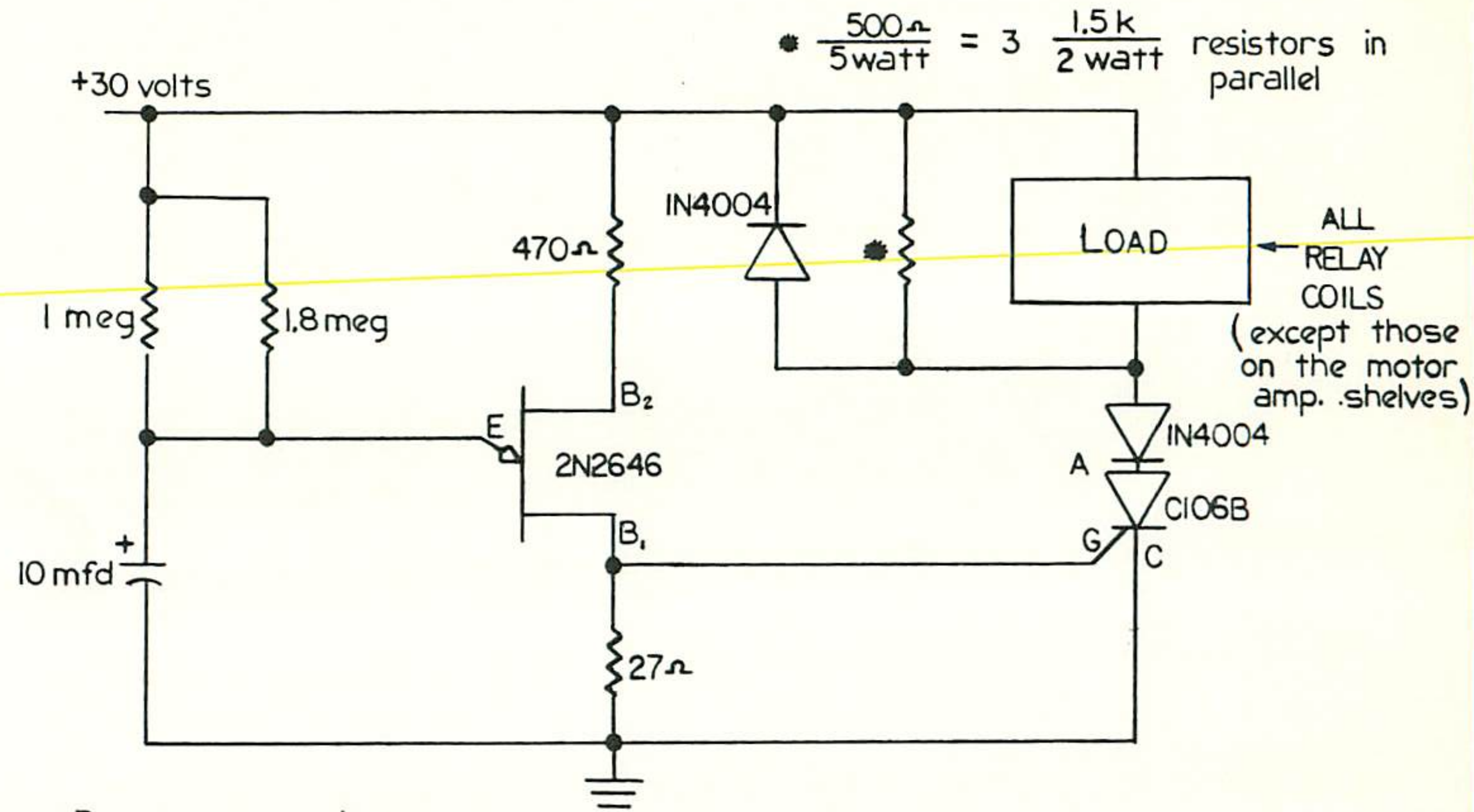


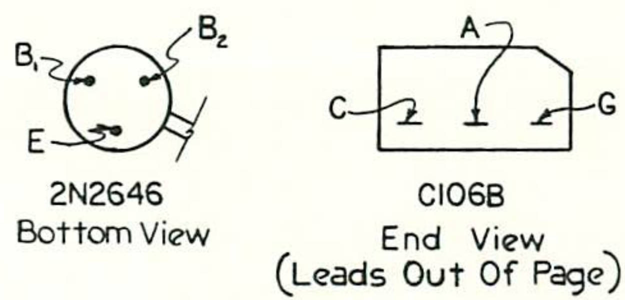
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
PRESSURE TRANSDUCER	
Dr. By: Major L. Nimock	
Ck. By: M.F. Jue	App. By: R.D. Benton
10 - 8 - 73	Dr. No. IET 73 - 102



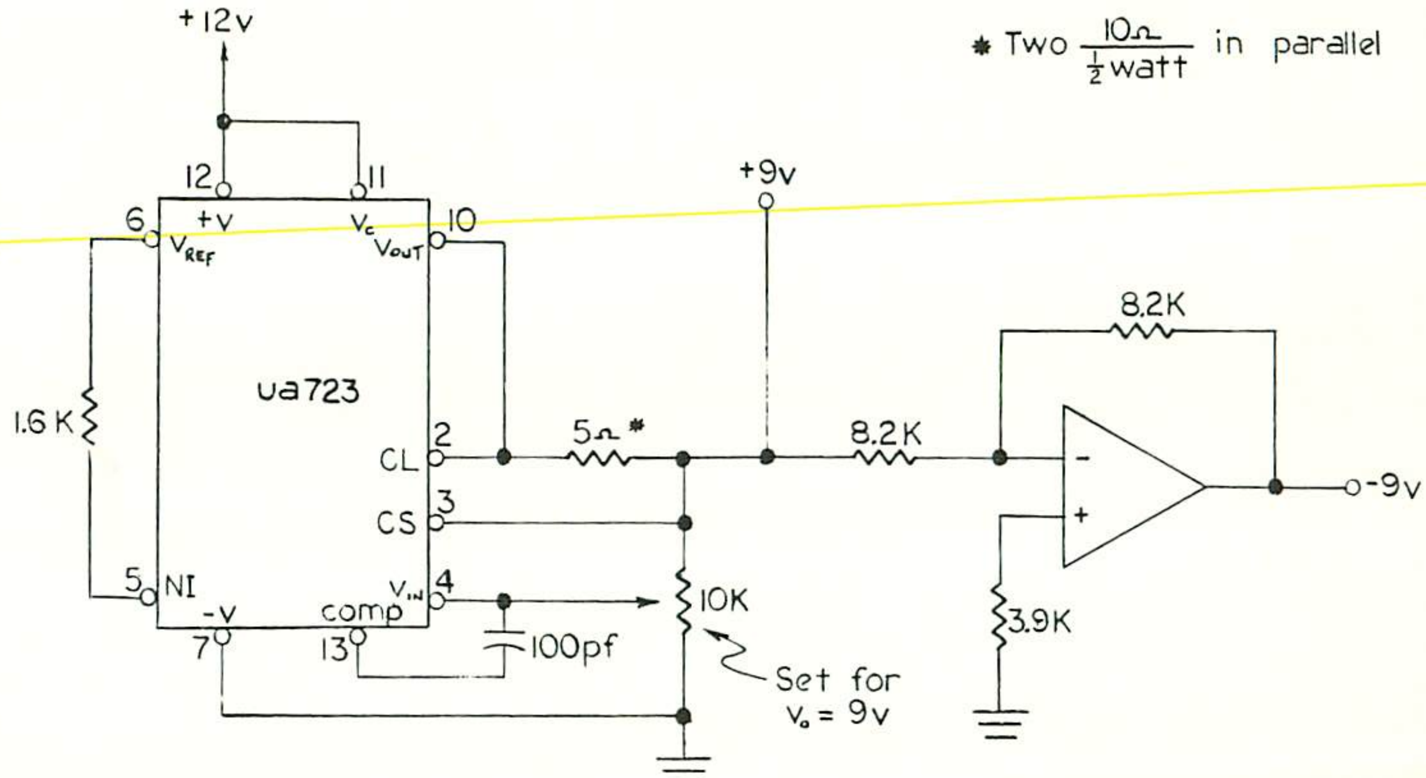
NOTE; 2 Circuits Required

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
TURN OFF TIME DELAY CIRCUIT for T.V. Lights	
Dr.By; Major L. Nimock	
Ck.By: M.F.Jue	App By: R.D.Benton
9-28-73	Dr. No. IET73-103

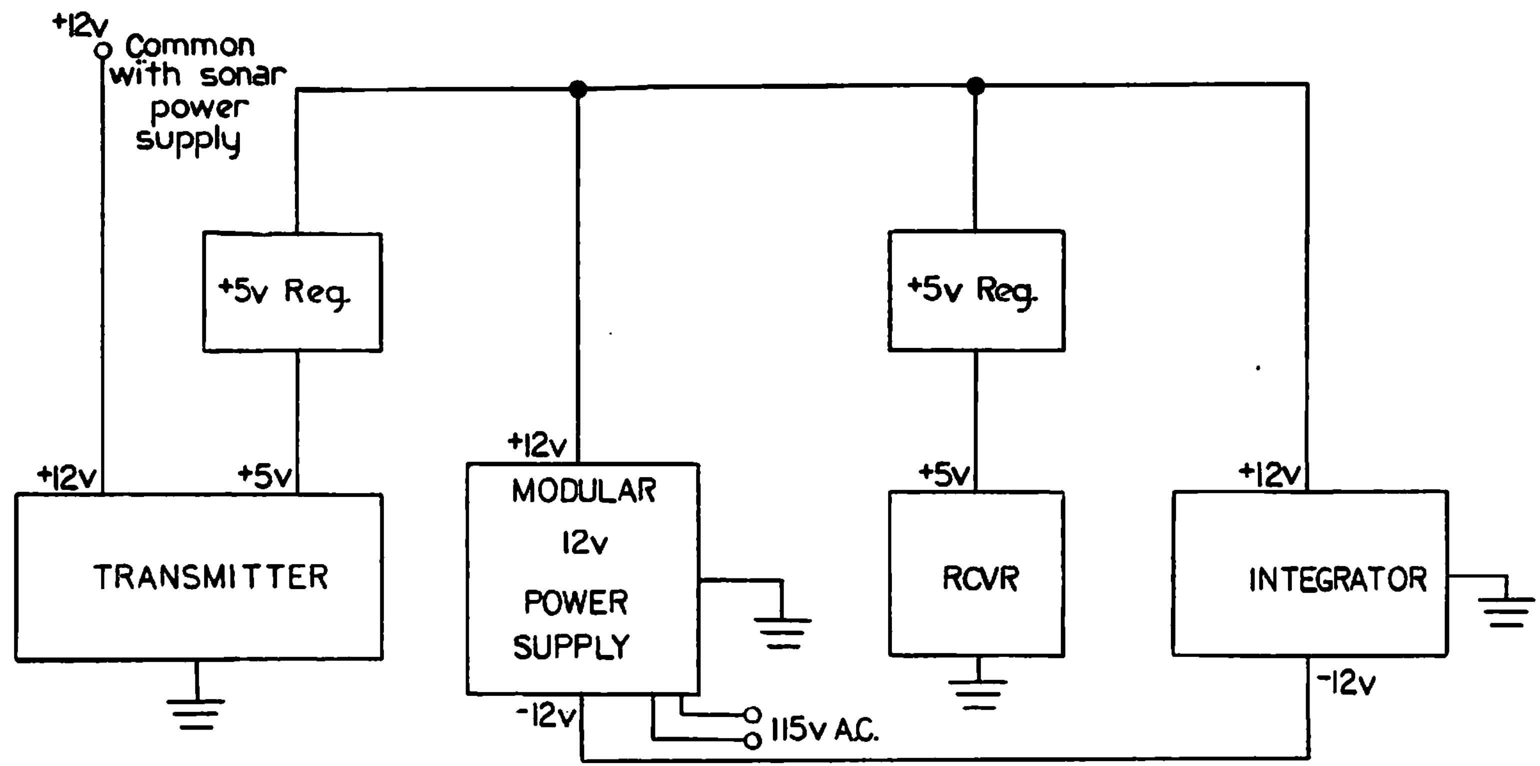




MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
TURN ON POWER DELAY CIRCUIT	
Dr. By: Major L. Nimock	
Ck By: M.F. Jue	App. By: R.D. Benton
10 - 1 - 73	Dr. No. IET 73 - 104

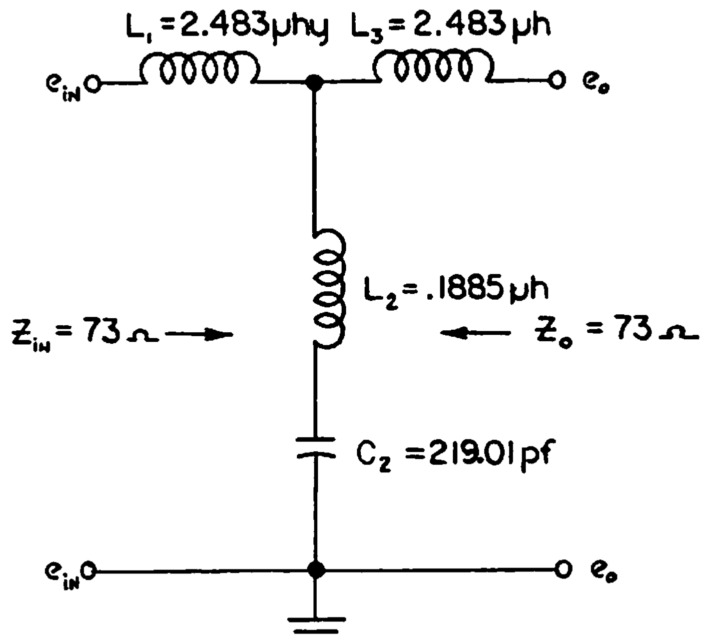


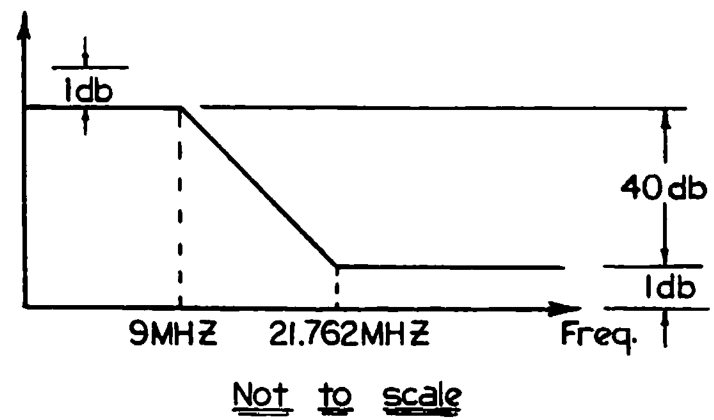
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
±9v REGULATOR	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: RDB.
10 - 8 - 73	Dr. No. IET73-105



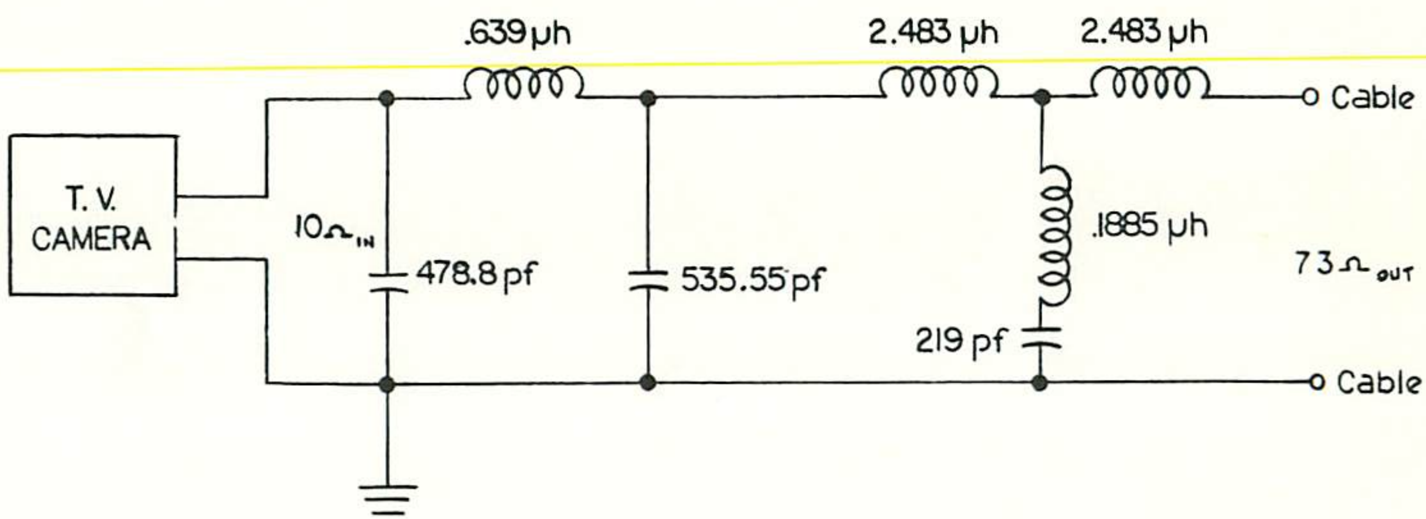
NOTE: Voltages are measured with respect to ground references.

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
POWER DISTRIBUTION FOR RCVR and TRANSMITTER (on Rufas)	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
10-8-73	Dr. No. IET 73-106

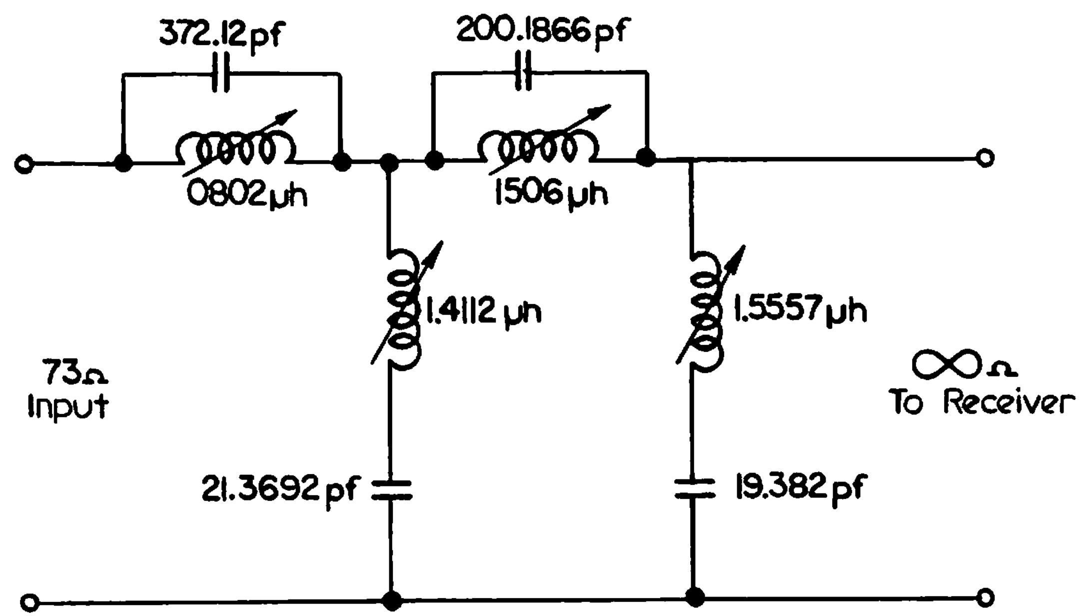




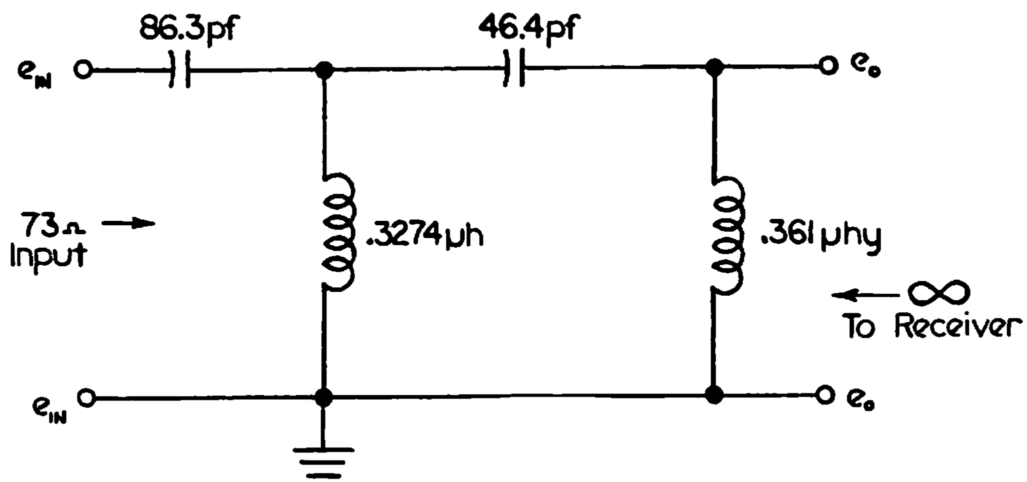
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
LPF-1S AT T.V. MONITOR	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
10-23-73	Dr. No. IET 73-107



MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
LPF-1R AT T.V. CAMERA	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
10-22-73	Dr. No. IET 73-108



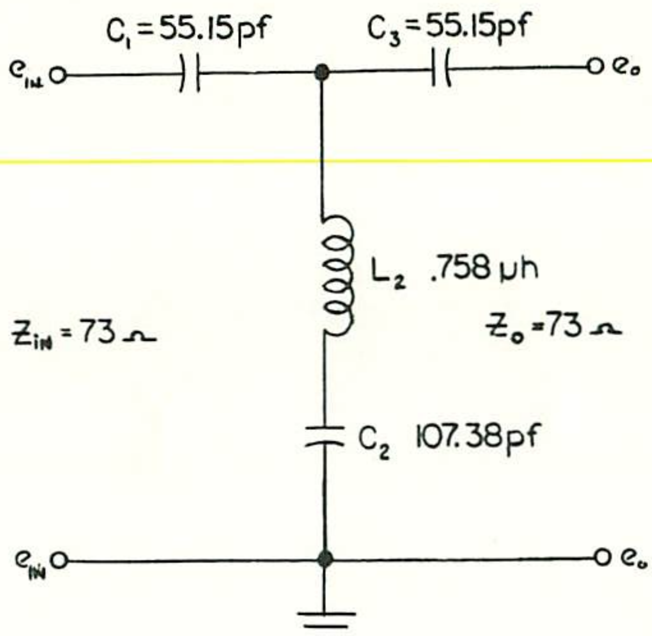
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
BRF-1R AT RECEIVER	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
10-26-73	Dr. No. IET73-109

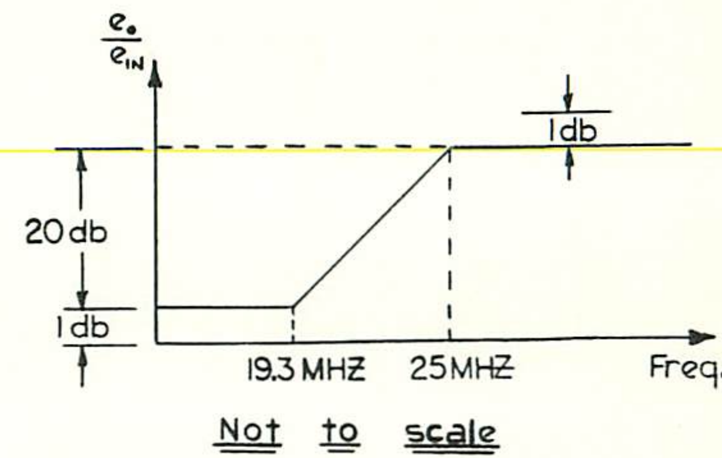


NOTE

This is located at Rufus receiver. Isolate receiver from T.V. camera.

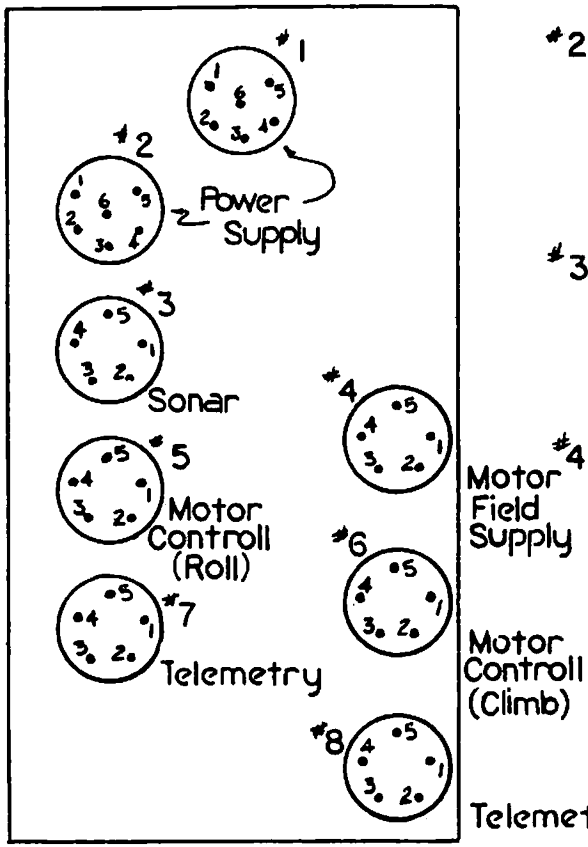
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
HPF - 1R AT RECEIVER	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: RDB.
10-25-73	Dr. No. IET73-110





MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
HPF-2R AT TRANSMITTER	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
10-23-73	Dr. No. IET 73-111

NOTE: HD-Heavy Duty
NU-Not Used



POWER SUPPLY INPUT TO BUS

#1
1. Ground
2. +12v HD
3. +12v
4. -12v
5. +28v
6. NU

#2
1. NU
2. NU
3. +15v
4. -15v
5. NU
6. NU

SONAR

#3
1. Ground
2. -15v
3. +15v
4. NU
5. +12v

MOTOR FIELD SUPPLY OUTPUT

#4
1. NU
2. Ground
3. Ground
4. +28v
5. +28v

MOTOR CONTROL (ROLL)

#5
1. NU
2. Ground
3. +12v HD
4. -12v
5. +28v

MOTOR CONTROL (CLIMB)

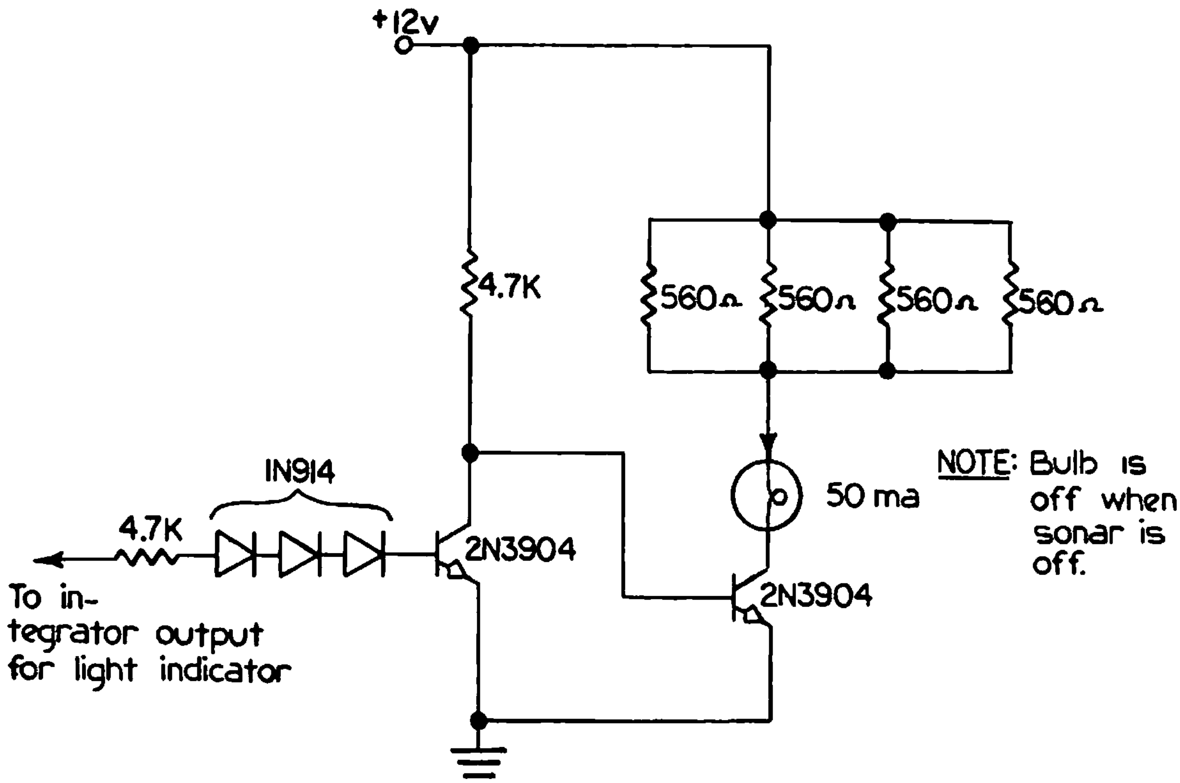
#6
1. NU
2. Ground
3. +12v HD
4. -12v
5. +28v

TELEMETRY

#7
1. NU
2. -15v
3. +15v
4. NU
5. NU

#8
1. -12v
2. Ground
3. NU
4. +12v
5. +12v HD

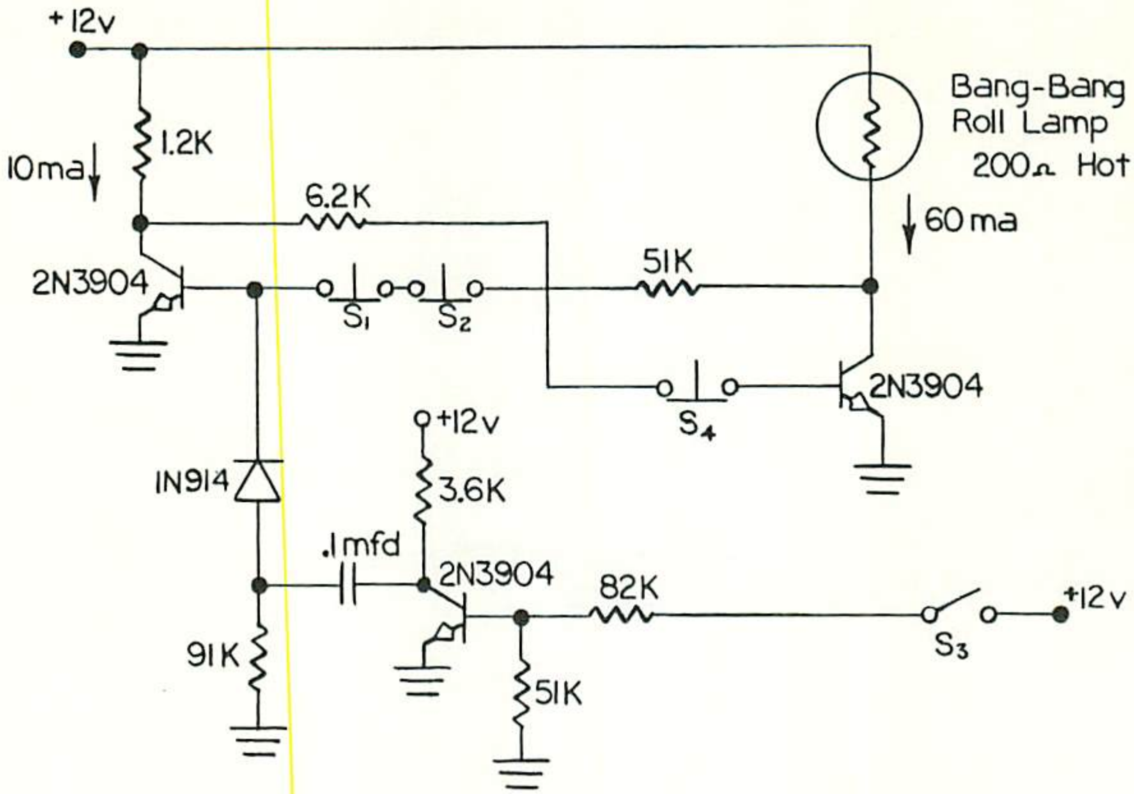
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
POWER BUSS	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
11 - 5 - 73	Dr. No. IET73-112



NOTE: This indicator is built into height-above-bottom meter.

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
UNDER 20FT. LIGHT INDICATOR	
Dr. By: Major L. Nimock	
Ck.By: M.F.J.	App. By: R.D.B.
12 - 3 - 73	Dr. No. IET73 - 113

NOTE: 2 Circuits Req'd.



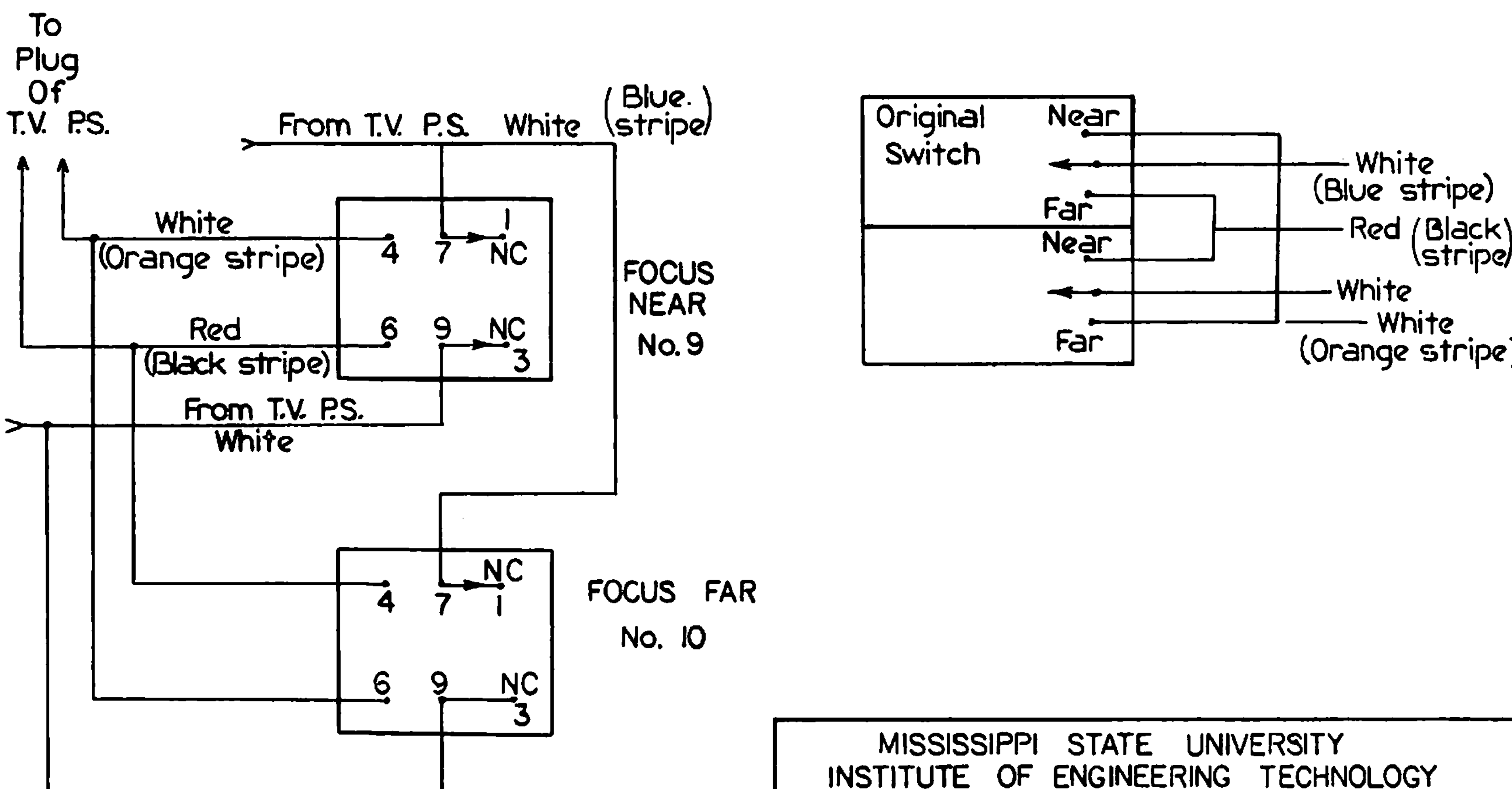
S_1 — Normally closed switch on Roll Right

S_2 — Normally closed switch on Roll Left

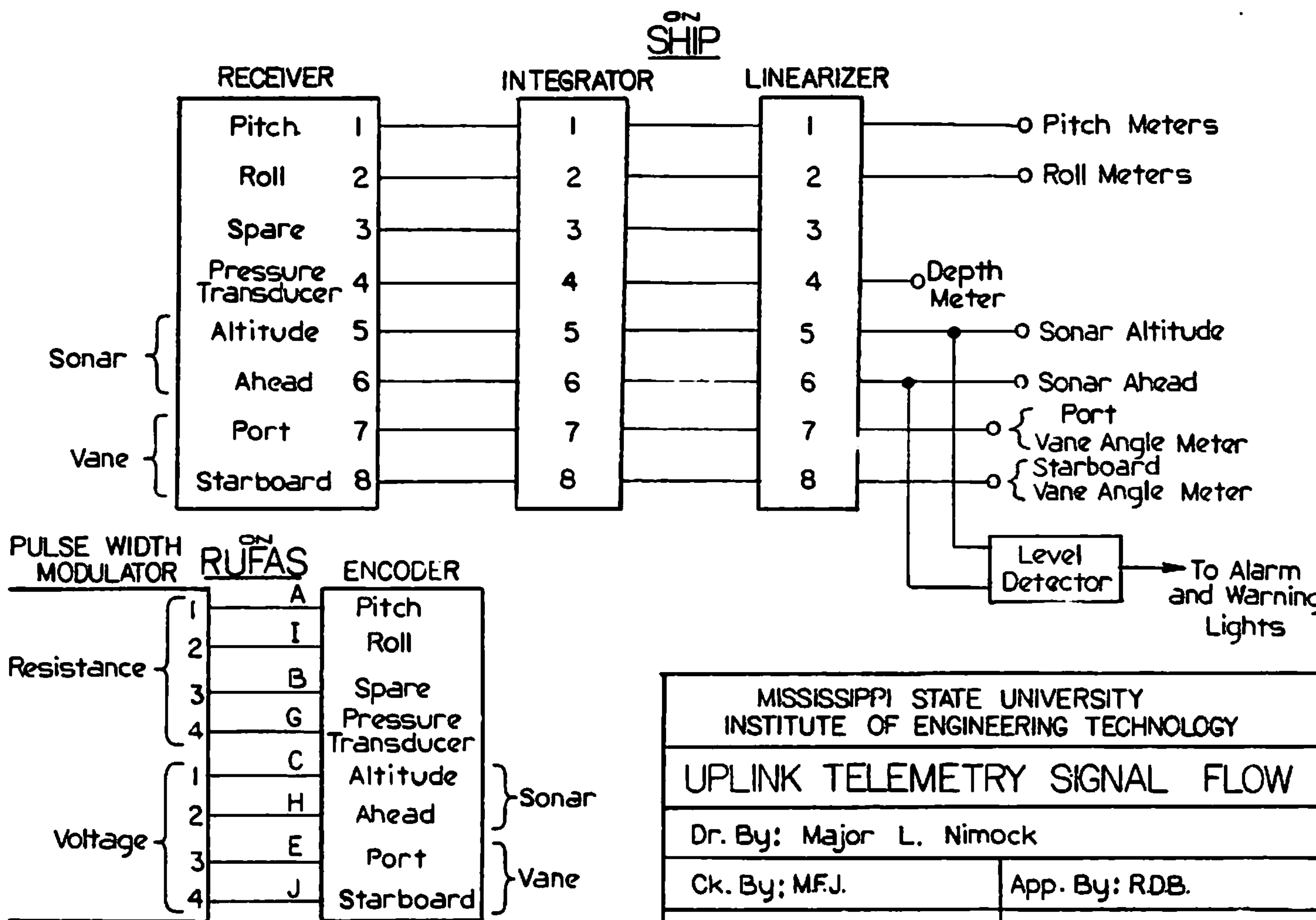
S_3 — Normally closed switch on Manual/Auto Roll Control on Control Box

S_4 — NC, Break Latch Switch

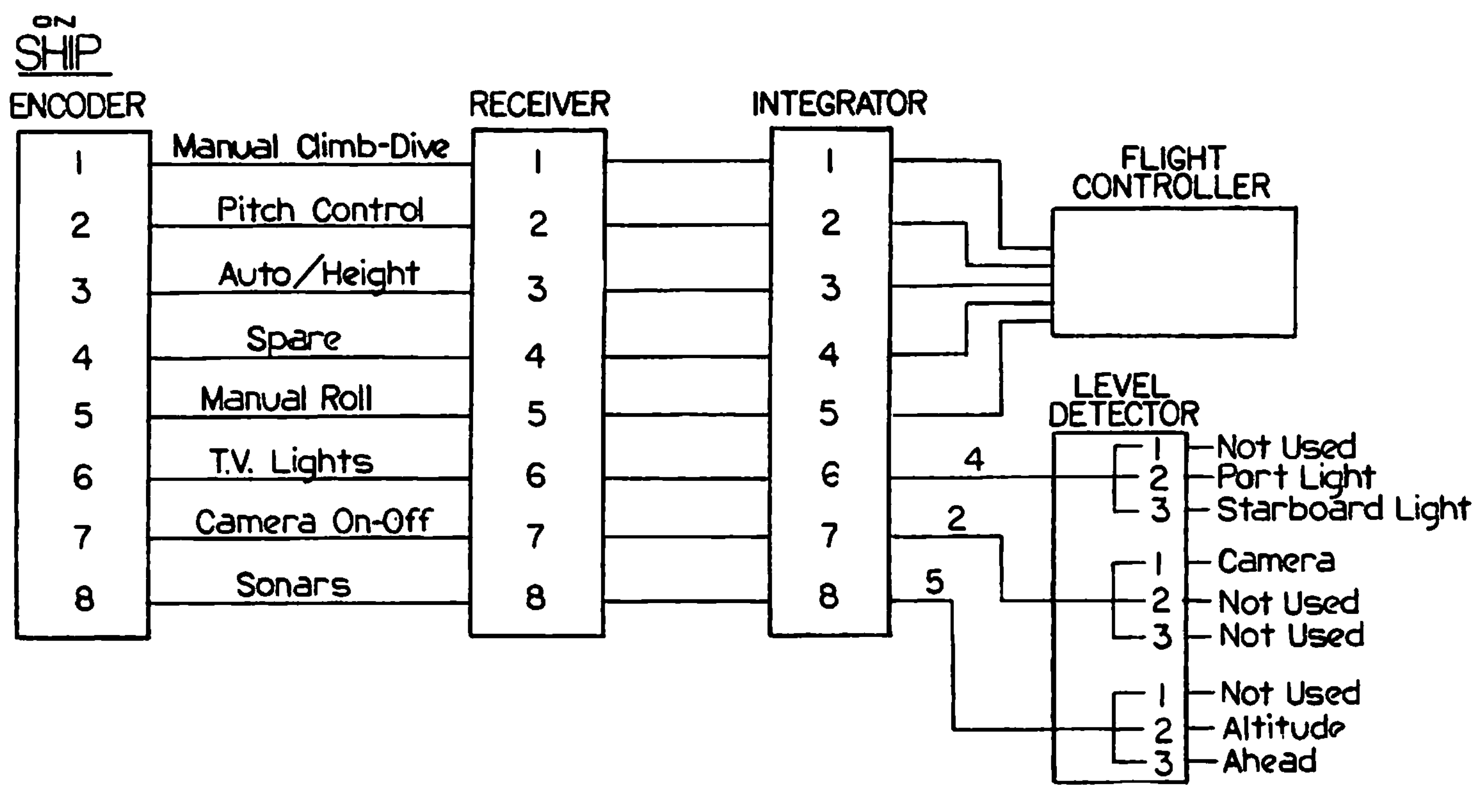
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
LIGHT INDICATING SYSTEM FOR SWITCHING FROM BANG-BANG TO MANUAL AUTOMATIC MODE	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
12-4-73	Dr. No. IET73-114



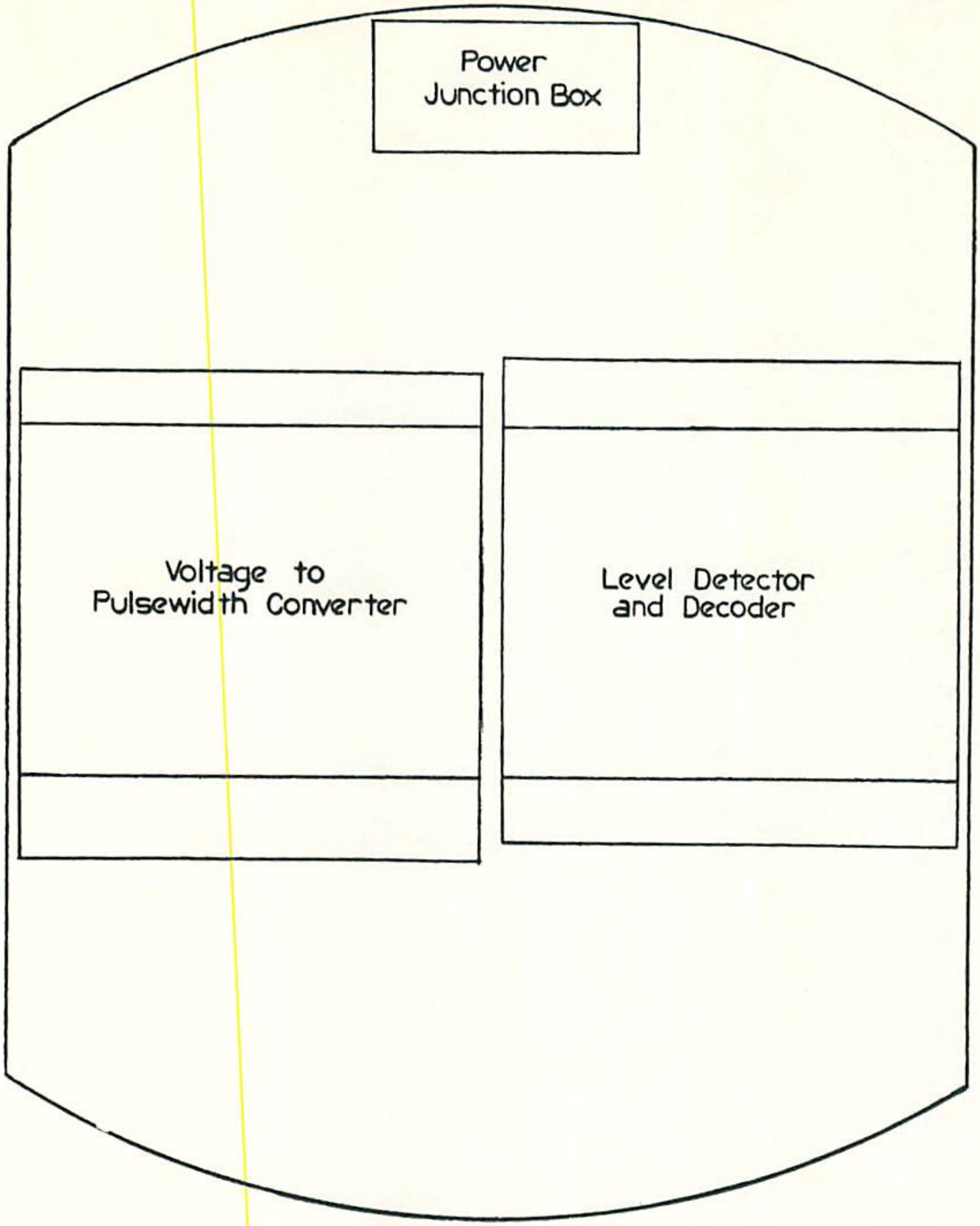
MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
MODIFICATION TO T.V. POWER SUPPLY (FOCUS CONTROL)	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
11 – 1 – 73	Dr. No. IET73-115



MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
UPLINK TELEMETRY SIGNAL FLOW	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
1-14-74	Dr. No.: IET73-116



MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
DOWNLINK TELEMETRY SIGNAL FLOW	
Dr. By Major L. Nimock	
Ck. By M.F.J.	App. By R.D.B.
1-18-74	Dr. No. IET73-117

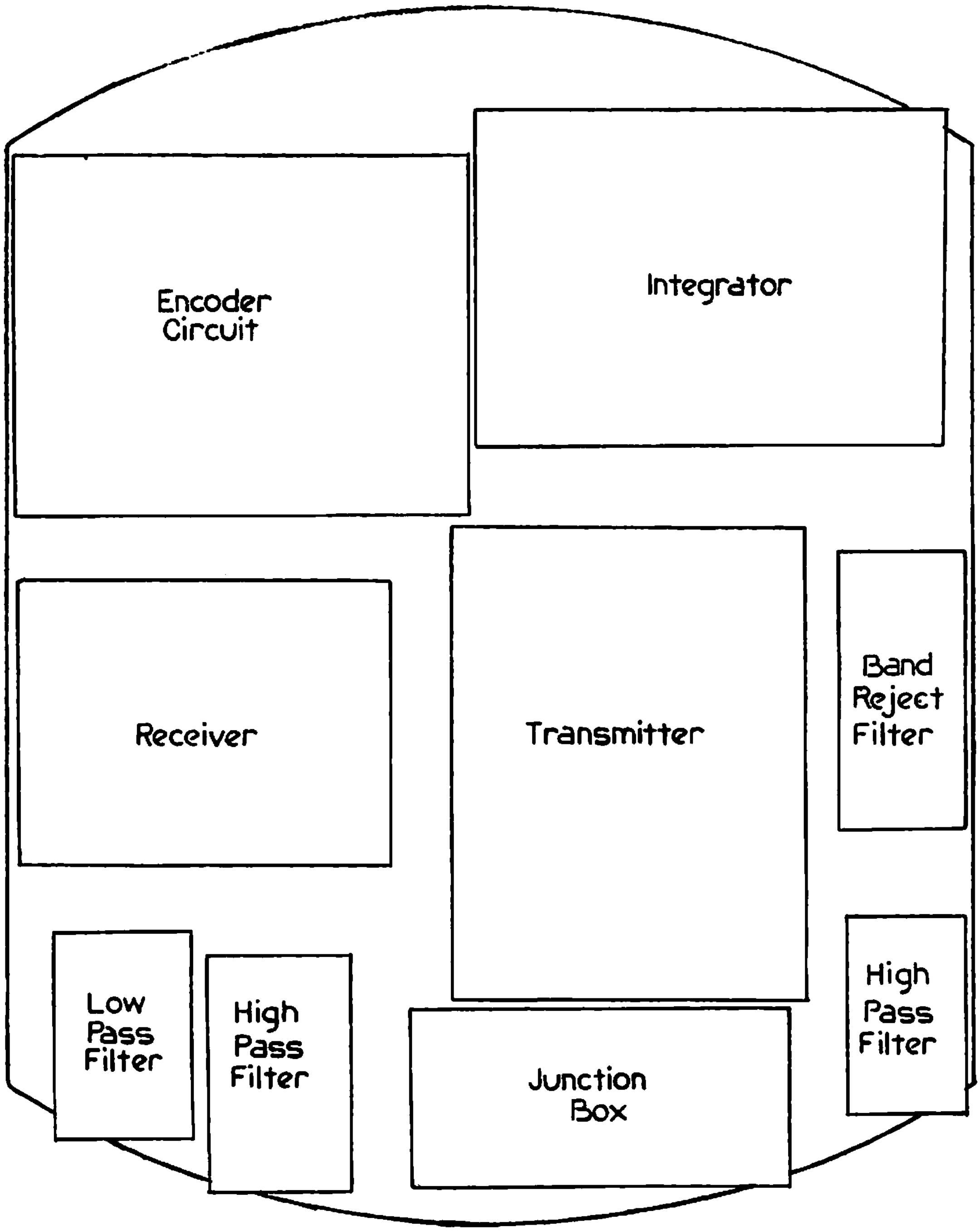


MISSISSIPPI STATE UNIVERSITY
INSTITUTE OF ENGINEERING TECHNOLOGY

RUFAS TELEMETRY SHELF
(Underside)

Dr. By: Major L. Nimock

1 - 23 - 74	Dr. No. IET73 - 118

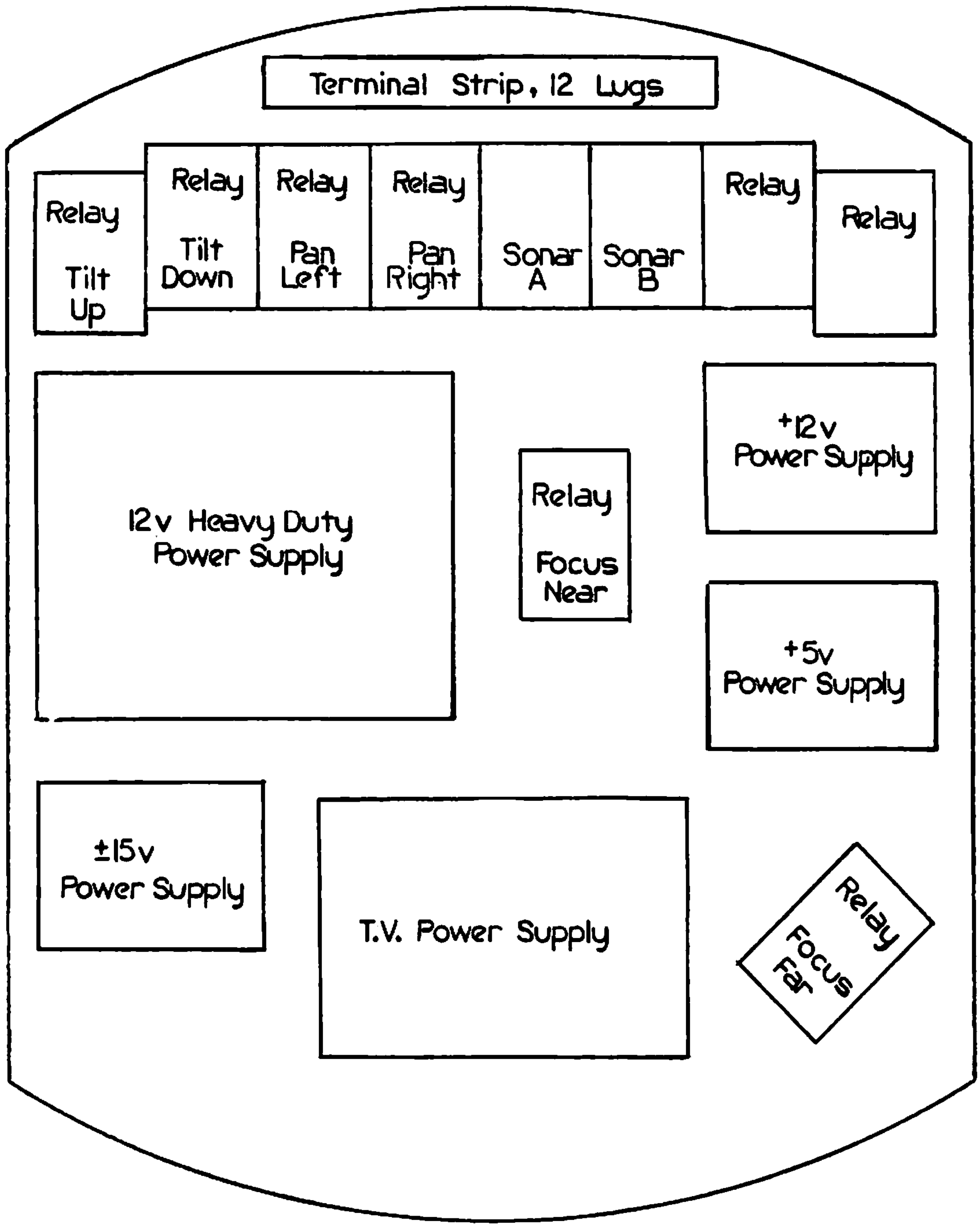


MISSISSIPPI STATE UNIVERSITY
INSTITUTE OF ENGINEERING TECHNOLOGY

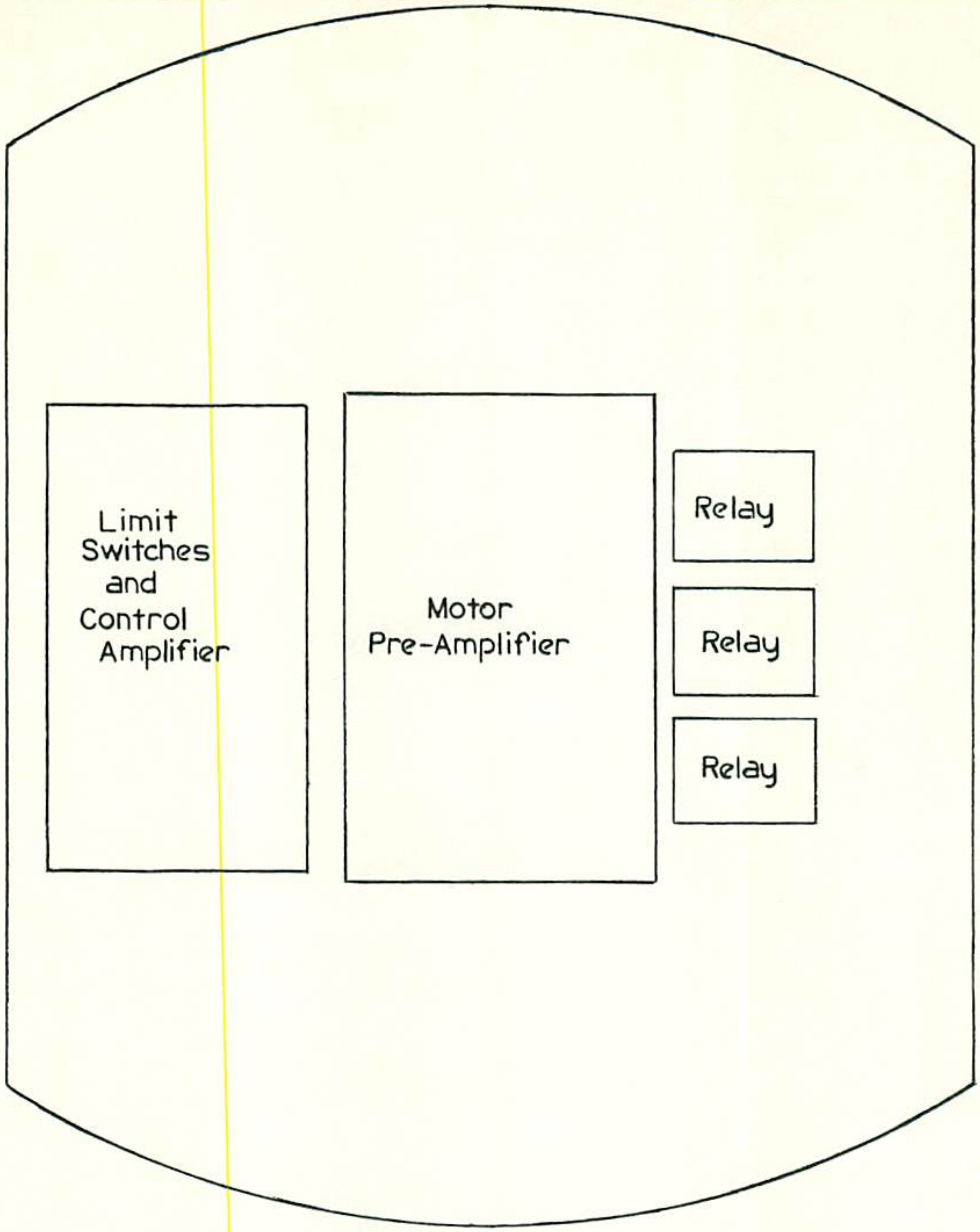
RUFAS TELEMETRY SHELF
(Top)

Dr. By Major L. Nimock

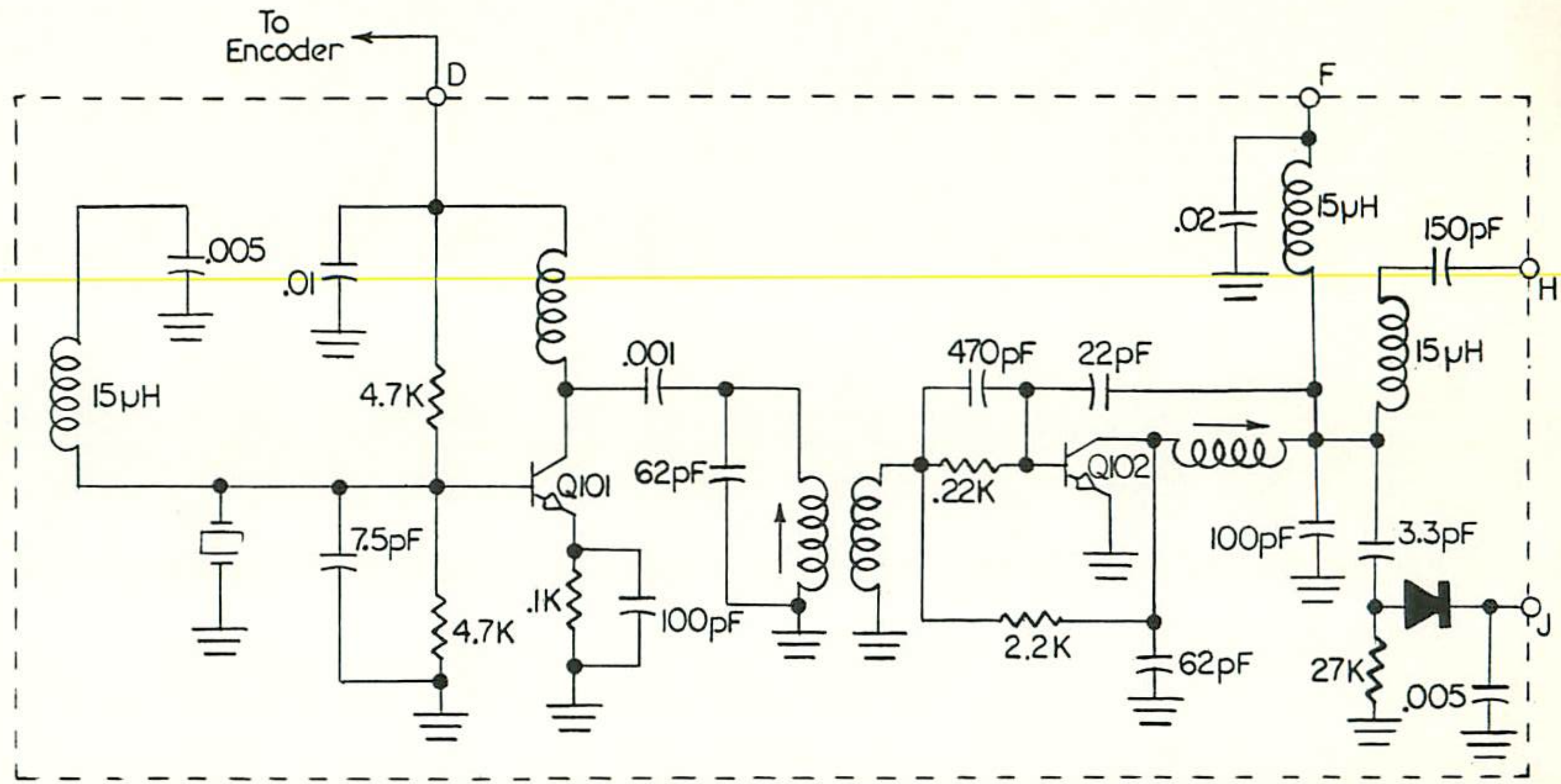
1 - 21 - 74	Dr. No. IET73 - 119



MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
RUFAS POWER SUPPLY SHELF	
Dr. By: Major L. Nimock	
1 - 21 - 74	Dr. No. IET73-120

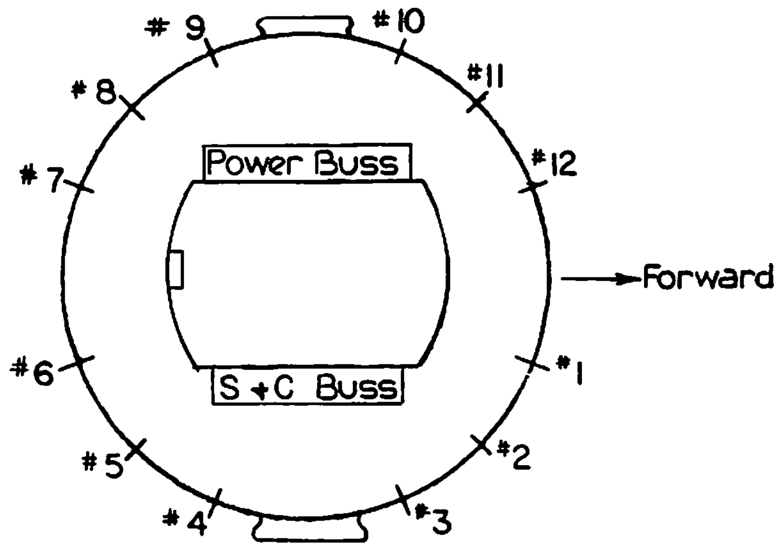


MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
CLIMB-DIVE MOTOR SHELF	
Dr. By: Major L. Nimock	
1 - 21 - 74	Dr. No. IET73-121



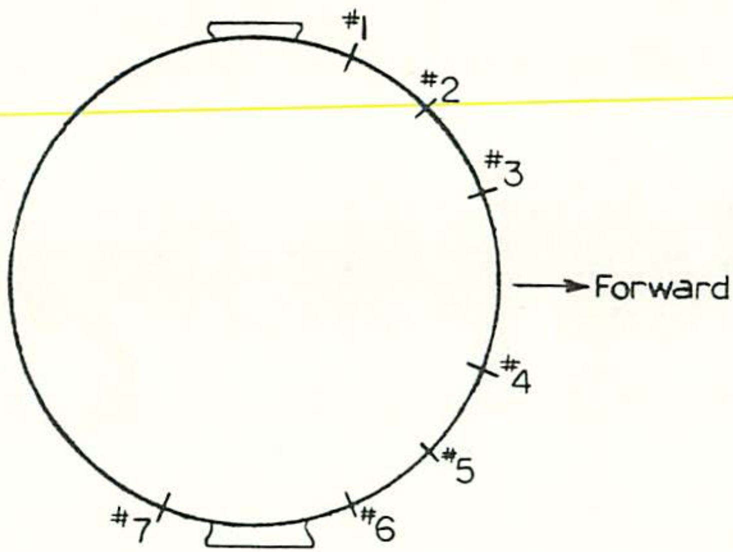
NOTES
1. Capacitor values less than 1 are in μF.
2. Point "D" connects to point "R" on Encoder.
3. Point "H" is an output.
4. Point "J" connects to meter.

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
RF TRANSMITTER	
Dr. By Major L. Nimock	
Ck. By M.F.J.	App. By R.D.B.
2 - 6 - 74	Dr. No. IET73 - 122



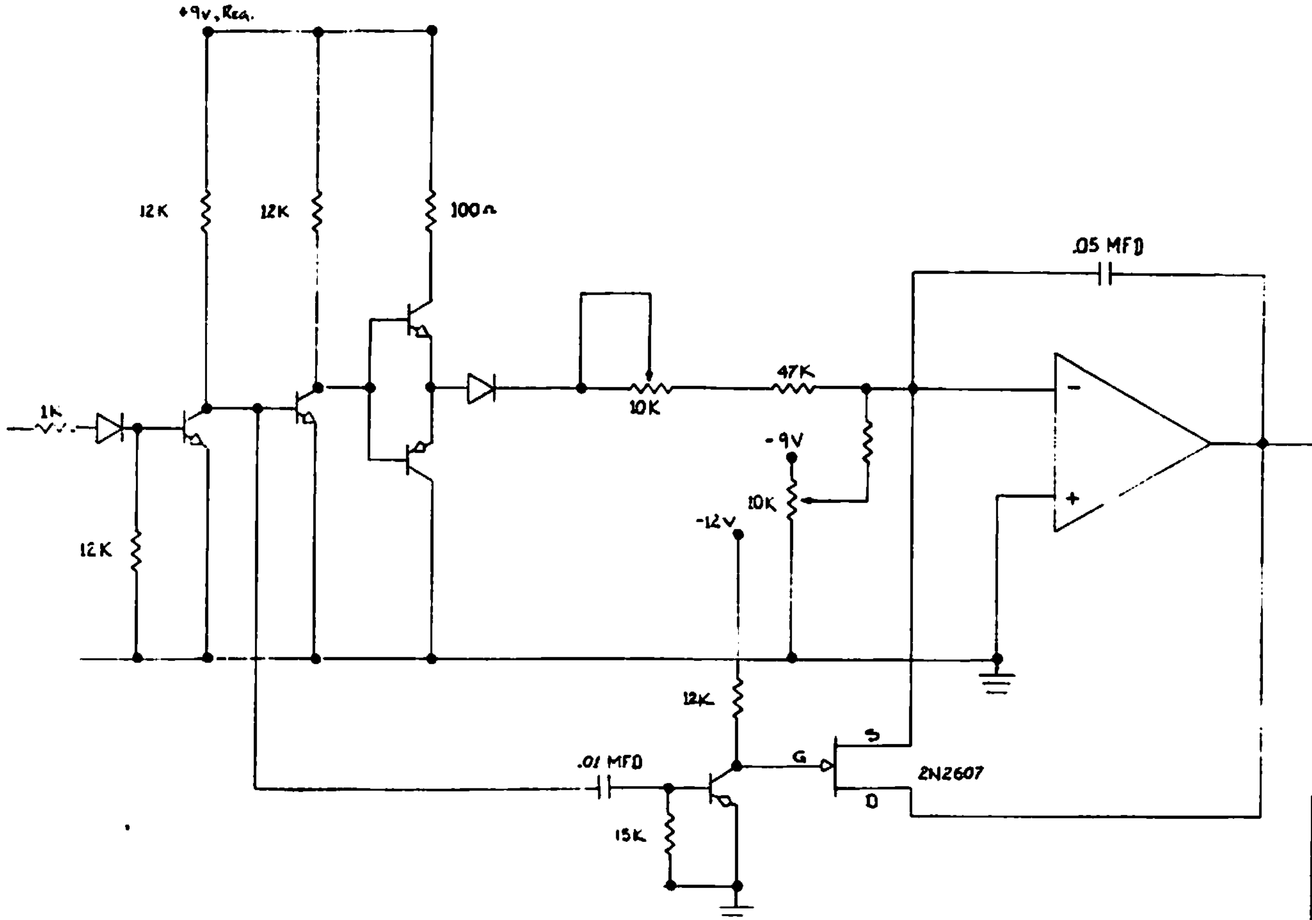
1. Pan Motor (TV)
2. Tilt Motor (TV)
3. Spare
4. 115vAC. and ØLL (Big 4-pin Plug)
5. Down Sonar (Coax)
6. Control Signals for TV Lights & Camera
7. Telemetry (Coax)
8. Field Supply & Vane Feedback Pots
9. Armature of Roll & Dive Motors
10. +28v Power
11. TV
12. Forward Sonar (Coax)

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
ELECTRONIC SPHERE PENETRATORS	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
2 - 12 - 74	Dr. No. IET73 - 123



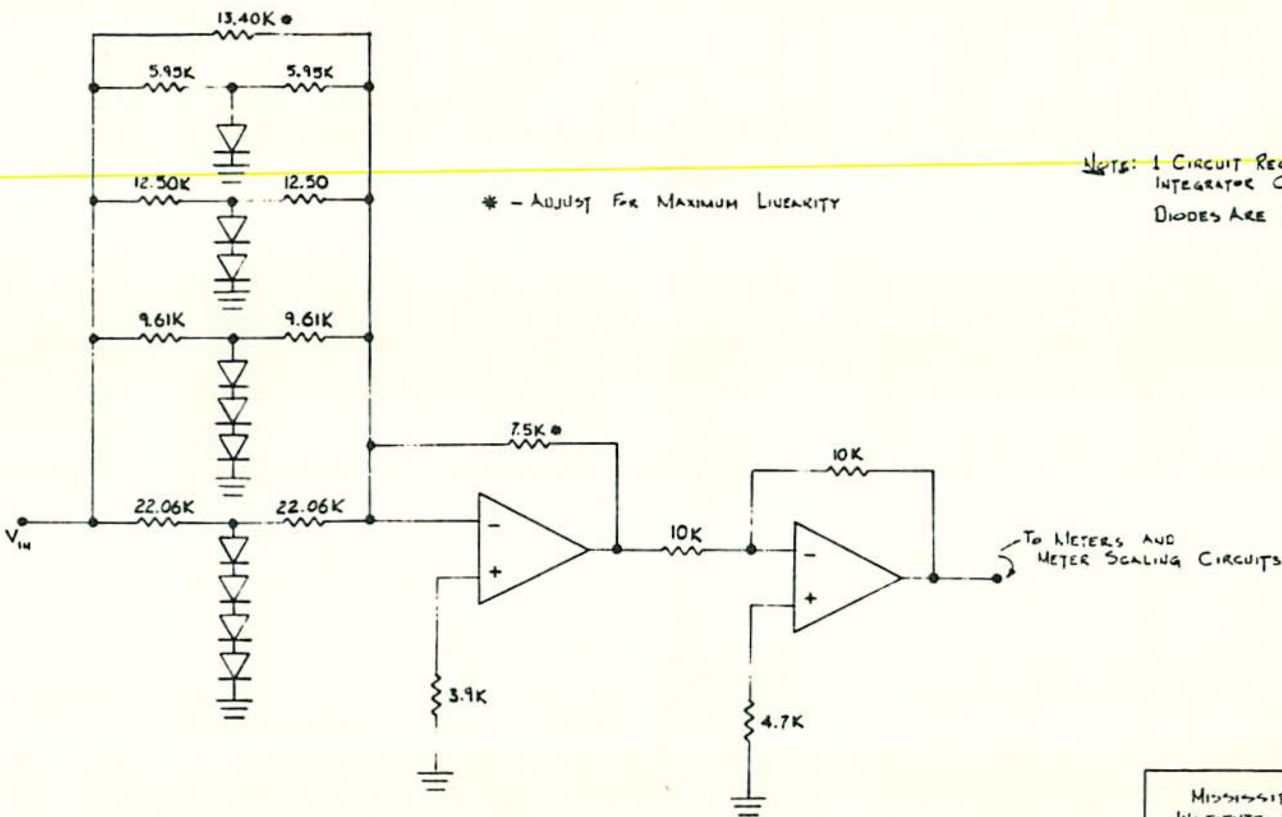
#1. TV Light (Left Side)
2. 3 Phase A.C. Power
3. Strobe Power
4. Control Signals (TV Lights and Movie Camera) from Electronic Sphere
5. +28v D.C. Power to Electronic Spere
6. TV Light (Right Side)
7. Spare

MISSISSIPPI STATE UNIVERSITY INSTITUTE OF ENGINEERING TECHNOLOGY	
CAMERA SPHERE PENETRATORS	
Dr. By: Major L. Nimock	
Ck. By: M.F.J.	App. By: R.D.B.
2 - 12 - 74	Dr. No. IET73 - 124



Note:
All Resistors 5%, ½ Watt
All PNP Transistors Are 2N3906
All NPN Transistors Are 2N3904
All Diodes Are 1N914
(Unless Otherwise Specified)

Mississippi State University Institute Of Engineering Technology	
Pulse Width Demodulator	
Dr. By: Major L. Nimock	
Ck'd By: Martin F. Jue	
App'd By: Richard D. Benton	
Date 4-10-73	Dr. No. IET73-201



* – Adjust for Maximum Linearity

Note: 1 Circuit Required at Each Integrator Output on Console (8 Total)

Diodes Are 1N914

Mississippi State University Institute of Engineering Technology	
Linearizer Circuit	
Drawn By: Major L. Nimock	
Ck'd. By: M. F. Jue	App'd. By: R.D. Benton
9-21-73	Dr. No. IET73-202