

R. Lawson

AC SPARK PLUG DIVISION
General Motors Corporation
Milwaukee, Wisconsin

XDE

34-S-12

ENGINEERING
DESIGN INFORMATION
EXHIBIT

PRELIMINARY PERFORMANCE SPECIFICATION - APOLLO
INERTIAL SUBSYSTEM POWER SUPPLIES - BLOCK II

By
L. Gompert

Date
1/22/65

1. SCOPE

1.1 This specification establishes the preliminary performance requirements for the Block II Inertial Subsystem Power Supplies for the Apollo G and N System, hereafter called ISS Power Supplies. Those included are the Pulse Torque Power Supply, the Minus 28 VDC Power Supply, the 800 cps 1% Power Supply, the 800 cps 2.5% Power Supply, and the 3.2 K cs 1% Power Supply.

2. APPLICABLE DOCUMENTS

2.1 The following documents shall form a part of this specification to the extent specified herein. Unless otherwise specified herein, the latest issue in effect shall apply.

SPECIFICATIONS

NASA Drawings (issued by MIT)

2010015	Schematic, Pulse Torque Power Supply
2010003	Schematic, Minus 28 VDC Power Supply
2010009	Schematic, 800 cps AAC, Filter and Multivibrator
2010008	Schematic, 800 cps 1% Amplifier
2010007	Schematic, 800 cps 2.5% Amplifier
2010012	Schematic, 3200 cps AAC, Filter and Multivibrator
2010006	Schematic, 3200 cps 1% Amplifier

Procurement Specifications

PS-2007106	Pulse Torque Power Supply
PS-2007107	Minus 28 VDC Power Supply
PS-2007112	800 cps AAC Filter
PS-2007110	800 cps 1% Amplifier
PS-2007111	800 cps 2.5% Amplifier
PS-2007109	3200 cps AAC Filter
PS-2007108	3200 cps 1% Amplifier

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OTHER DOCUMENTS

ACSP, NAA, and NASA

DD Memo 185	Apollo Guidance Computer - Electrical Interface Document
MH	Interface Control Document - G and N Electrical Input Power
MH	Interface Control Document - Thermal Requirements
ND	NASA Document - Environmental Requirements

3. REQUIREMENTS

3.1 GENERAL. - The ISS Power Supplies shall meet their performance requirements under the conditions specified herein. These power supplies consist of modules and their associated interconnect wiring.

3.1.1 SERVICE CONDITIONS

3.1.1.1 ELECTRICAL INPUTS

3.1.1.1.1 DC POWER SOURCE. - The ISS power supplies are operated from the spacecraft primary 28 VDC power system, reference MH . The prime power may be supplied from fuel cells, re-entry batteries, or recovery batteries. Values given here are sensed on the input side of the isolation diodes. Prime power will be supplied to the 3.2 K cs power supply during both Standby and Operate modes of the ISS, while it will be supplied to all other power supplies during the Operate mode only. Characteristics of the spacecraft prime DC power are as follows:

- (a) The steady state voltage limits shall be between 26.8 and 29.8 volts DC.
- (b) The transient voltage limits shall be between 25.8 and 31.8 volts DC.
- (c) Power required by the supplies covered in this performance requirement is 190 watts nominal. The supplies are approximately 62% efficient.
- (d) The nominal voltage shall be 28.3 VDC.

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3.1.1.1.2 GUIDANCE REFERENCE CLOCK INPUTS. - Each power supply shall meet its requirements with the guidance reference clock synchronization pulses. These pulses are supplied by the Apollo Guidance Computer (AGC) and have the following characteristics at the ISS-AGC interface.

- a. PULSE AMPLITUDE - Plus 7 V \pm 3 V
- b. DROOP - Less than 20% at 2 usec point
- c. BACKSWING - Less than 4 V
- d. PULSE WIDTH (Half Amplitude) - 3 \pm .5 microseconds
- e. RISE TIME (10-90%) - Less than 0.5 microseconds
- f. FALL TIME (10-90%) - Depends upon load used. It shall be similar to the rise time.
- g. NOISE -
 - (1) The noise impressed on the pulse shall not exceed an amplitude of 3 V.
 - (2) Ripple or spikes during the absence of a pulse shall be less than 0.2 V peak to peak.
- h. FREQUENCY - As listed below for each power supply to within \pm 0.5 ppm (parts per million):
 - (1) 12.8 K pps, zero phase shall be supplied to the Minus 28 VDC Power Supply and to the Pulse Torque Power Supply.
 - (2) 800 pps zero and pi phase shall be supplied to the 800 cps 1% Power Supplies.
 - (3) 3.2 K pps at phases of 0°, 90°, 180°, and 270° shall be supplied to the 3.2 K cs microsynchron excitation power supply.
- i. IMPEDANCE - 510 ohms plus line impedance for each clock pulse signal load.

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<p>3.1.1.1.3 ENVIRONMENTAL REQUIREMENTS. - The environmental requirements shall be specified in ND . All the ISS power supplies shall meet their performance requirements while in the system configuration. Interface Control Document MH applies for the thermal interfaces. Ambient room temperature shall be $77 \pm 18^{\circ}$ F ($25 \pm 10^{\circ}$ C).</p> <p>3.1.1.1.4 LIFE</p> <p>a. OPERATING. - The ISS power supplies shall meet their performance specifications for at least 2000 hours of operation, excluding the suppliers test time of the completed unit.</p> <p>b. SHELF. - The ISS power supplies shall have a shelf life after final acceptance of at least 5 years without operation, at an ambient room temperature of $77^{\circ} \pm 18^{\circ}$ F.</p> <p>c. STORAGE. - There are no applicable requirements.</p> <p>3.2 PULSE TORQUE POWER SUPPLY. - The Pulse Torque Power Supply shall provide outputs of plus 120 VDC, plus 28 VDC, plus 20 VDC and minus 20 VDC. It shall meet the requirements of this section while in the system configuration.</p> <p>3.2.1 PLUS 120 VDC PULSE TORQUE SUPPLY OUTPUT</p> <p>3.2.1.1 VOLTAGE. - Plus 120 VDC $\pm 3\%$.</p> <p>3.2.1.2 REGULATION. - $\pm 1\%$ over rated input and load variations.</p> <p>3.2.1.3 NOISE. - 0.5 volts maximum peak-to-peak over a bandwidth of at least 0 to 350 K cs.</p> <p>3.2.1.4 LOAD. - 56.4 watts nominal. 54 watts minimum to 68.5 watts maximum with a line impedance of _____.</p> <p>3.2.2 PLUS 28 VDC PULSE TORQUE SUPPLY OUTPUT</p> <p>3.2.2.1 VOLTAGE. - Plus 28 VDC $\pm 5\%$. There are three (3) such outputs.</p>		
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<p>3.2.2.2 REGULATION. - $\pm 1\%$ over rated input and load variations.</p> <p>3.2.2.3 NOISE. - 0.2 volts maximum peak-to-peak over a bandwidth of at least 0-350 K cs.</p> <p>3.2.2.4 LOAD. - 0.56 watts nominal. 0.25 watts minimum to _____ watts maximum with a line impedance of _____. There are three (3) such loads.</p> <p>3.2.3 PLUS 20 VDC PULSE TORQUE SUPPLY OUTPUT</p> <p>3.2.3.1 VOLTAGE. - Plus 20 VDC $\pm 5\%$.</p> <p>3.2.3.2 REGULATION. - $\pm 1\%$ over rated input and load variations.</p> <p>3.2.3.3 NOISE. - 0.2 volts maximum peak-to-peak over a bandwidth of at least 0-350 K cs.</p> <p>3.2.3.4 LOAD. - 2.6 watts nominal. 2 watts minimum to 3 watts maximum with a line impedance of _____.</p> <p>3.2.4 MINUS (-) 20 VDC PULSE TORQUE SUPPLY OUTPUT</p> <p>3.2.4.1 VOLTAGE. - Minus (-) 20 VDC $\pm 5\%$.</p> <p>3.2.4.2 REGULATION. - $\pm 5\%$ over rated input and load variations.</p> <p>3.2.4.3 NOISE. - 0.5 volts maximum peak-to-peak over a bandwidth of at least 0-350 K cs.</p> <p>3.2.4.4 LOAD. - 0.4 watts nominal. 0.125 watts minimum to _____ watts maximum with a line impedance of _____.</p> <p>3.3 MINUS (-) 28 VDC POWER SUPPLY. - The Minus 28 VDC Power Supply shall meet the requirements of this section while in the system configuration.</p> <p>3.3.1 VOLTAGE. - Minus (-) 27.0 VDC ± 4.5 VDC over rated input and load variations.</p>		
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<p>3.5.2.1 PHASE B. - Minus (-) $90^\circ \pm 12^\circ$ from the synch pulse and minus (-) $90^\circ \pm 3^\circ$ from the 1% 800 cps amplifier output.</p> <p>3.5.2.2 PHASE A. - Minus (-) $180^\circ \pm 15^\circ$ from the clock synch pulse or minus (-) $90^\circ \pm 3^\circ$ from phase A.</p> <p>3.5.3 FREQUENCY. - Same as 1% amplifier.</p> <p>3.5.4 HARMONIC DISTORTION</p> <p>3.5.4.1 PHASE B HARMONIC DISTORTION. - 4% maximum.</p> <p>3.5.4.2 PHASE A HARMONIC DISTORTION. - 6% maximum.</p> <p>3.5.5 LOAD</p> <p>3.5.5.1 PHASE B LOAD. - 17.6 watts nominal. _____ watts minimum to _____ watts maximum including load power factor compensation. The line impedance shall be _____.</p> <p>3.5.5.2 PHASE A LOAD. - 22.6 watts nominal. _____ watts minimum to _____ watts maximum with a line impedance of _____.</p> <p>3.6 28 V 3.2 K cs POWER SUPPLY. - The 3.2 K cs power supply shall meet the requirements of this section.</p> <p>3.6.1 VOLTAGE. - 28.5 VAC $\pm 2\%$ at the feedback side. (28.6 VAC ref. at supply).</p> <p>3.6.2 FREQUENCY. - 3.2 K cs ± 0.5 ppm.</p> <p>3.6.3 HARMONIC DISTORTION. - 1% maximum.</p> <p>3.6.4 PHASE. - The 3.2 K cs feedback voltage from the IMU shall be 28.5 VAC $\pm 2\%$ at $+0.8^\circ \pm 0.5^\circ$ with respect to the synch pulse.</p> <p>3.6.5 LOAD. - 4.3 watts nominal. 3.5 watts minimum to 4.9 watts maximum including load compensation. The line impedance shall be _____.</p>		
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4. QUALITY ASSURANCE PROVISIONS

4.1 GENERAL. - The ISS power supply test requirements specified in this section shall be considered sufficient to verify the performance requirements specified in section 3. Performance requirements not explicitly verified by test shall be considered inherent performance by design and demonstrated at breadboard level testing, or by prior compliance to quality assurance provisions at a lower level. The performance requirements shall be tested with the power supply in the Inertial Subsystem configuration.

4.2 INPUTS

4.2.1 DC POWER SOURCE. - The DC power source shall meet the requirements of section 3.1.1.1.1. The operating characteristics of each power supply shall be tested for nominal input voltage, 28.3 VDC.

4.2.2 CLOCK SYNCHRONIZATION PULSES. - The synchronization pulses shall meet the requirements of section 3.1.1.1.2

4.3 ISS POWER SUPPLIES OPERATING CHARACTERISTICS

4.3.1 PULSE TORQUE POWER SUPPLY. - Each output shall be measured with nominal input voltage and nominal load. The output voltage and noise for each output shall be:

<u>Voltage</u>	<u>Voltage Tolerance</u>	<u>Noise</u>
120 VDC	± 2.4 VDC	0.5 V p-p max
28 VDC	± .8 VDC	0.2 V p-p max
20 VDC	± .55 VDC	0.2 V p-p max
-20 VDC	± .8 VDC	0.5 V p-p max

Noise shall be peak-to-peak voltage measured over a bandwidth of 0 to 350 K cs.

4.3.2 MINUS 28 VDC POWER SUPPLY. - The output shall be measured with nominal input voltage and at nominal load. The output voltage shall be minus 27.0 VDC ± 1.0 VDC, and the impressed noise voltage (including ripple) shall be less than 3.0 volts peak-to-peak over a bandwidth of 0 to 350 K cs.

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<p>4.3.3 28 V 800 CPS 1% POWER SUPPLY. - The output shall be measured with nominal input voltage and nominal load while receiving synch input pulses. The output shall be:</p> <ul style="list-style-type: none"> a. Voltage 28.0 ± 0.28 VAC b. Frequency 800 ± 0.0004 cps c. Phase (with respect to synch pulse) $0^\circ \pm 9^\circ$ <p>4.3.4 28 V 800 CPS 2.5% POWER SUPPLIES. - The output of each power supply shall be measured with nominal input voltage and nominal load.</p> <p>4.3.4.1 PHASE B SUPPLY</p> <ul style="list-style-type: none"> a. Voltage 28.0 ± 1.0 VAC b. Phase (with respect to synch pulse) $-90^\circ \pm 12^\circ$ <p>4.3.4.2 PHASE A SUPPLY</p> <ul style="list-style-type: none"> a. Voltage 28.0 ± 1.7 VAC b. Phase (with respect to synch pulse) $-180^\circ \pm 15^\circ$ <p>4.3.5 28 V 3.2 K CS POWER SUPPLY. - The feedback voltage shall be measured with nominal input voltage and nominal load and shall be:</p> <ul style="list-style-type: none"> a. Voltage 28.5 ± 0.4 VAC b. Frequency 3200 ± 0.0016 cps c. Phase (with respect to synch pulse) $+0.8^\circ \pm 1/2^\circ$ 									
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<p>5. PREPARATION FOR DELIVERY. - Not applicable to this specification.</p> <p>6. NOTES</p> <p>6.1 INTENDED USE</p> <p>6.1.1 PULSE TORQUE POWER SUPPLY. - The Pulse Torque Power Supply provides minus (-) 20 VDC to the PIPA loops and plus 20 VDC to the PIPA and Gyro loops. It provides plus 120 VDC to the PIPA and Gyro loops, and individual plus 28 VDC outputs to the X PIPA PVR, the Y PIPA PVR, and the Z PIPA PVR.</p> <p>6.1.1.1 DESCRIPTION OF OPERATION. - The 120 VDC and 28 VDC outputs are derived from a multivibrator, a power amplifier and a rectifier and filter. The plus 20 VDC and the minus 20 VDC outputs are derived directly from the plus 28 VDC prime power and from the minus 27.5 VDC power.</p> <p>A 12.8 K pps synchronizing signal from the AGC reference clock is supplied to an amplifier-inverter, see figure 1. The output of the inverter is applied to a multivibrator-chopper causing it to be synchronized at 6.4 K cs. The multivibrator-chopper drives the primary of a transformer which has 28 VDC prime power applied to its center tap. The secondary of the transformer is also center tapped and is coupled to a darlington connected push pull power amplifier stage. The output of this amplifier consists of a transformer having four secondaries; one with center tap return for the 120 VDC output and one each for the X, Y, and Z PIPA 28 VDC PVR supplies. The 120 VDC output is filtered, regulated and again filtered. The 28 VDC outputs are identical in design to each other. They are derived from a full wave bridge rectifier whose output is filtered regulated and again filtered. There is a turn-on time delay circuit for the 120 V and 28 VDC outputs. It controls the operation of the multivibrator chopper. There is an additional turn-on time delay for each 28 VDC output.</p> <p>The 28 VDC prime power is applied to a regulator and filter to provide the plus 20 VDC output. The minus 27.5 VDC power input is applied to a 20 V \pm 5% voltage reference zener to provide the minus 20 VDC output.</p>		
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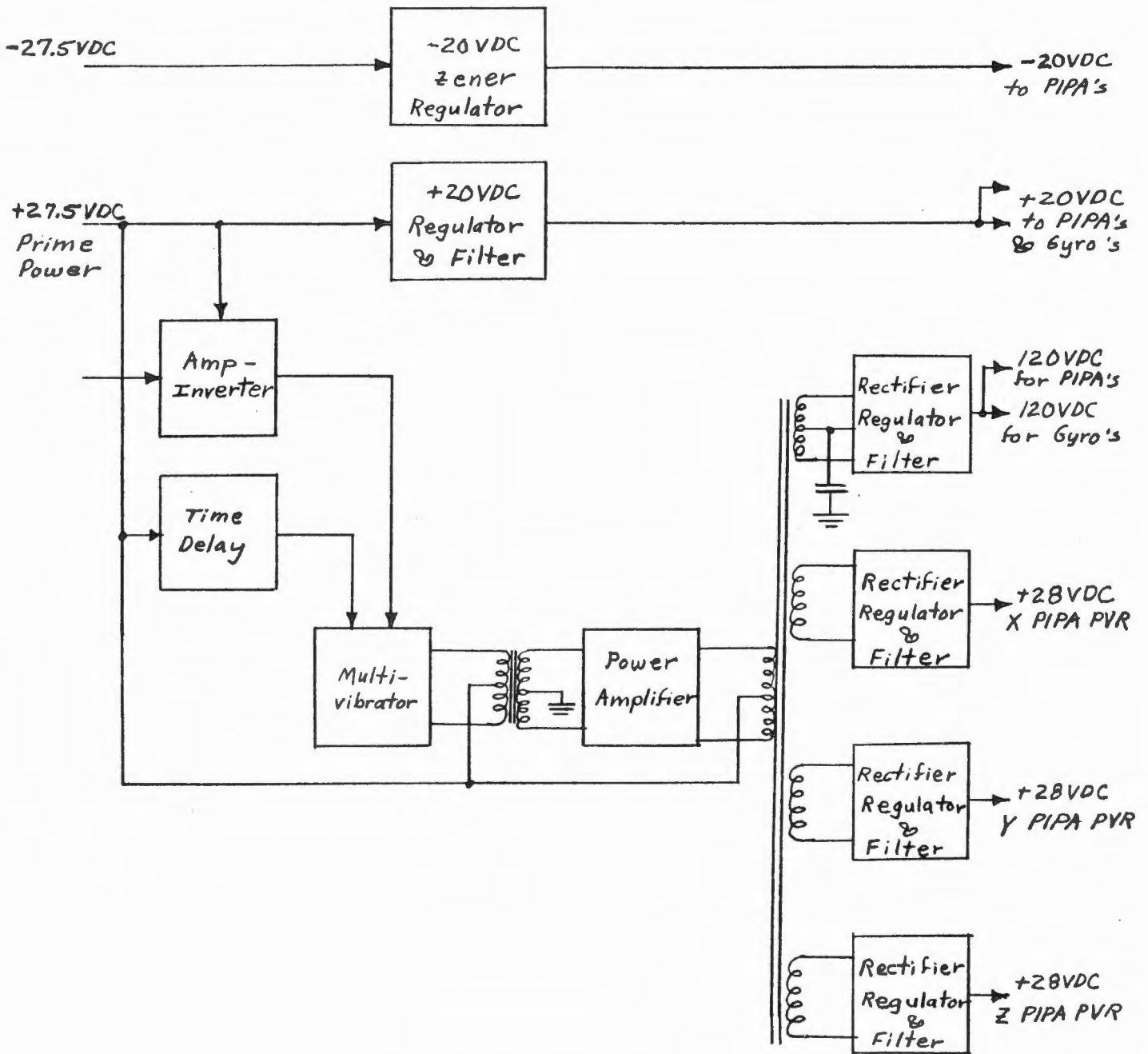


Figure 1
Block Diagram
PULSE TORQUE POWER SUPPLY

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6.1.2 MINUS (-) 28 VDC POWER SUPPLY. - This supply provides 28 VDC to the three gimbal servo amplifiers, the three coarse align amplifiers, and the three AC differential amplifiers. The block diagram for this power supply is shown in figure 2.

6.1.2.1 DESCRIPTION OF OPERATION. - The 12.8 K pps clock synchronization pulse input is amplified and inverted, and used to synchronize a multivibrator-chopper at 6.4 K cs. The multivibrator-chopper consists of a low output impedance multivibrator used to drive the primary of a transformer which has 28 VDC applied to its center tap. The secondary of the transformer is also center tapped and is coupled to a darlington connected push-pull power amplifier stage. The output of this amplifier is transformer coupled to a full wave rectifier and filter with the positive side referenced to ground to provide a minus 27.5 VDC output.

6.1.3 800 CPS POWER SUPPLIES. - The 800 cps 1% supply provides IMU and CDU resolver excitation, demodulator reference and FDAI and Auto Pilot reference. The 800 cps 2.5% supplies provide Gyro wheel excitation, IMU Blower excitation and PIPA fixed heat. There is one 800 cps 1% zero phase supply, and two 800 cps 2.5% minus 90° phase supplies. The 800 cps 1% supply provides the input to one 800 cps 2.5% supply whose output is shifted minus 90°. This output is applied to the second 2.5% amplifier whose output is shifted minus 90° from its input, or minus 180° from the 800 cps 1% supply voltage. The 800 cps 2.5% amplifiers are identical. The block diagram for these supplies is shown in figure 3.

6.1.3.1 800 CPS 1% SUPPLY - DESCRIPTION OF OPERATION. - The 800 cps 1% Supply consists of an automatic amplitude control circuit (AAC), a multivibrator, and 800 cps filter, and a 1% power amplifier. The output of the 800 cps filter is applied to the transformer input of the 1% amplifier. The secondary of the input transformer is applied to a darlington push pull input stage which in turn drives a push pull tuned transformer output stage. A portion of the output is fed back to the input for stability and regulation. A portion is also supplied to the AAC where the positive peaks are detected and added to a DC reference. The sum is filtered and provides a DC bias to a multivibrator-driven chopper. The bias controls the amplitude of the chopped signal. The multivibrator is synchronized by zero and pi phase clock signal inputs and will free run at 700 cps to 790 cps. The 800 cps chopped signal is passed through an 800 cps filter whose output is the input to the 1% amplifier.

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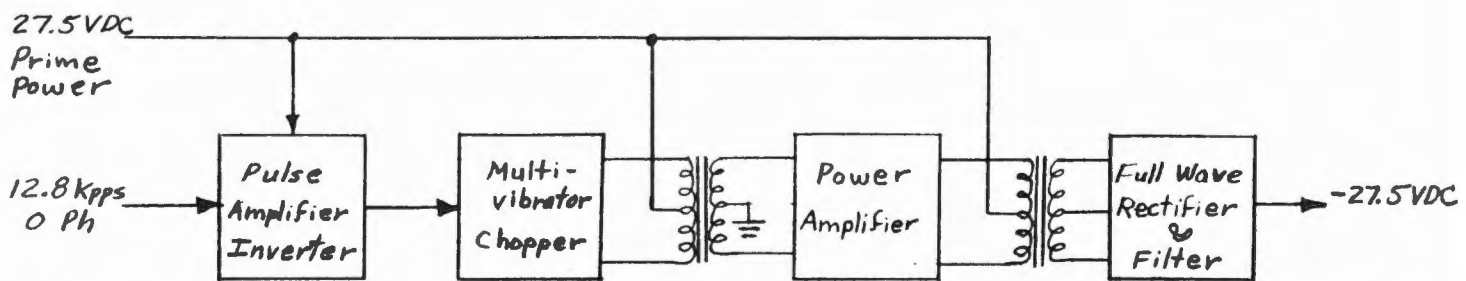


Figure 2
Block Diagram
MINUS 28 VDC POWER SUPPLY

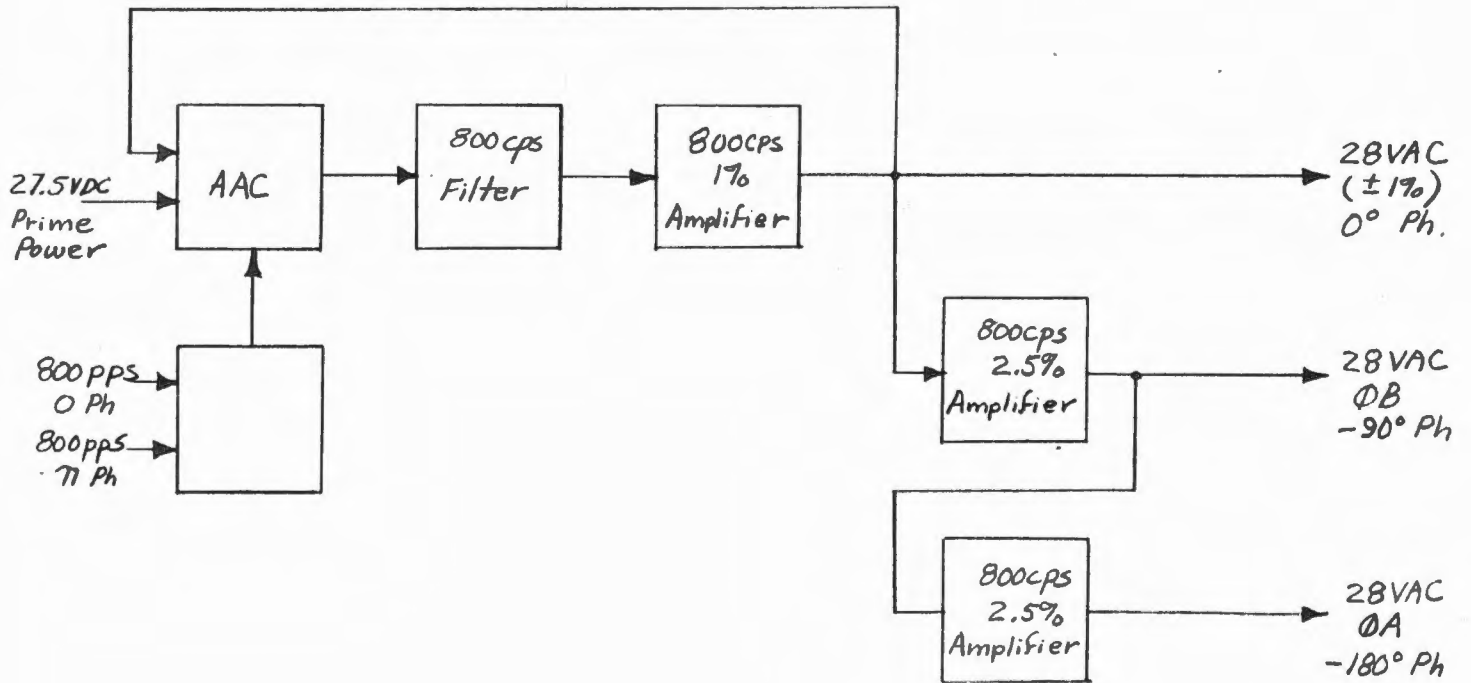


Figure 3
Block Diagram
800 CPS POWER SUPPLY

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6.1.3.2 800 CPS 2.5% AMPLIFIER - DESCRIPTION OF OPERATION. - The input transformer of the 800 cps 2.5% amplifier serves as an in-phase and an out-of-phase mixing point for two portions of the input signal and a feedback signal, and has its primary center tap at signal low. One portion of the input signal is applied to the in-phase side of the transformer and a feedback signal is applied to the out-of-phase side of the transformer. A second portion of the input signal is also applied through a phase shifting capacitor to the out-of-phase side of the transformer. At the cut-off frequency of the phase shifting capacitor the second portion of the input signal starts to become appreciable and, together with the in-phase component of the input signal, provides an output signal shifted minus 90°. This is set to occur at 800 cps. At a higher frequency the capacitor becomes a short, and the out-of-phase input predominates causing the output to have a minus 180° phase shift. The amplifier stage is a darlington connected push-pull amplifier working into an output transformer tuned for 800 cps.

6.1.4 3.2 K CS POWER SUPPLY. - The 3.2 K cps power supply provides excitation voltage to the Gyro and PIPA ducosyn suspension coils and to the Gyro and PIPA signal generators. It also has a failure detector load and the load of its own AAC and phase lock circuits. The power supply consists of an Automatic Amplitude Control (AAC), a multivibrator, a chopper, and a filter circuit supplying a 1% amplifier. A phase lock circuit consists of a multivibrator, phase discriminator, differential amplifier, and amplitude controlled DC error source. It controls a variable inductor in the filter above to provide phase lock control. The block diagram for this supply is shown in figure 4.

6.1.4.1 DESCRIPTION OF OPERATION. - The operation of the 3.2 K cs 1% amplifier is similar to the operation of the 800 cps 1% amplifier, see 6.1.4.1. The output is 28 VAC which is transformed to 2 VAC for the PIPA's and 4 VAC for the IRIG's inside the IMU. The feedback point for the AAC is the primary of the stepdown transformer in the IMU. The operation of the 3.2 K cs AAC, multivibrator, and chopper is the same as for the 800 cps supply except that the 3.2 K cs AAC has a transformer input, see 6.1.3.1. The 3.2 K cs filter is similar to the 800 cps filter except that its inductance is controlled by a phase lock circuit to control the phase of the 3.2 K cs signal at the Gyro and PIPA loads. The phase lock circuit consists of a multivibrator synchronized by 3.2 K cs 90° and 270° clock signals. The output of the multivibrator is applied to the primary of a center tapped transformer, and supplies a 90° phase signal to a diode and resistor bridge phase detector. The

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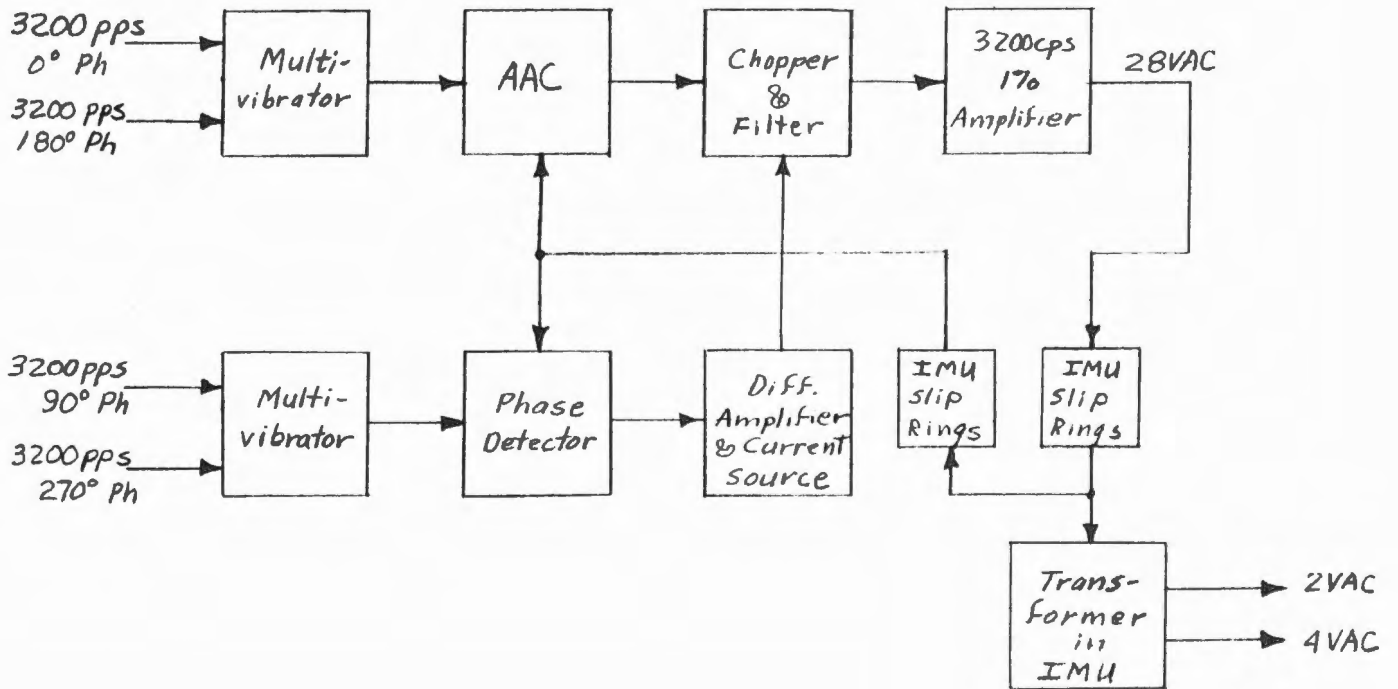


Figure 4
Block Diagram
3200 CPS POWER SUPPLY

<p align="center">AC SPARK PLUG DIVISION General Motors Corporation Milwaukee, Wisconsin</p>	<p>XDE 34-S-12</p>	
<p>PRELIMINARY PERFORMANCE SPECIFICATION - APOLLO INERTIAL SUBSYSTEM POWER SUPPLIES - BLOCK II</p>	<p align="center">ENGINEERING DESIGN INFORMATION EXHIBIT</p>	
	<p>By L. Gompert</p>	<p>Date 1/22/65</p>
<p>feedback signal from the IMU is applied to a second transformer as a second input to the phase detector. The secondaries of each transformer input are center tapped and provide the output terminals for the phase error signal. This error signal is applied to a differential amplifier which in turn controls the DC current output to the variable inductor in the filter section. Consequently, if the phase of the load voltage lags, the DC error current will decrease the 3.2 K cs filter inductance tending to increase the phase of the power supply output.</p> <p>Written by: <u>Leon T. Gompert</u> L. T. Gompert Inertial Subsystem Group Apollo Engineering</p> <p>Approved by: <u>C. J. Sudman</u> C. J. Sudman Inertial Subsystem Group Apollo Engineering</p> <p><u>J. J. Wachholz</u> J. J. Wachholz, Head System's Instrumentation Group Apollo Engineering</p>		
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