

IBM

W. H. Shield, Jr.
Saturn IB/V - Instrument Unit

Technical Manual

MSFC No. III 5-510-14

IBM No. 66-966-0014

Control Signal Processor



MSFC No. III-5-510-14

IBM No. 66-966-0014

TECHNICAL MANUAL

**SATURN IB/V INSTRUMENT UNIT
CONTROL SIGNAL PROCESSOR**

Prepared under Contract

NAS 8-14000

by

International Business Machines Corporation

Federal Systems Division

Huntsville, Alabama

This publication replaces MSFC No. III-5-510-14/IBM No. 66-966-0014 dated 1 March 1966.

15 November 1966
Changed 1 October 1972

INSERT LATEST CHANGED PAGES, DESTROY SUPERSEDED PAGES

LIST OF EFFECTIVE PAGES

NOTE: The portion of the text affected by the changes is indicated by a vertical line in the outer margins of the page.

Page	Issue	Page	Issue
*Title	1 October 1972	2-41	Original
*A	1 October 1972	2-42 Blank	Original
i thru ii Deleted	15 July 68	2-43	Original
iii	Original	2-44 Blank	Original
iv Blank	Original	*2-45	1 October 1972
*1-1	1 October 1972	2-46 Blank	Original
1-2 thru 1-4	15 July 68	3-1	Original
1-5 thru 1-11	Original	3-2 Blank	Original
*1-12	1 October 1972		
1-13	Original		
1-14 Blank	Original		
2-1	15 July 68		
2-2	Original		
*2-3	1 October 1972		
2-4 Blank	Original		
2-5 thru 2-8	15 July 68		
2-9	Original		
*2-10	1 October 1972		
2-11	Original		
2-12	15 July 68		
2-13	Original		
*2-14	1 October 1972		
2-15	15 July 68		
*2-16	1 October 1972		
*2-17	1 October 1972		
2-18 Blank	Original		
*2-19	1 October 1972		
2-20 Blank	Original		
*2-21	1 October 1972		
2-22 Blank	Original		
*2-23	1 October 1972		
2-24 Blank	Original		
*2-25	1 October 1972		
2-26 Blank	Original		
*2-27	1 October 1972		
2-28 Blank	Original		
*2-29	1 October 1972		
2-30 Blank	Original		
*2-31	1 October 1972		
2-32 Blank	Original		
2-33	Original		
2-34 Blank	Original		
2-35	Original		
2-36 Blank	Original		
2-37	Original		
2-38 Blank	Original		
2-39	Original		
2-40 Blank	Original		

* The asterisk indicates pages changed, added, or deleted by the current change.

Original	Revision	Change No. 1	Change No. 2				
1 March 66	15 Nov 66	15 July 68	1 Oct 72				

RELATED DOCUMENTS

The following technical manuals have been published under NASA contract on the IU, its sub-systems, and components. Another listing, including technical manuals, handbooks, reports, etc., is located in Technical Manual IBM No. 66-966-0006.

Requests for these listed documents should be addressed to:

IBM Corporation
Federal Systems Division
P. O. Box 1250
Huntsville, Alabama 35807

ATTN Department 966, Manual Distribution

If the requester is located at IBM Huntsville, requests shall be made on Form 955-0924, Technical Manual Request.

Title	Number		Title	Number	
	IBM	MSFC		IBM	MSFC
GENERAL			ENVIRONMENTAL CONTROL SUBSYSTEM		
Apollo-Saturn Emergency Detection System Description (AS-200 Series Vehicles)	66-966-0010	III-5-509-6	Environmental Control System Description	66-966-0009	III-5-509-5
Apollo-Saturn Emergency Detection System Description (AS-500 Series Vehicles)	66-966-0022	III-5-509-7	GUIDANCE AND CONTROL SUBSYSTEM		
Astrionics System Handbook	None	None	Control Accelerometer	66-966-0012	III-5-510-12
Component Handling Equipment, Description and Operating Instructions	66-966-0005	III-5-510-10	Control-EDS Rate Gyro Package	66-966-0013	III-5-510-13
EDS Q-Ball Sensor Assembly (50Z12580-1)	66-966-0027	III-5-510-22	Control Signal Processor	66-966-0014	III-5-510-14
IU System Description and Component Data	66-966-0006	III-5-509-4	Flight Control Computer (S-IU-203)	66-966-0015	III-5-510-15
Operation and Maintenance Instructions, Heat Substitute Cart Part No. 85Z06676	67-966-0001	III-5-510-25	Flight Control Computer (200 Series Vehicles)	66-966-0021	III-5-510-19
Structure Repair Manual	65-966-0011H	III-5-510-1	Flight Control Computer (500 Series Vehicles)	66-966-0025	III-5-510-21
System Test Reference Manual Volume I: Control System Volume II: Guidance System Volume III: ST-124M-3 Inertial Stabilizer System	66-966-0004	III-5-509-3	Navigation, Guidance, and Control System Description	66-966-0003	III-5-509-2
S-IVB Forward/IU Umbilical Assembly, Saturn IB	67-966-0004	MSFC-MAN-009	MEASURING AND TELEMETRY SUBSYSTEM		
S-IVB Forward/IU Umbilical Assembly, Saturn V	67-966-0005	MSFC-MAN-010	Measuring Rack and Measuring Rack Selector (S-IU-204 thru 212/501 thru 515)	66-966-0017	III-5-510-16
RADIO FREQUENCY SUBSYSTEM			Measuring and Telemetry System Description (Replaces Instrumentation System Description, 65-966-0021).	67-966-0008	III-5-509-9
C-Band Radar Transponder Set SST-135C (S-IU-203)	66-966-0008	III-5-510-11	ELECTRICAL SUBSYSTEM		
C-Band Radar Transponder Set (S-IU-204/501 and Subsequent)	66-966-0020	III-5-510-18	5 Volt Measuring Voltage Supply	65-966-0019H	III-5-510-8
CCS Power Amplifier	67-966-0002	III-5-510-23	56 Volt Power Supply (S-IU-202 thru 212/501 thru 515)	65-966-0018H	III-5-510-7
CCS Transponder	67-966-0003	III-5-510-24	Auxiliary Power Distributors *	65-966-0013H	III-5-510-2
Command Decoder (S-IU-204 thru 212/501 thru 515)	66-966-0019	III-5-510-17	Battery	66-966-0024	III-5-510-20
Command Receiver	67-966-0014	III-5-510-26	Control Distributor *	65-966-0016H	III-5-510-5
Command System Description	67-966-0007	III-5-509-8	Emergency Detection System Distributor *	65-966-0015H	III-5-510-4
			Measuring Distributors *	65-966-0017H	III-5-510-6
			Power Distributor *	65-966-0014H	III-5-510-3
			Switch Selector, Model II	66-966-0001	III-5-510-9

* These manuals are at the S-IU-201 level. No plans exist to update their contents to later vehicle configurations.

COMMENT SHEET

Your comments will help improve this publication. List your suggestions regarding additions, deletions, errors, or omissions on this comment sheet.

Manual Title _____

IBM Manual Number _____ Change Date _____

Comments _____

Name _____

Please forward completed comment sheets to:

Address _____

Department 966
IBM Huntsville Facility
Space Systems Center
Huntsville, Alabama

(Use additional sheets as required)

CONTENTS

Section	Page	Section	Page
I	INTRODUCTION AND DESCRIPTION		
1-1	Introduction	2-6	Comparator
1-2	Description	2-7	Rate Switch
1-3	Electrical Characteristics . . .	2-8	Wheel Speed Sensor
1-4	Dimensions and Weight	2-9	1600-Hertz Filter
		2-10	Mother Board Component Description
II	PRINCIPLES OF OPERATION		
2-1	General Operation	III	PREPARATION FOR USE AND SHIPMENT
2-2	Detailed Operation	3-1	Preventive Maintenance (Not Applicable).
2-3	DC Power Supply	3-2	Repair
2-4	Static Inverter		
2-5	Demodulator		

ILLUSTRATIONS

Number	Title	Page	Number	Title	Page
1-1	Control Signal Processor (Three- Quarter View)	1-1	1-10	1600-Hertz Filter Printed Circuit Board Assembly.	1-12
1-2	Control Signal Processor with Top Cover Removed	1-2	1-11	Mother Board Assembly	1-13
1-3	DC Power Supply Printed Circuit Board Assembly.	1-5	2-1	Control Signal Processor Block Diagram	2-3
1-4	Static Inverter Printed Circuit Board Assembly.	1-6	2-2	Control Signal Processor Schematic Diagram	2-17
1-5	Demodulator Printed Circuit Board Assembly.	1-7	2-3	DC Power Supply Schematic Diagram	2-27
1-6	Comparator Printed Circuit Board Assembly.	1-8	2-4	Inverter Schematic Diagram	2-29
1-7	Yaw and Pitch Rate Switch Printed Circuit Board Assembly	1-9	2-5	Demodulator Schematic Diagram. . .	2-31
1-8	Roll Rate Switch Printed Circuit Board Assembly.	1-10	2-6	Comparator Schematic Diagram . . .	2-33
1-9	Wheel Speed Sensor Printed Circuit Board Assembly	1-11	2-7	Rate Switch Schematic Diagram . . .	2-35
			2-8	Wheel Speed Schematic Diagram . . .	2-43
			2-9	1600-Hertz Filter Schematic Diagram	2-45
			2-10	Relay Logic Schematic Diagram . . .	2-45

SECTION I

INTRODUCTION AND DESCRIPTION

1-1 INTRODUCTION

This technical manual defines the principles of operation, and maintenance and repair instructions for the Control Signal Processor (see Figure 1-1).

The Control Signal Processor[†] is electrically located in a flight configuration inside the Instrument Unit (IU) with the Control-EDS Rate Gyro Package^{††} and the following systems or subsystems: Flight Control Computer; Emergency Detection System

[†] Hereafter the nomenclatures Control Signal Processor and Signal Processor shall be interchangeable.

^{††} Hereafter the nomenclatures Control-EDS Rate Gyro Package and Rate Gyro Package shall be interchangeable.

(EDS); and the Digital Data Acquisition System (DDAS). Primary power is supplied by Saturn Launch Vehicle IU battery power of 26 to 30 Vdc. The primary function of the Signal Processor is to drive and monitor the gyros in the Rate Gyro Package during flight, as well as process the gyro error signals for vehicle attitude control. If a malfunction occurs, the Signal Processor sends signals to the Flight Control Computer and EDS. The Signal Processor also supplies data to the DDAS for both normal operations and malfunctions during flight and during Ground Support Equipment (GSE) checks.

1-2 DESCRIPTION

The Signal Processor is a self-contained, pressurized unit that includes 25 separate printed

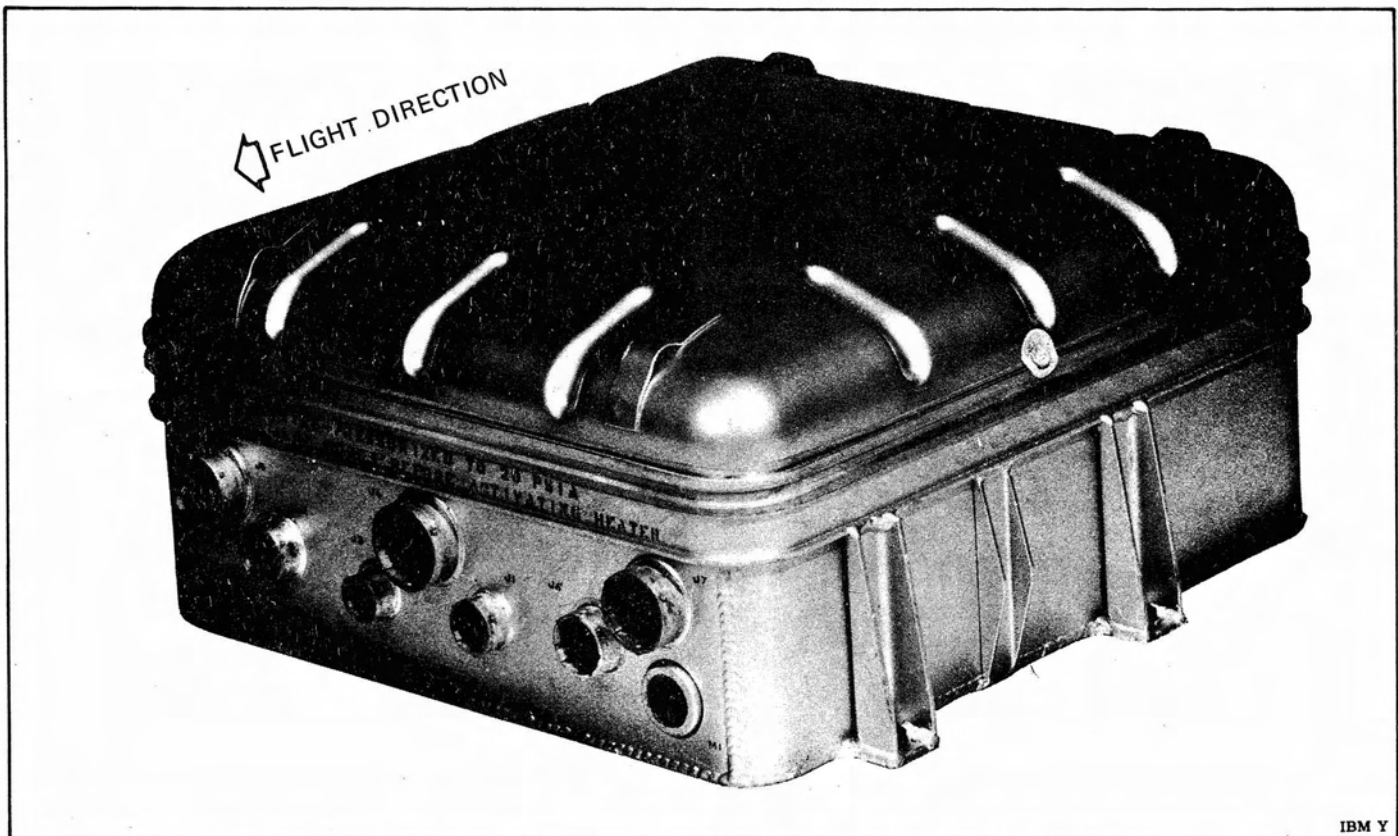


Figure 1-1. Control Signal Processor (Three-Quarter View)

Control Signal Processor
Section I

circuit boards mounted on an internal mother board, 7 input and output connectors mounted on the front of the case, 1 elapsed-time meter mounted on the front of the case, and 2 valves (used to pressurize the case) mounted on the rear of the unit. Figure 1-2 illustrates the unit with the cover removed.

The printed circuit boards include the following operating circuits: 3 dc power supplies, 3 static inverters, 3 printed circuit boards containing 3 identical 1600 Hz filters mounted on each board, 1 printed circuit board containing 3 identical comparator circuits, 3 printed circuit boards containing 3 rate switches, 3 wheel speed sensors and 9 demodulators. The 7 connectors are identified as J1 through J7 and supply the following inputs and outputs: Connector J1 carries demodulator output signals to the Flight Control Computer; connector J2 carries output signals to the EDS; connector J3 delivers vehicle

battery power to the Signal Processor; connector J4 carries the Signal Processor signals to the DDAS; connector J5 carries all of the rate gyro input and output signals to the Signal Processor; and connector J6 carries the GSE input signals to the Signal Processor. Connector J7 is only used for bench tests and is capped during GSE checks and flight. The elapsed-time meter indicates the total time the Signal Processor has been in operation.

The case of the Signal Processor is made of aluminum. The cover is secured to the case with solder. A heating element developing 3700 watts is attached to the case when the cover is being removed or secured. Once the cover is secured, the case is pressurized at 20 psia with a mixture of gas consisting of 99 percent nitrogen and 1 percent helium. The 1 percent helium is added because the mass spectrometer used to detect leakage responds only to helium.



Figure 1-2. Control Signal Processor with Top Cover Removed

SECTION I

INTRODUCTION AND DESCRIPTION

1-1 INTRODUCTION

This technical manual defines the principles of operation, and maintenance and repair instructions for the Control Signal Processor (see Figure 1-1).

The Control Signal Processor[†] is electrically located in a flight configuration inside the Instrument Unit (IU) with the Control-EDS Rate Gyro Package^{††} and the following systems or subsystems: Flight Control Computer; Emergency Detection System

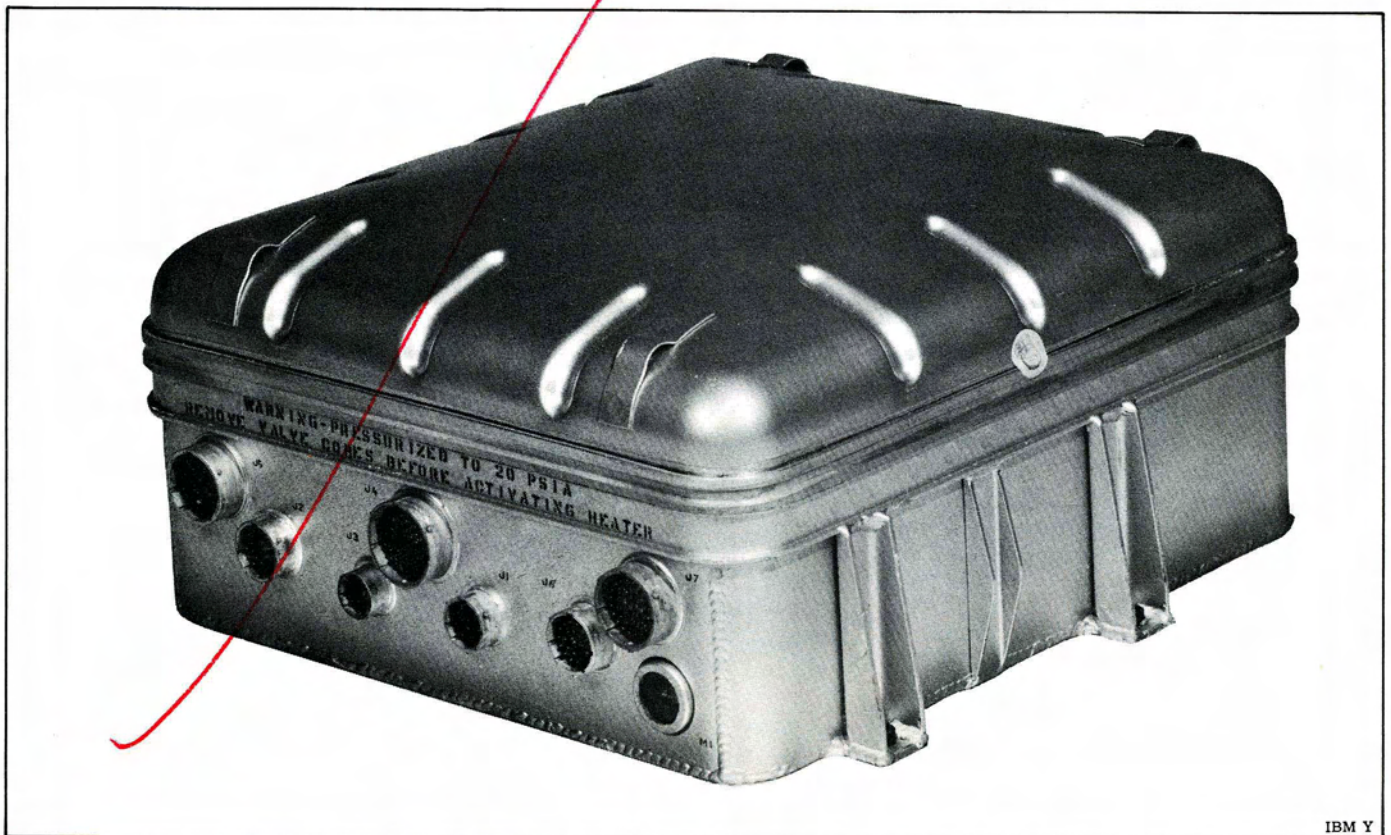
[†] Hereafter the nomenclatures Control Signal Processor and Signal Processor shall be interchangeable.

^{††} Hereafter the nomenclatures Control-EDS Rate Gyro Package and Rate Gyro Package shall be interchangeable.

(EDS); and the Digital Data Acquisition System (DDAS). Primary power is supplied by Saturn Launch Vehicle IU battery power of 26 to 30 Vdc. The primary function of the Signal Processor is to drive and monitor the gyros in the Rate Gyro Package during flight, as well as process the gyro error signals for vehicle attitude control. If a malfunction occurs, the Signal Processor sends signals to the Flight Control Computer and EDS. The Signal Processor also supplies data to the DDAS for both normal operations and malfunctions during flight and during Ground Support Equipment (GSE) checks.

1-2 DESCRIPTION

The Signal Processor is a self-contained, pressurized unit that includes 25 separate printed



IBM Y

Figure 1-1. Control Signal Processor (Three-Quarter View)

Control Signal Processor
Section I

circuit boards mounted on an internal mother board, 7 input and output connectors mounted on the front of the case, 1 elapsed-time meter mounted on the front of the case, and 2 valves (used to pressurize the case) mounted on the rear of the unit. Figure 1-2 illustrates the unit with the cover removed.

The printed circuit boards include the following operating circuits: 3 dc power supplies, 3 static inverters, 3 printed circuit boards containing 3 identical 1600 Hz filters mounted on each board, 1 printed circuit board containing 3 identical comparator circuits, 3 printed circuit boards containing 3 rate switches, 3 wheel speed sensors and 9 demodulators. The 7 connectors are identified as J1 through J7 and supply the following inputs and outputs: Connector J1 carries demodulator output signals to the Flight Control Computer; connector J2 carries output signals to the EDS; connector J3 delivers vehicle

battery power to the Signal Processor; connector J4 carries the Signal Processor signals to the DDAS; connector J5 carries all of the rate gyro input and output signals to the Signal Processor; and connector J6 carries the GSE input signals to the Signal Processor. Connector J7 is only used for bench tests and is capped during GSE checks and flight. The elapsed-time meter indicates the total time the Signal Processor has been in operation.

The case of the Signal Processor is made of aluminum. The cover is secured to the case with solder. A heating element developing 3700 watts is attached to the case when the cover is being removed or secured. Once the cover is secured, the case is pressurized at 20 psia with a mixture of gas consisting of 99 percent nitrogen and 1 percent helium. The 1 percent helium is added because the mass spectrometer used to detect leakage responds only to helium.

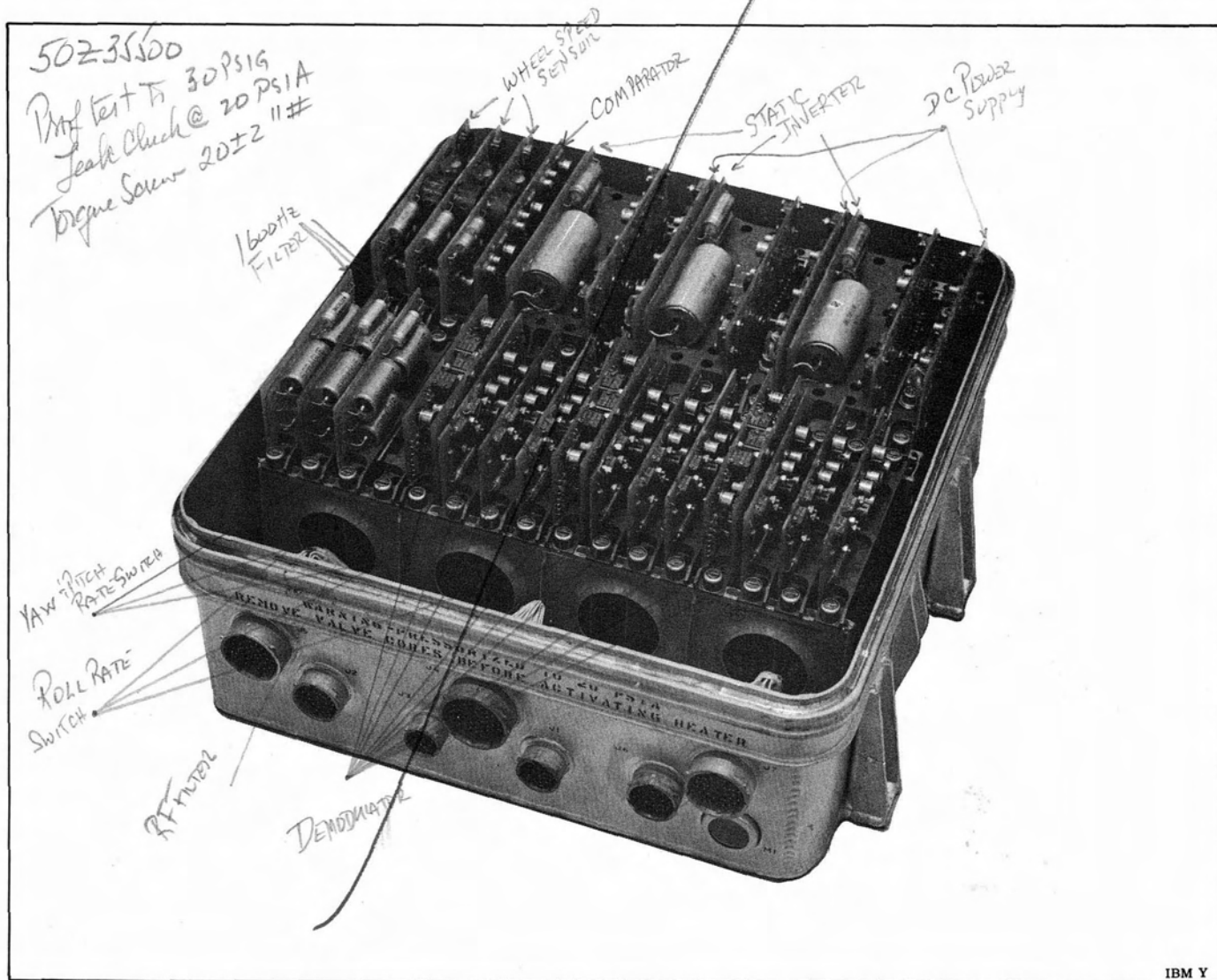


Figure 1-2. Control Signal Processor with Top Cover Removed

Figures 1-3 through 1-9 illustrate the front and rear views of each of the seven different types of printed circuit boards contained in the Signal Processor. Figure 1-10 illustrates the front and rear view of the mother board.

1-3 ELECTRICAL CHARACTERISTICS

The electrical characteristics of the Signal Processor and each of its printed circuit boards are listed in Table 1-1.

1-4 DIMENSIONS AND WEIGHT

The dimensions and weight of the Signal Processor are as follows:

Length:	14.75 inches
Width:	15.5 inches
Height:	7.0 inches
Weight:	37.9 pounds <i>39# MAX.</i>

Table 1-1. Signal Processor Electrical Characteristics

Nomenclature	Electrical Characteristics	Values
Signal Processor	Input voltage	22 to 32 Vdc
	Input current (maximum)	6 amperes
	Output signal to gyros (9 gyros)	26 Vrms 400 Hz
	Input signal from gyros (amplitude)	0.565 Vpp/deg/sec
	Output signal to DDAS (switched)	28 Vdc
	Output signal to EDS (switched)	28 Vdc
DC Power Supply	Input voltage	22 to 32 Vdc
	Input current	420 to 665 ma
	Output voltages	26 to 30 Vdc 58 to 62 Vdc
	Ripple voltage on both output voltages	Less than 1.0 Vrms
Static Inverter	Input voltage	22 to 32 Vdc
	Input current (maximum)	1 ampere
	Output voltage	25.74 to 26.26 Vrms
	Output frequency	396 to 404 Hz
Demodulator	Power supply voltage	58 to 62 Vdc
	Power supply current (maximum)	38 ma
	Input signal	0.565 Vpp/deg/sec

Table 1-1. Signal Processor Electrical Characteristics (cont)

Nomenclature	Electrical Characteristics	Values
Rate Switch	Reference voltage	25.74 to 26.26 Vrms
	Reference frequency	396 to 404 Hz
	Output voltage for 11.312 Vpp input	0 ± 45 Vdc (Polarity depends on phase)
	Noise level with 2.0 Vrms	Less than 400 mV
	Input signal	
	Roll	0 to 4 Vrms
	Yaw and Pitch	0 to 2 Vrms
	Trigger voltage during flight (yaw and pitch)	
	Saturn IB	
	5 degrees/second	0.94 to 1.06 Vrms
9.2 degrees/second	1.78 to 1.90 Vrms	
Saturn V		
4 degrees/second	0.74 to 0.86 Vrms	
9.2 degrees/second	1.78 to 1.90 Vrms	
Trigger voltage during flight (roll)	3.9 to 4.1 Vrms	
1600 Hz Filter	DC input voltage (used only during GSE checkout)	0 to ±28 Vdc (variable)
Wheel Speed Sensor	Power Supply voltage	22 to 32 Vdc
	Power Supply current (maximum)	0.150 ampere
	AC input voltage	0.4 to 0.9 Vpp
	AC input frequency	0 to 2000 Hz
	Operating frequency of relay circuits	1,500 to 1,650 Hz
Comparator	Power Supply voltage	26 to 30 Vdc
	Power Supply current (maximum)	67 ma
	Signal input from demodulator	0 to ±45 Vdc
	Algebraic trigger voltage difference between reference and command channels	±7.3 to ±7.5 Vdc

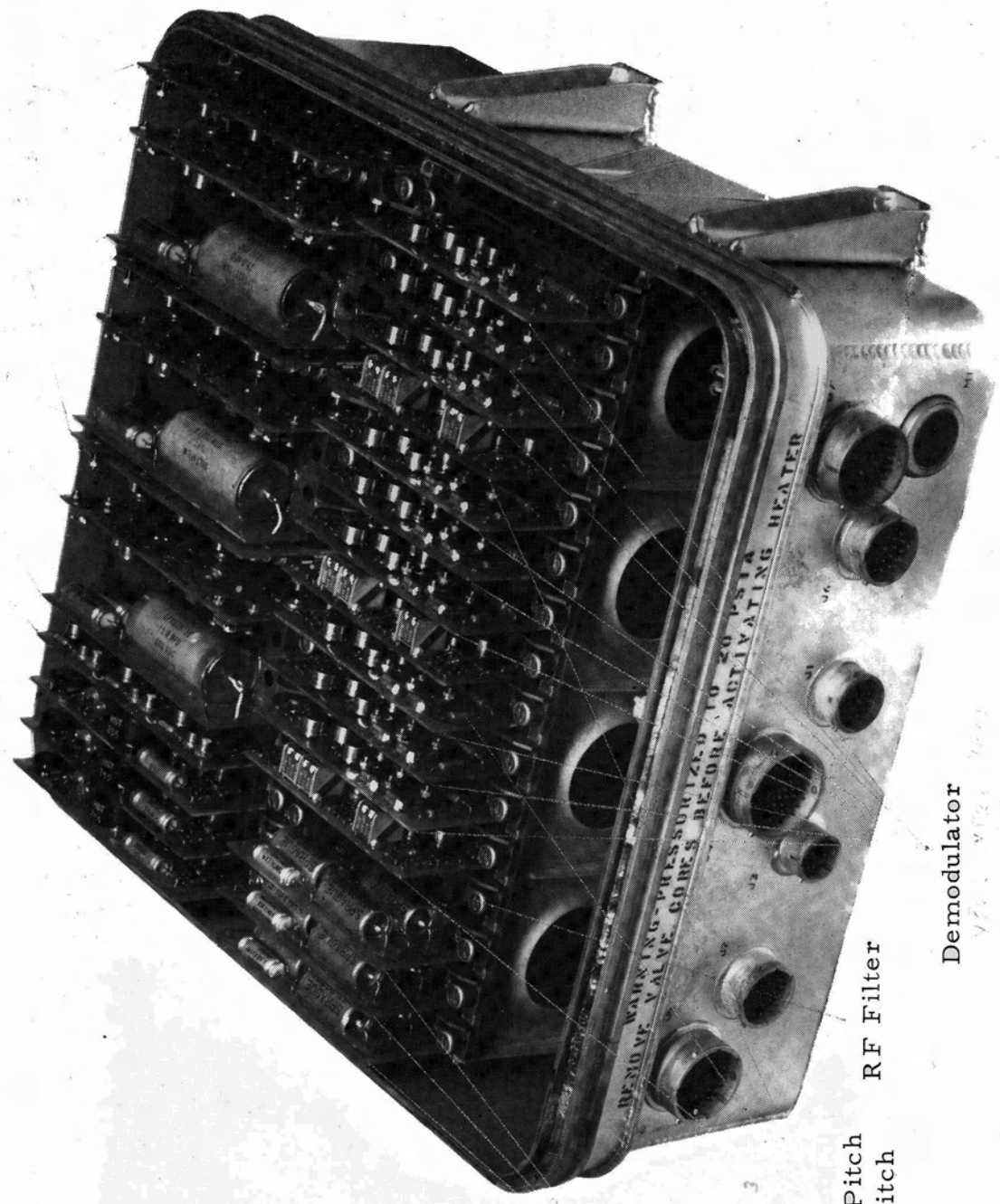
Handwritten notes:
21/1/1971
M. J. ...
...

Wheel Speed
Sensor

Static Inverter

Comparator

DC Power Supply



1600 Hz
Filter

Yaw & Pitch
Roll, Rate Switch

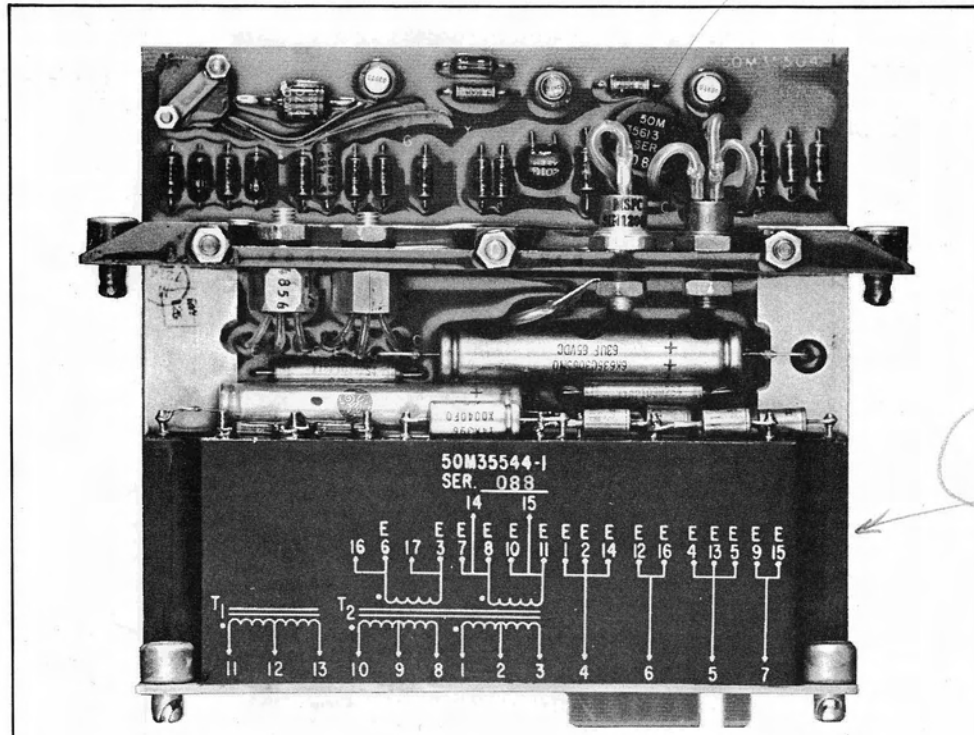
RF Filter

Demodulator

Handwritten note:
V.F. ...

INDUCTOR
50Z33B13

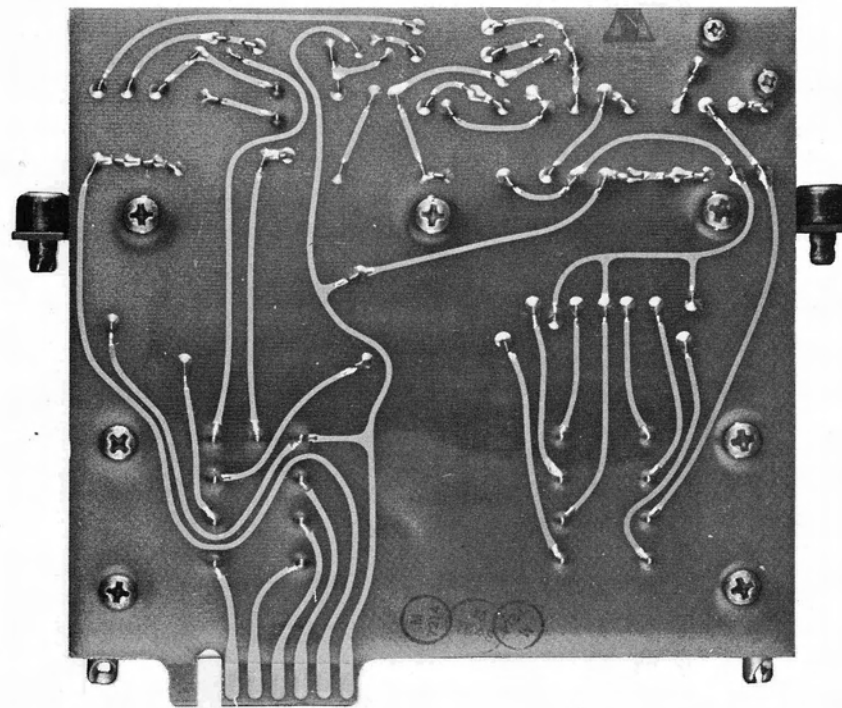
Conf. Final Crated
both scales of hand
Martin Process P21014F
EPS 85080
Test Request 50Z33B13
kittlet / yulet 7916032
Schematic 50Z33565
MM MODULE TEST EQUIP
TD-704019
TD-704020



XFR ASSY
50Z33544

3/cap
2/ind
6 total

Front View



Rear View

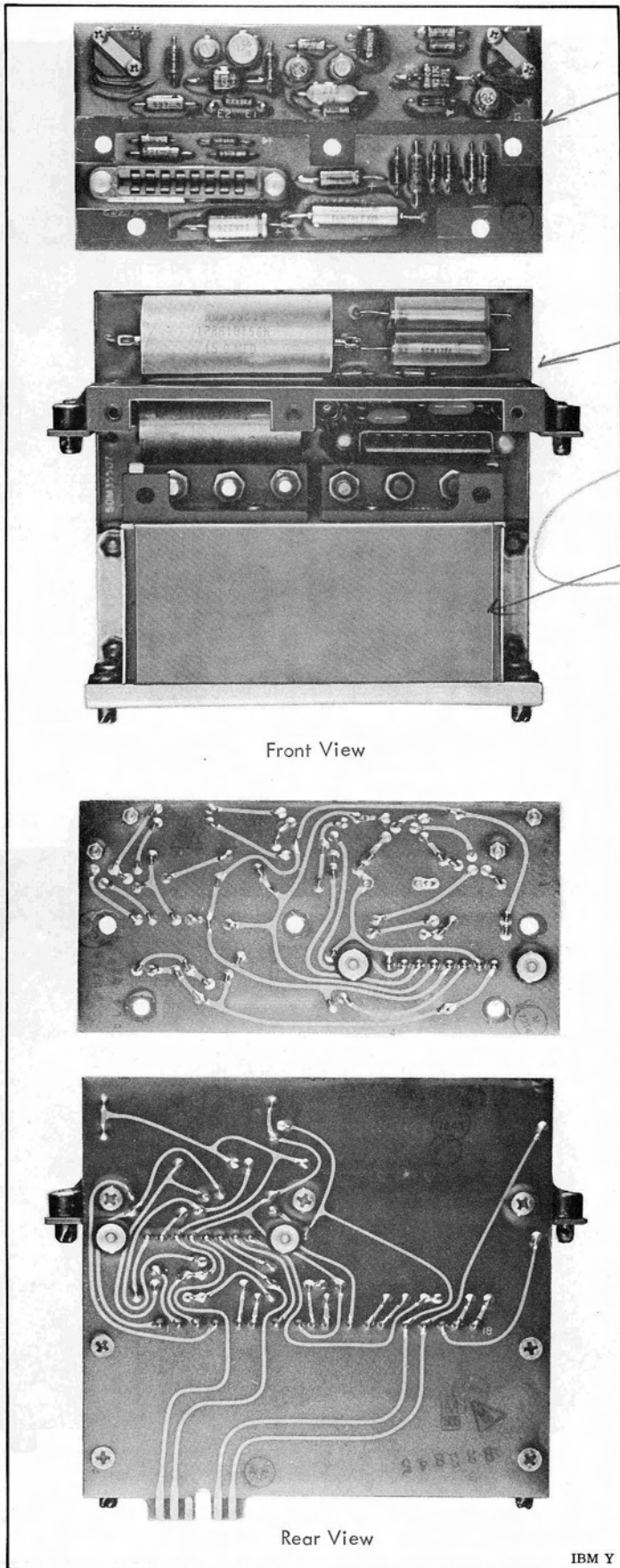
IBM Y

Figure 1-3. DC Power Supply Printed Circuit Board Assembly

7914853

Control Signal Processor
Section I

*Schematic 50Z35508
Martin Cross P21014F
EPS85080
Cryminal Coating Rth Aides
Test Request 50Z35260*



50Z35528

50Z35507

*XFR Assy
50Z35587*

*3/ CSP
1/ lead
3 total*

Front View

Rear View

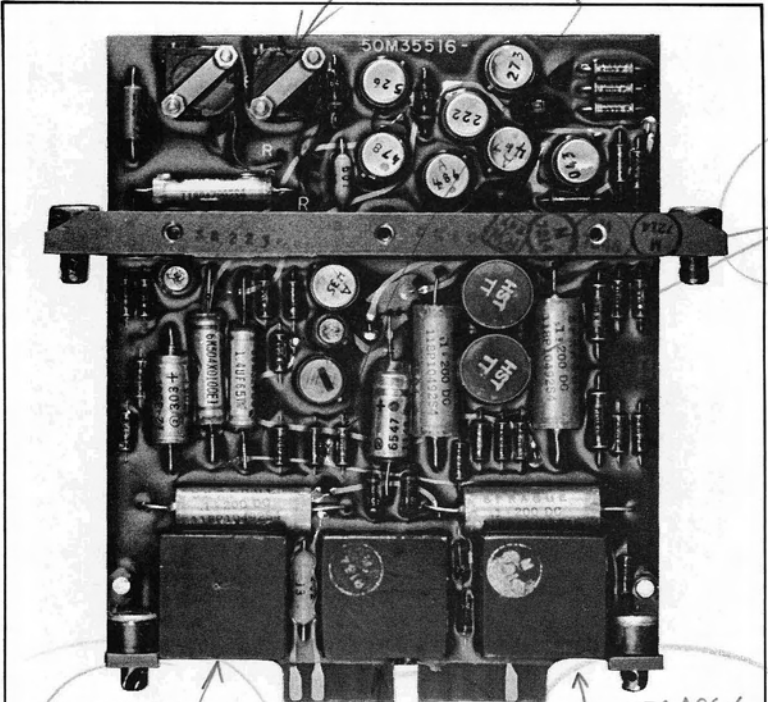
IBM Y

Figure 1-4. Static Inverter Printed Circuit Board Assembly *50Z35507*

*Conformal Coating both sides
Martin Process P21014F
Schematic 50235517
Test Regmt 50235518*

R8 32502-501-202

R7



*INDUCTOR
50232858
2 ea*

*XFRASSY
50235552*

*XFRASSY
50235551
Front View*

*XFRASSY
50235558*

*9/258
5/12nd
45° etched*



~~*50235516*~~
7914850

Rear View

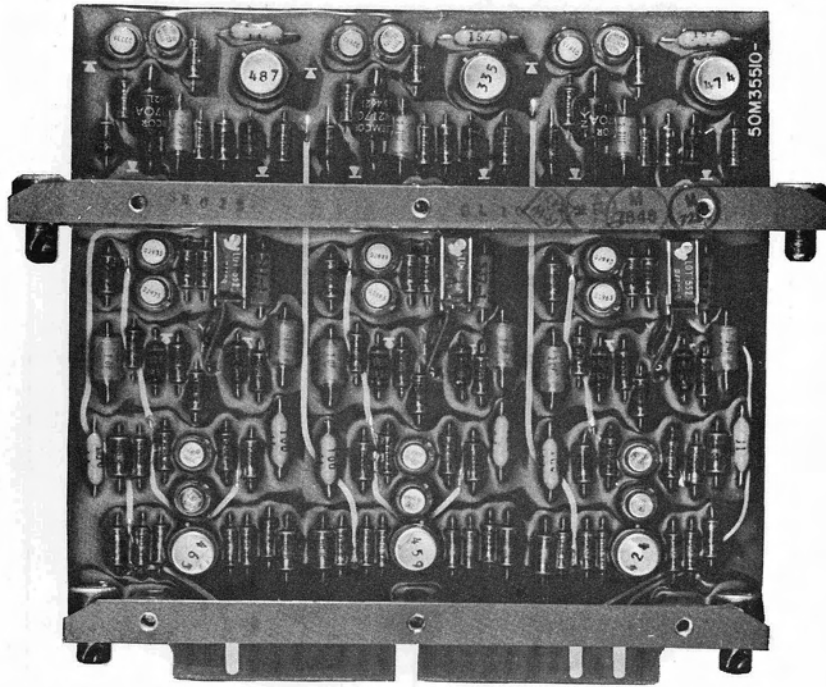
IBM Y

Figure 1-5. Demodulator Printed Circuit Board Assembly

Control Signal Processor
Section I

*Circuit Board Gated with Address
Martin Loren P21014F
Schematic J023J083
Test Points J023J063*

Shy-His 866-F-1220



Front View



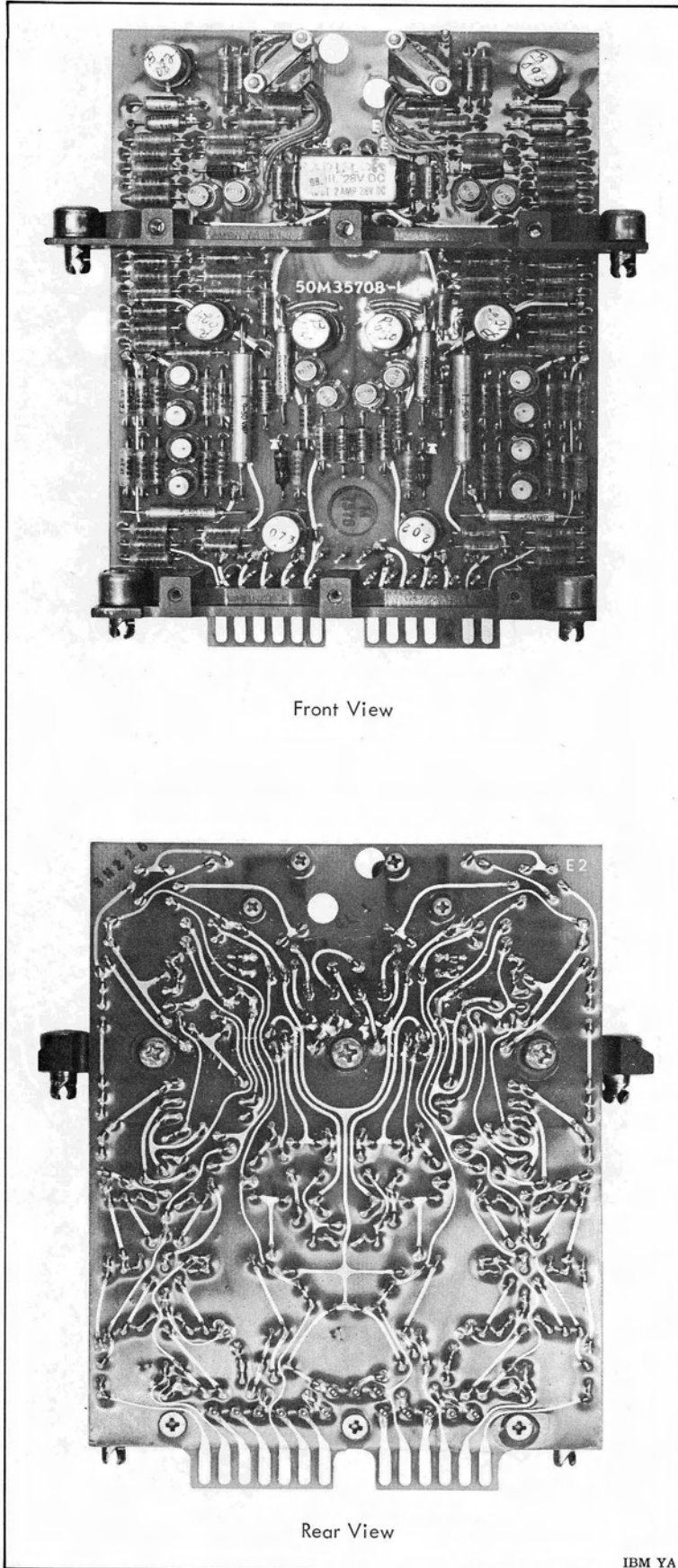
Rear View

IBM Y

Figure 1-6. Comparator Printed Circuit Board Assembly

J023J070

*Conformal Coating
Martin Process P21014F
Schematic 502 35712
Test Reqs 502 35725*



Front View

Rear View

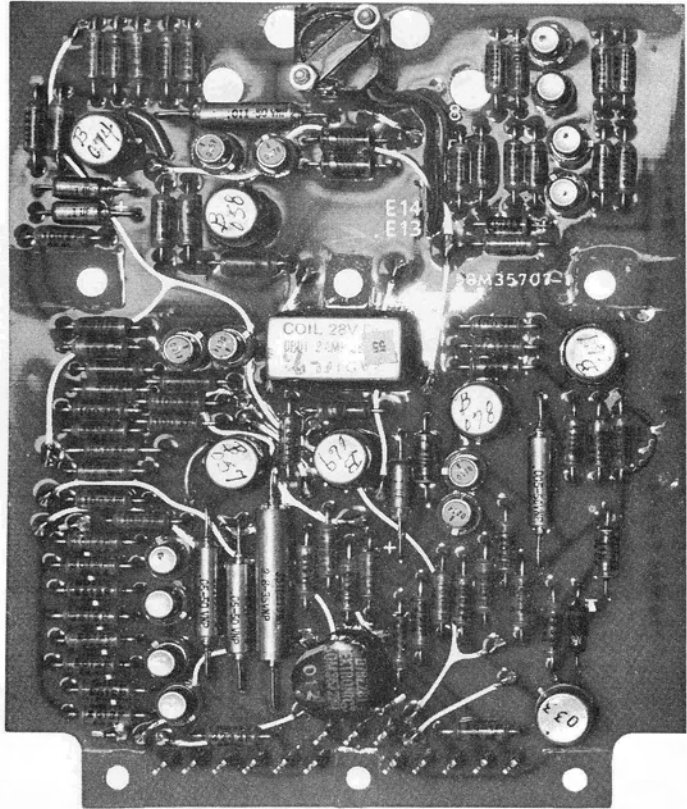
IBM YA

502 35709

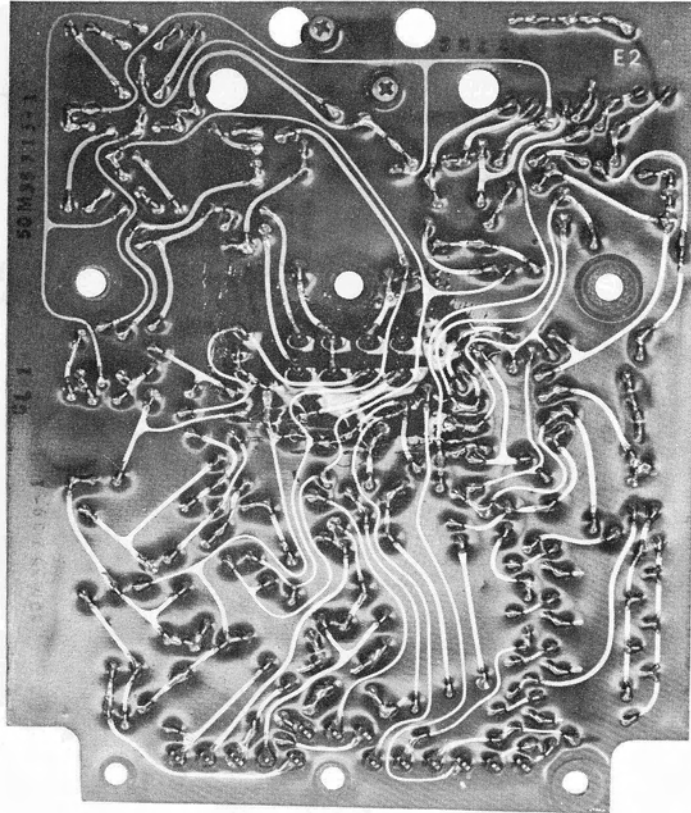
Figure 1-7. Yaw and Pitch Rate Switch Printed Circuit Board Assembly

Control Signal Processor
Section I

*Conformal Coating
Schematic 10235712
test Reprints*



Front View



Rear View

IBM Y

10235713

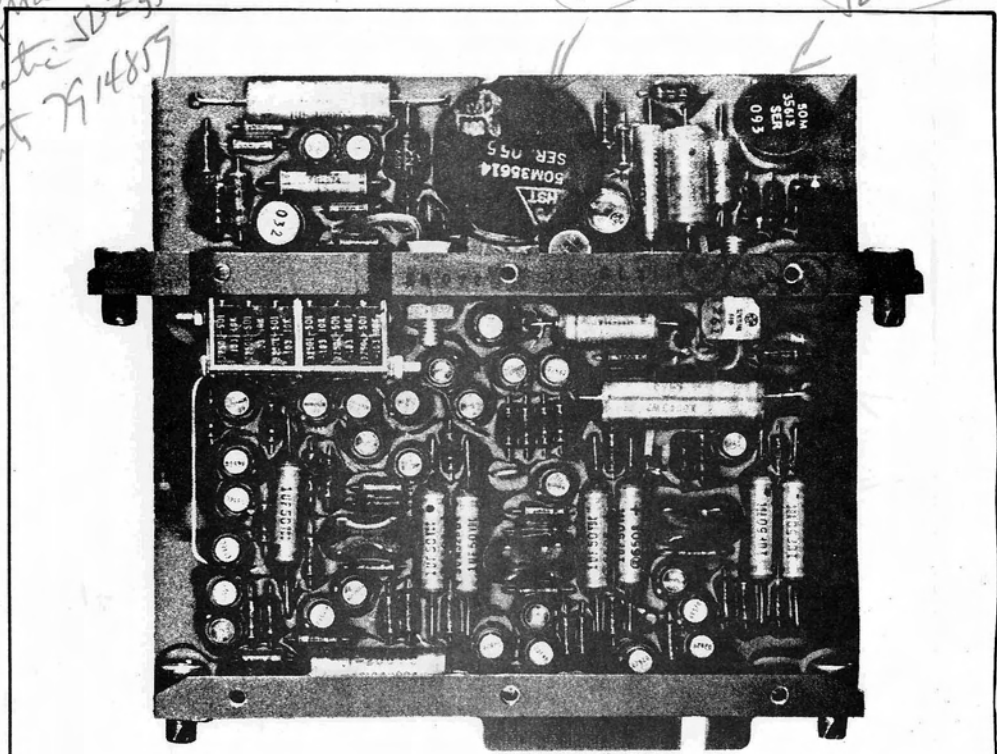
Figure 1-8. Roll Rate Switch Printed Circuit Board Assembly

Confocal Catalog
 Main Power P21014F
 Schematic ID235514
 Test Report 7914859

XF72
 ID231214

INDICATED
 ID235514

Control Signal Processor
 Section I



Front View

3/csp
 2/ Ad
 6 total



Rear View

IBM Y

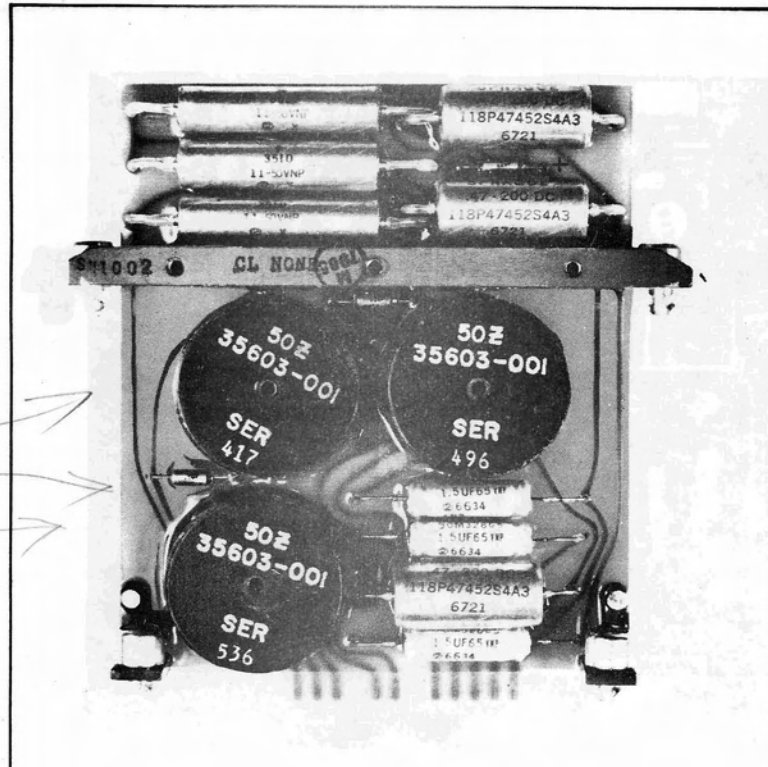
7914856

Figure 1-9. Wheel Speed Sensor Printed Circuit Board Assembly

**Control Signal Processor
Section I**

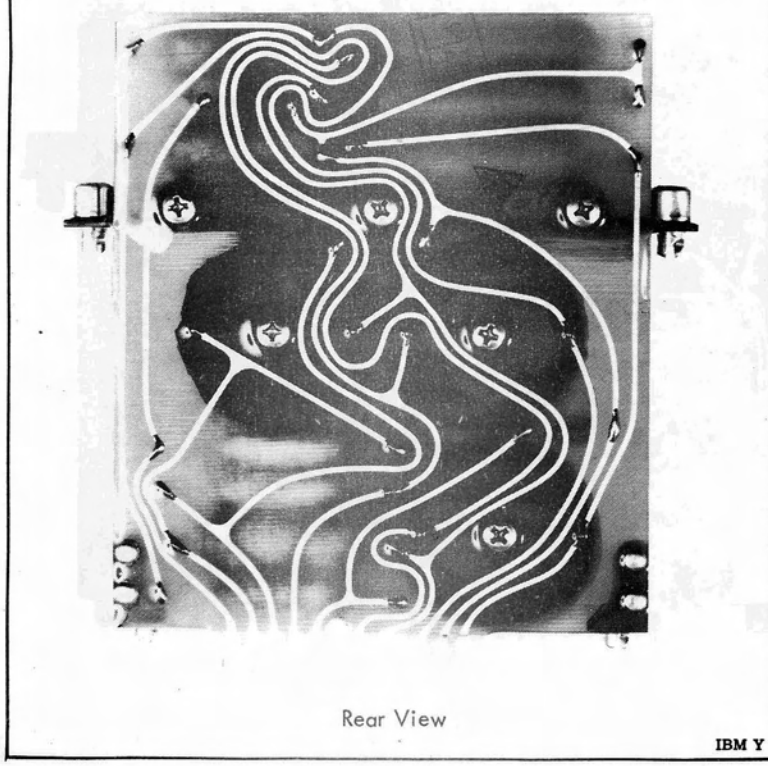
*Confirmed Correcting
Master Process P221014F
Schematic J22-35559
Test Report J22-35215*

*Inductor
J22-35203
3cc*



Front View

*3/CSP
3/Ref
9 Total*



Rear View

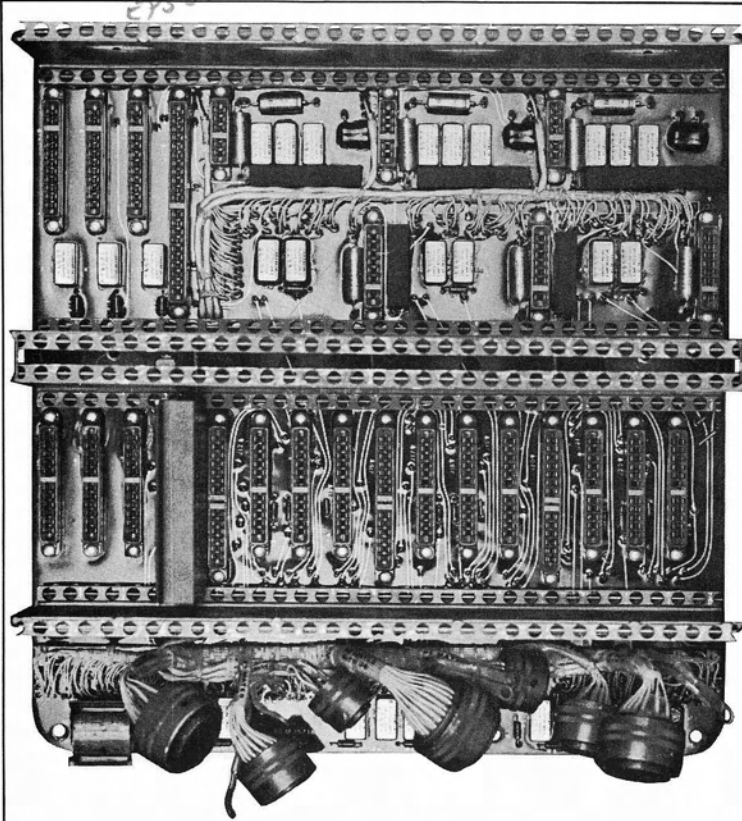
IBM Y

7915961

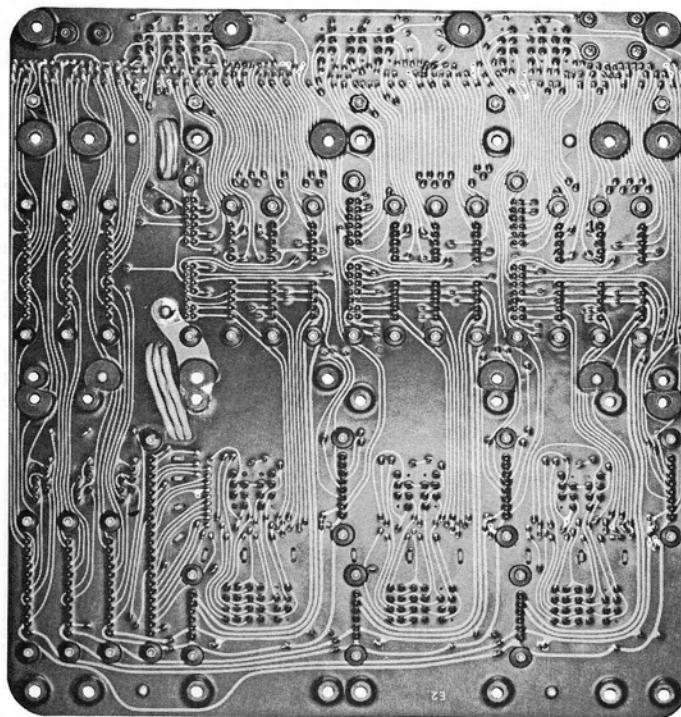
Figure 1-10. 1600-Hertz Filter Printed Circuit Board Assembly

Confidential Contract
Rivet, Martin Process
See Cable Schematic
test Regmt?
21003F
EPS 20004
P 86017F
50235717
P21014F
EPS 85121
EPS 85280
EPS 85081

3md P61009



Front View



Rear View

IBM YA

50235716

Figure 1-11. Mother Board Assembly

SECTION II

PRINCIPLES OF OPERATION

2-1 GENERAL OPERATION

The Signal Processor is a self-contained unit that is electrically located between the Rate Gyro Package and the Flight Control Computer of the Attitude Control System. See Figure 2-1. The inputs to the Signal Processor are IU battery power and rate gyro error signals. The output signals of the Signal Processor are sent to the Digital Data Acquisition System (DDAS), Emergency Detection System (EDS), Flight Control Computer, and Rate Gyro Package.

The Signal Processor contains three operating groups: Group 1, Group 2, and Group 3. Each group contains a dc power supply, a static inverter, 1600 Hz filter circuits, demodulators, rate switch circuits, a gyro wheel speed sensor, a comparator, and associated relay logic. Each group is identical in operation and arranged in a "pair" and "spare" configuration.

Battery power is supplied to the dc power supply, static inverter, and wheel speed sensor through an RFI filter mounted on the mother board of the Signal Processor.

There are three dc power supply circuits. Each power supply provides 28 Vdc to the rate switch circuit, comparator circuit, and relays associated with its particular group. The dc power supply also supplies 60 Vdc to its three associated demodulators.

There are three static inverters in the Signal Processor. Each inverter supplies 26 Vrms, 400 Hz drive voltage to three rate gyros (roll, pitch, and yaw) and sends 26 Vrms, 400 Hz to 3 demodulators, 1 in each group, where it is used as a reference voltage.

■ There are 3 gyros for each of the 3 axes (roll, pitch, and yaw) that are monitored and maintained - this makes a total of 9 gyros. It should be noted that each group contains a roll, pitch and yaw gyro. During flight, vehicle motion is sensed by each rate gyro of each group and a 400 Hz error signal is produced. The error signals in each motion are fed, in parallel, to the circuits in their respective group. The rate gyros are monitored by

a wheel speed sensor in each group. The 1600 Hz filters only insure that the signal is not shorted during GSE checks of the attitude control loop.

The 3 demodulators for each channel receive the rate gyro error signals, amplify them, compare them to the 400 Hz reference signal, and rectify them. The final output is a plus or minus dc voltage proportional to the ac input amplitude. Polarity of the signal is dependent on phase. Reference and command demodulators for each motion (roll, pitch, and yaw) send an output signal to associated comparators. The standby demodulators substitute for the command demodulators if a failure is indicated by the comparator. Each of the 9 demodulators sends a continuous telemetry output to the DDAS so that both normal operation and malfunctions are continually monitored.

The three rate switch circuits for each group receive the rate gyro error signals, rectify them, and convert the signals to dc levels. When the dc levels reach a preset trigger level, a differential amplifier switch in each rate switch circuit develops an output that actuates a relay located on the mother board. The energized relay transmits a 28 Vdc signal to the EDS. The rate switch circuit associated with the roll gyros also sends a continuous dc analog signal to the DDAS.

The EDS must receive two error signals in any 1 of the 3 planes of motion (roll, pitch, or yaw) before an abort is initiated. This allows for a malfunction of any 1 circuit in the Signal Processor without abort of mission or commanded destruction of the vehicle.

Three channels, contained on each wheel speed printed circuit board, compare the frequency of rotation of a set of gyros (roll, pitch, and yaw). During normal operation, each wheel speed sensor associated with the 3 gyros sends a continuous signal through respective relays mounted on the mother board to the DDAS. If a malfunction occurs in rate gyro wheel speed for a particular channel (either in roll, pitch, or yaw), a relay is deenergized and the DDAS signal is interrupted. The wheel speed circuits also monitor the gyros during GSE checks. A dc

Control Signal Processor Section II

precession signal is applied to the torquer winding of the rate gyro through the 1600 Hz filters, to create an artificial error signal. This error signal does not change the 1600 Hz frequency, but it does produce an output from the demodulators and rate switches for GSE checks.

The Signal Processor contains 3 comparators. Each comparator is associated with 1 of the 3 motions (roll, pitch, or yaw) of deviation of the vehicle. Each comparator has as its input, a signal from a command and a reference demodulator. If a malfunction occurs during flight in either the command or reference demodulator, the comparator for a particular motion (either roll, pitch, or yaw) actuates a relay and switches to the standby demodulator. The switching action also sends a 28 Vdc signal to the DDAS. If a malfunction occurs in the standby demodulator during flight, and the command and reference demodulators are functioning properly, no switching action occurs. During GSE checks, if the relays associated with the comparators are actuated, a 28 Vdc unlatch signal is sent to the relay logic to reset all the relays to their flight operating condition.

2-2 DETAILED OPERATION

The following paragraphs offer a more detailed description of the Signal Processor. During this discussion reference will be made to the schematic diagrams, Figure 2-2 through 2-10, located at the end of this section.

Figure 2-2 is a detailed schematic diagram of the Signal Processor. Since each of the 3 groups of channels of the Signal Processor is identical in operation, only the operation of Group 1 assemblies will be discussed.

Battery power of 22 to 32 Vdc is applied to the Signal Processor through J3, pins A and B, to RFI filter FL1. See Figure 2-2, Sheet 1. Filter FL1 attenuates noise on the power input lines generated by the inverter, wheel speed sensor, and power supply assemblies. Power supply A26 receives input power through J33, pins A and B, and generates 28 Vdc and 60 Vdc. The 28 Vdc power is fed from J33, pins E and F to the following: pins 8 and M of rate switch A13; pins 17 and 22 of comparator A20. The 60 Vdc power is fed from J33, pins C and D, to pins 5 and 9 on connectors J21, J22, and J23 of demodulators A14, A15, and A16, respectively. Paragraph 2-3 describes the detailed component operation of the power supply, and Figure 2-3 is its schematic diagram.

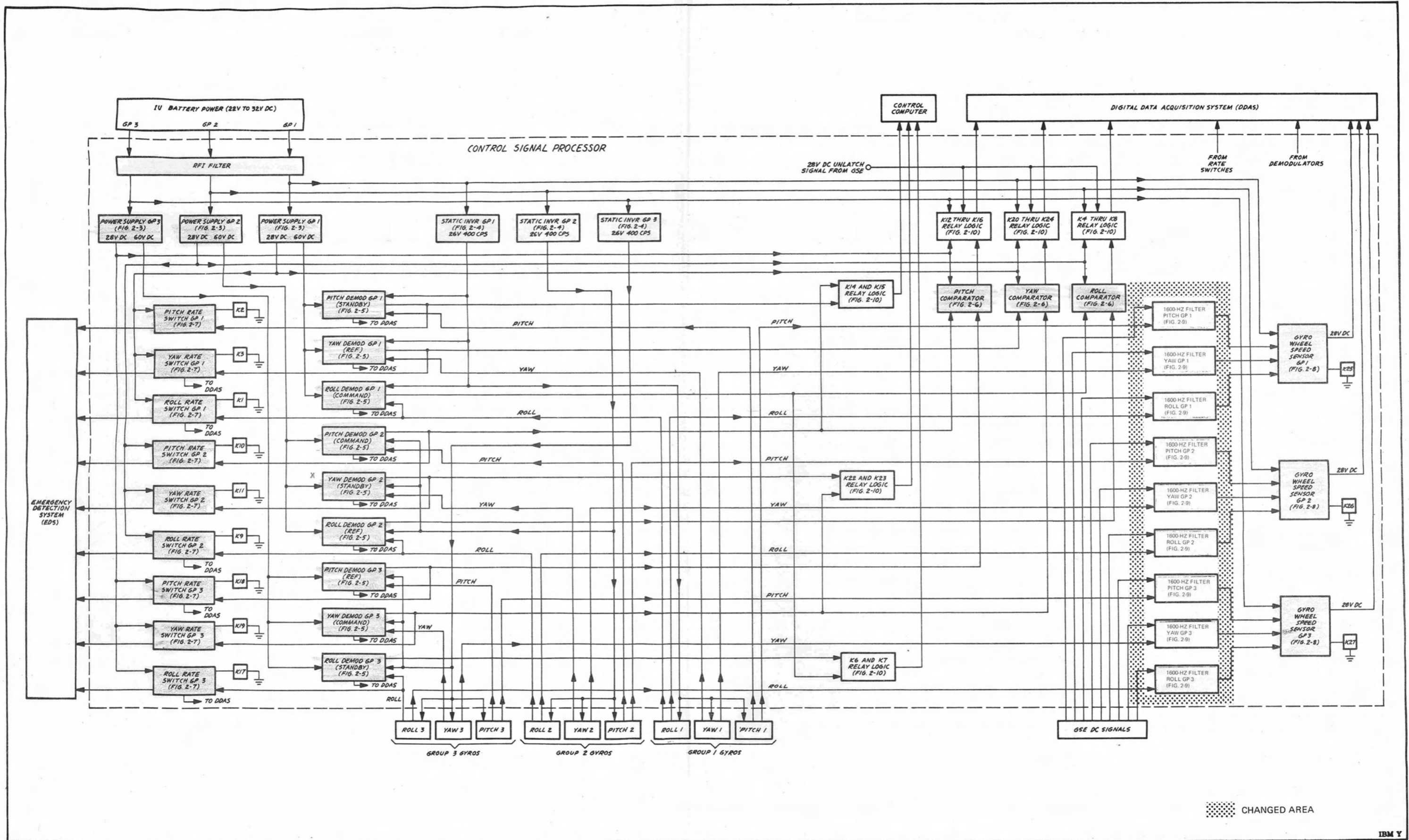
The static inverter receives input power on J32, pins 1 and 2, and generates an output of 26 Vac, 400 Hz. The output voltage is fed to the Rate Gyro Package through connector J5, pins A and B, as excitation power to the gyros. A parallel output voltage is fed to pins 3 and 4 on connectors J21, J22, and J23 of demodulators A14, A15, and A16, respectively, where it is used as a reference voltage. The Group 2 static inverter also supplies power to elapsed time indicator M1 through fuses F1 and F2. Paragraph 2-4 describes the detailed component operation of the static inverter, and Figure 2-4 is its schematic diagram.

For monitoring purposes during GSE checks, both the static inverter and the power supply provide parallel output voltages to test connector J7, pins A, B, W, V, X, and Y.

The three roll demodulators A8, A12, and A16 (associated with the roll comparator) receive a 0 to 11.312 volts peak to peak, 400 Hz error signal from the Rate Gyro Package through J5, pins G and H, pins J and K, and pins L and M, to pins 8 and 10 of J23, J19, and J15, respectively. Demodulators A8 and A12 receive a 26-volt, 400 Hz reference signal and 60 Vdc input power from Group 2 and Group 3 static inverters and power supplies through the identical pins of their respective jacks, as did demodulator A16. There are 2 outputs from each demodulator. One of the outputs, a telemetry signal, is sent to the DDAS for both normal and malfunctioning operation through J4, pins A and B, G and H, and N and P, from pins M and N of J23, J19, and J15, respectively. The other output of each demodulator is sent to Group 1 (roll) comparator A20 and the Flight Control Computer via connector J1.

Demodulator A16 is the command channel output that is sent to comparator A20 from J23, pins B and 1, to J27, pins 11 and 14. A parallel path also goes to the normally closed contacts of K6 and K7. Demodulator A12, the reference channel output, sends its output from J19, pins B and 1, to comparator connector J27, pins 13 and 10. The standby channel output of demodulator A8 sends its output from J15, pins B and 1, to the normally open contacts of K6 and K7. Paragraph 2-5 describes the detailed component operation of the demodulator, and Figure 2-5 is its schematic diagram.

The positive or negative dc levels from command and reference channel demodulators A16 and A12 are compared by comparator A20. When the difference between the two channel inputs is more than ± 7.3 to ± 7.5 Vdc, the comparator establishes a



CHANGED AREA

IBM Y

Figure 2-1
Control Signal Processor Block Diagram

Changed 1 October 1972

2-3/2-4

ground for K5 on pins 8 and 9 of J27. Paragraph 2-6 describes the component operation of the comparator, and Figure 2-6 is its schematic diagram. Paragraph 2-10 describes the operation of the relay logic of K4 through K8, and Figure 2-10 is its schematic diagram. Once relay K5 has been actuated by comparator A20, the standby demodulator signal is sent to the Flight Control Computer through J1, pins A and B. A GSE 28 Vdc reset signal is sent through J6, pin M, to actuate K4 and to reset K4 and K5 in preparation for flight.

Battery power for the EDS switch point is supplied to roll rate switches A13, A9, and A5 through pins 5 and 11 of J20, J16, and J12, respectively. Rate switches A9 and A5 receive 28 Vdc power from Group 2 and Group 3 power supplies. The 28 Vdc power enters on pins 8 and M of J16 and J12, respectively. Each rate switch (A13, A9, and A5) receives a 0 to 11.312 volts peak to peak, 400 Hz error signal from the Rate Gyro Package through J5, pins G and H, pins J and K, and pins L and M, to pins A and 4 of J20, J16, and J12, respectively. As long as an error signal is introduced to the rate switches from the Rate Gyro Package, a telemetry analog output is sent to the DDAS through J4, pins U, S, and Q, from pin 1 of rate switches A5, A9, and A13 only. The yaw and pitch rate switches provide this same output but they are not connected to DDAS connector J4.

During flight, if the gyros in the Rate Gyro Package exceed specified yaw, pitch, and roll rates (refer to Table 1-1), a 28 Vdc signal is sent from pins 2 and 12 of J20, J16, and J12 to the EDS through J2, pins V, W, and X. Paragraph 2-7 describes the detailed component description of the rate switch, and Figure 2-7 is its schematic diagram. The operation of K1, K9, and K17 is described in paragraph 2-10.

During GSE checks, a variable dc torque signal is applied to the three rate gyros (roll, yaw, and pitch) through J6, pins B, C, D, and A. (See Figure 2-2, Sheet 3.) Filter A1 receives this dc signal on J10, pins 8, 10, 12, and torquer common pin 11. The rate gyros are electrically precessed to check the vehicle control loop for proper operation. During flight, the rate gyros send a 1500 Hz to 1700 Hz wheel speed signal through J5 to filter A1, pins B, C, D, and E, to J26, pin 11, on wheel speed A17 and to J10, pins 2, 4, and 7, on filter A1. Filter A1 prevents the gyro error signal from being shorted by the GSE torquer power supply during GSE checks.

Wheel speed A17 receives 28 Vdc power from vehicle battery power through J26, pins 1 and 2. If the wheel speed of the rate gyros is above 1650 Hz or

below 1500 Hz during flight, relay K25 is deenergized through J26, pins 4 and 5. Relay K25 normally open contacts interrupt the telemetry signal to the DDAS. During normal operation, contacts 1 and 3, and 4 and 6 are closed and send a continuous signal to the DDAS through J4, pins J and K. Paragraph 2-8 describes the detailed component operation of wheel speed circuit A17, and Figure 2-8 is its schematic diagram. Paragraph 2-9 describes the detailed component operation of filter A1, and Figure 2-9 is its schematic diagram.

2-3 DC POWER SUPPLY

The dc power supply is a static dc-to-dc converter. See Figure 2-3. Its input is IU battery power which provides 26 Vdc to 30 Vdc. The outputs of the dc power supply are +28 Vdc and +60 Vdc. Each output is independent of the other and is separated from battery return by transformer action. The dc power supply can be divided into 2 sections: the voltage regulator and the 1 kHz chopper and bridge rectifier. There are three identical dc power supply circuits in the Signal Processor.

Voltage Regulator.

The voltage regulator is a series-switching type. It can be subdivided into three operating stages consisting of a free-running multivibrator, a switched regulator, and a 1 kHz chopper. Transistors Q3 and Q4, resistors R1, R4 through R7, capacitor C1, and diodes CR1, CR3, and CR4 are associated with the free-running multivibrator. The switched regulator consists of transistors Q1 and Q2, inductor L1, transformer T1, capacitor C2, resistors R2 and R3, and diode CR2. The 1 kHz chopper consists of transistors Q5 and Q6, and resistors R14 and R15.

Transistors Q3 and Q4 together with R5 and C1 form a free-running multivibrator whose duty cycle is a function of the current flowing into the base of Q4. The resistor-capacitor combination of R5 and C1 performs a positive feedback loop from the collector of Q3 to the base of Q4. The base current has 2 components: One is proportional to the difference between the input voltage and the reference voltage; the other is due to the charge and discharge of C1. The values of R5 and C1 cause the free-running multivibrator to oscillate at a frequency of approximately 8 kHz. Resistors R4 and R6 are the collector loads for Q3 and Q4, respectively. Diodes CR1 and CR4 are used for temperature compensation of Q3 and Q4. Resistor R1 is tied through CR1 between the emitter of Q4 and battery return. This combination of resistor and diode provides a current path for controlling the free-running multivibrator.

Resistor R13 is a sensistor, a temperature sensitive device, which changes its ohmic value over the temperature range. It is used in the circuit to compensate for changes in transformer T2 temperature, and other parameters not compensated for by diodes. Resistor R16 is placed in parallel with R13 to compensate linearly instead of exponentially for temperature changes. Resistor R10 forms a network in conjunction with R8, R9, R11, and R12 to allow the reference voltage on the base of Q4 to be set for nominal operation. Diode CR3 is a Zener diode whose nominal voltage is 9.4 Vdc. Diode CR3, in conjunction with R7, establishes the bias on the emitter of Q4.

Transistors Q1 and Q2, with their associated parts, comprise the switched regulator. Resistors R2 and R3 are base current limiting resistors for Q2 and Q1, respectively. Inductor L1 decreases switching transients by increasing the rise time of pulses appearing at the base of Q1. Capacitor C2 forms an integrating or averaging type of function. Diode CR2 forms a conducting path for T1 during the OFF time of the switched regulator. This protects the collector to emitter junctions of Q1 and Q2.

The voltage regulator operates in the following manner. Upon application of battery power, transistor Q1 will try to delivery energy from the negative terminal of the battery, via T1 into C2. However, its base has no positive bias, and current will not flow. Transistor Q4 is turned ON by the voltage divider formed by R1, R7 through R13, and R16. When Q4 turns ON, a sequence of events starts which causes C2 to charge to a predetermined value (approximately 20 volts). When Q4 turns ON, it drives Q3 into saturation. With Q3 in saturation, a positive battery voltage is placed on the base of Q2. This voltage is also applied as feedback to the base of Q4 to hold Q4 ON for the period determined by the RC time constant of R5 and C1. Transistor Q2 turns ON, thus driving Q1 into saturation. When Q1 is saturated, C2 charges through T1 toward ground level. The charge action of C2 will turn Q4 OFF; Q4, in turn, causes Q3 to turn OFF. At this time, C1 starts discharging into the base of Q2. This turns Q2 OFF, which turns Q1 OFF. This sequence tends to keep a regulated 20 Vdc across C2. When Q1 turns OFF, the current flow is interrupted in T1, causing the voltage on the plate of CR2 to rise above the positive battery level. Diode CR2 becomes forward biased and conducts current until the energy stored in T1 is dissipated. Diode CR2 must carry the maximum load current and have a voltage rating of the maximum battery value (30 Vdc).

Potentiometer R10 is used as a fine adjustment for the reference voltage under the nominal battery conditions (the reference voltage is that voltage which is necessary to turn Q4 ON) and as the output of the dc power supply loaded to its nominal value. This setting is checked by monitoring of the output voltages to ensure they are within specification tolerances. The duty cycle of the voltage regulator under these conditions shall be approximately 50 percent. As the battery input voltage becomes more positive, the duty cycle of the voltage regulator will become less than 50 percent, since, during the ON period of Q1, more voltage is impressed across T1 and thereby more energy is transferred out of C2 in a shorter period of time. As the battery input voltage becomes less positive than 28 Vdc, the duty cycle of the voltage regulator will become greater than 50 percent, since less voltage is impressed across T1 during the ON period of Q1 and a longer period of time elapses for the same amount of energy to be drawn from C2.

Square-Wave Generator and Full-Wave Rectifier.

Transistors Q5 and Q6 and their associated parts comprise a square-wave generator. An output transformer and two full-wave rectifiers complete the second section of the dc power supply.

The square-wave generator consists of transistors Q5 and Q6, resistors R14 and R15, diode CR5, and transformer T2. The resistive network formed by R14 and R15 forms a positive biasing network which insures that the square-wave generator will start upon application of battery power. This combination is also used to supply additional drive to either Q5 or Q6 during their ON state. Diode CR5 is used to compensate for base-emitter changes of Q5 and Q6 over the temperature range of -55°C to $+125^{\circ}\text{C}$ (-67°F to $+257^{\circ}\text{F}$). Transistors Q5 and Q6 are used to drive the primary of T2 and deliver the required power to the load of the dc power supply.

The square-wave generator operates in the following manner. Upon application of the drive voltage, transistor Q5 saturates and Q6 is turned OFF, the +20 Vdc regulated voltage is connected directly across winding number 3 (terminals 1 and 2) of T2, and a voltage is induced in each feedback winding. The voltage which is induced in each base winding is of the correct polarity to hold Q6 OFF and Q5 ON.

When the regulated voltage is supplied to winding number 3, there is a current flow through the coil, which causes the flux in the coil to increase linearly with time until the core saturates. Upon saturation, the current flowing in the base drive windings rises very quickly. At this point, the coil

can induce practically no voltage due to the small change in flux. The voltages that were induced in all windings then start to collapse. Transistor Q5 loses its base drive, thus causing it to cutoff. The current flow must then drop abruptly to zero and the flux will drop by a proportioned amount. This minute decrease of flux induces voltages in all the windings. These induced voltages are of opposite polarity to the previous induced voltages. The voltage in the base windings is then the correct polarity to turn Q6 ON and Q5 OFF. The regulated +20 Vdc is then placed directly across winding number 4 (terminals 2 and 3). This causes a current to flow in winding number 4, which will continue until negative saturation is reached. At this time, the current flow will increase and then cease. The cycle will continue to repeat itself.

The output of T2, which appears across winding numbers 5 and 6 (terminals 16 and 17, and terminals 14 and 15, respectively), is a 1kHz square wave. The amplitude of the square wave is determined by the number of turns on the primary and secondary winding of T2.

The secondary of transformer T2, capacitors C3 through C6, and diodes CR6 through CR13 comprise the full-wave rectifier of the dc power supply. Capacitors C5 and C6 decrease switching transients caused by T2. Diodes CR6, CR8, CR10, and CR12 make up the +28 Vdc rectifier. Capacitor C3 is the filtering capacitor for this rectifier. Diodes CR7, CR9, CR11, and CR13 comprise the +60 Vdc bridge rectifier. Capacitor C4 filters the ac ripple component for this rectifier. The output of the secondary windings of transformer T2 is a square wave with a frequency of 1 kHz. Since each of the rectifiers is a full-wave rectifier, after the square wave has been rectified to direct current, the only ripple that needs filtering is the ripple caused by the rise and fall time of the square wave. Because of the positive bias which is placed on the bases of Q5 and Q6, this time lag or ripple is extremely small. Therefore, the capacitors used in each of the full-wave rectifiers are the only filtering required.

2-4 STATIC INVERTER

The purpose of the static inverter (see Figure 2-4) is to produce highly regulated 26 volt, 400 Hz power from the IU 26 to 30 Vdc battery input power. The 26-volt, 400 Hz power is used to operate the gyros in the Rate Gyro Package and the demodulator circuits contained in the Signal Processor. The static inverter includes the following stages: a frequency regulator, 400 Hz chopper, square-wave power amplifier, 400 Hz bandpass filter, and an ac

voltage regulator which consists of a feedback transformer, rectifier, free-running multivibrator, and switched regulator. There are three identical static inverters in the Signal Processor.

Frequency Regulator

The frequency regulator consists of transistors Q1 and Q2, capacitor C8, diodes CR1 and CR2, and resistors R1, R3, R7, R8, R12, R15, R16, and R17. Resistors R1, R3, R7, R8, R12, R15, and R16 form a voltage divider network for the series voltage regulator, consisting of Q1 and Q2. Resistors R7 and R15 are sensistors whose primary function is to compensate for a change in flux density in A1T2 due to temperature changes. As the temperature increases, the output voltage of the series voltage regulator decreases; conversely, as the temperature decreases, the output voltage increases. This action regulates the output of the chopper to a constant frequency of 400 Hz despite variations of flux density of A1T2 due to temperature changes.

Resistor R16 is placed in parallel with R15 to regulate the compensation in temperature in a more linear fashion. Resistor R12 is a part of the bias network for Q2. Diode CR2 compensates for temperature changes in Q2. Resistor R7 is also a sensistor which aids R15 in compensating for flux density changes of A1T2 due to varying temperature. The value of R3 determines the mid-point setting of potentiometer R8. During GSE checks, the resistance value of R3 is established to center the potentiometer at 400 Hz for operating parameters of a particular static inverter. Resistor R17 establishes the bias for CR1. Diode CR1 is a Zener diode which establishes the reference voltage of 9.4 Vdc for series regulator Q1 and Q2. Capacitor C8 attenuates any ac ripple on the 26 to 30 Vdc battery line. The setting of R8 is adjusted for a 400 Hz output at ambient temperature with a 28 Vdc input.

After R8 has been adjusted for nominal operation, any increase in input power will increase the bias on Q2; conversely, a decrease in input power will decrease the bias of Q2. In either case, the output of Q1 will be regulated by the control action of Q2 and will be approximately +20 Vdc keeping the chopper output at 400 Hz.

400-Hertz Chopper

The 400 Hz chopper consists of transistors Q7 and Q9, transformer A1T2, and resistors R21 and R23. Resistors R21 and R23 form a positive biasing network which insures that the constant frequency

Control Signal Processor Section II

multivibrator will start upon application of battery power. This combination is also used to supply additional drive to either Q7 or Q9 during their ON state. Transistors Q7 and Q9 are used to drive the primary of T2 and develop the 400 Hz frequency for the output of the static inverter.

The operation of the chopper is as follows. Upon application of the drive voltage, if Q7 saturates and Q9 is cut off, the dc regulated voltage is applied directly across winding number 3 (terminals 8 and 12) of T2 and a voltage is induced in each base winding. The voltage which is induced in the base of Q9 is of the correct polarity to hold Q9 cut off, and the voltage induced in the base winding of Q7 holds transistor Q7 in the saturated state.

When the regulated voltage is supplied to winding number 3, there is a current flow through the coil which causes the flux in the coil to increase linearly with time until the core saturates. Upon saturation, current flowing in winding number 3 rises very quickly. At this point, the coil can induce practically no voltage due to the small change in flux. The voltages that were induced in all windings then start to collapse.

Transistor Q7 loses its base drive, thus causing it to cut off. The current flow must then drop abruptly to zero and the flux will drop a proportional amount. This minute decrease of flux induces voltages in all the windings. These induced voltages are of opposite polarity to those induced previously. The voltage in the base windings is then of correct polarity to turn Q9 ON and Q7 OFF. The regulated dc voltage is then placed directly across winding number 4 (terminals 8 and 18). This causes a current to flow in winding number 4 which will continue until negative saturation is reached. At this time, the current flow will increase and then cease. The cycle will continue to repeat itself.

Square-Wave Power Amplifier

The square-wave power amplifier consists of transistors Q8 and Q10, transformer A1T3, diodes CR8 and CR9, and resistors R20 and R22. Transistors Q8 and Q10 are current controlled Class B power amplifiers which are driven in push pull by the secondary of A1T2. The drive from the 400 Hz chopper is sufficient to insure that Q8 and Q10 are driven to saturation by its square-wave output. Resistors R20 and R22 serve as base current limiting resistors for Q8 and Q10. Transformer A1T3 serves two purposes: it changes the push-pull operation to single-ended operation, and isolates the load (the rate gyros and the demodulators). Capacitors C5 and C7 are filter

capacitors for the switched regulator. Diodes CR8 and CR9 serve two functions: when the voltage applied to the base of Q8 or Q10 goes negative, these diodes are forward biased and will prevent the base of either Q8 or Q10 from going negative; when either of these diodes is conducting current, it serves to present a constant load to the voltage regulator which drives the 400 Hz chopper. The dc voltage to the square-wave power amplifier is regulated by the switched regulator.

400-Hertz Bandpass Filter

The 400 Hz bandpass filter consists of inductors A1L2 and A1L3 and capacitors C4 and C6, it also includes the gyro inductance at the output. This bandpass filter has its center frequency at 400 Hz. It will filter out all odd harmonic frequencies and will shape the 400 Hz input square wave into a 400 Hz output sine wave. The sine wave is needed to drive the gyros and is used as a reference signal for the demodulators.

AC Voltage Regulator

The ac voltage regulator consists of feedback transformer A1T1, a dc rectifier, a free-running multivibrator, a switched transistor, and capacitor filtering. Diodes CR3 and CR4 are located in the secondary of A1T1. The center tap of the secondary of A1T1 is tied directly to battery power (26 to 30 Vdc). The primary of A1T1 is in parallel with the output of the 26-volt, 400 Hz bandpass filter and the load. When 26-volt, 400 Hz power is applied to the primary of A1T1, full-wave rectification occurs and the rectified peaks are passed on to charge capacitor C2. If the output voltage from the 26-volt, 400 Hz bandpass filter increases, the voltage on C2 becomes greater. This has the effect of changing the duty cycle of free-running multivibrator Q5 and Q6 so that the switched transistor has a decreased ON time. The increased OFF time of Q3 causes a greater average drop across Q3 and less dc for the filtered output. This action causes a reduction in regulated dc to the power amplifier and a constant drop in ac amplitude. Thus the original ac voltage increase has been compensated by a decrease in drive. Conversely, if the output voltage decreases across the output, the voltage across C2 becomes less, and Q3 stays ON for a longer period of time. This action causes a greater regulated output with a resultant increase in ac drive. The net result is a regulated 26 Vrms output.

The free-running multivibrator consists of transistors Q5 and Q6, resistors R9, R10, R11, R13, R14, R18, R19, R24, and R25, diodes CR6 and CR7,

and capacitor C1. The switched transistors stage consists of Q3 and Q4, resistors R4 and R5, diode CR5, and inductor L1. The operation of the voltage regulator is identical to the operation of the voltage regulator described in paragraph 2-3.

Resistor R2 assures that the free-running multivibrator turns ON when power is applied to the static inverter. Capacitor C3 feeds back a ripple component from the output of switched transistors Q3 and Q4 to the junction of C2 and R6. This ripple component is out of phase with the ripple component from the full-wave rectifier (diodes CR3 and CR4) and tends to reduce frequency modulation of the free-running multivibrator.

2-5 DEMODULATOR

The demodulator is driven by the error signal outputs of the rate gyros. See Figure 2-5. Nine demodulators are contained within the Signal Processor, one for each of the gyros in the Rate Gyro Package. The normal output of each gyro is a zero signal. However, due to abnormal vehicle motion, the output may be an amplitude-modulated carrier signal of 400 Hz. The purpose of the demodulator is to accept this error signal, amplify and demodulate it, extract the modulation component, and produce a dc signal as a final output. This final output is proportional to the amplitude of the modulated signal. The output of the demodulator is a two-line output, both of which are isolated from ground. With no input signal, the potential between both outputs is zero. When an error signal is developed, the polarity of one output is negative with respect to the other output — not with respect to ground. The dc output is applied to the Flight Control Computer and is proportional to the output of the rate gyros.

The demodulator is essentially made up of 4 stages consisting of an ac amplifier, a demodulator, rectifier-filter, and dc amplifier.

AC Amplifier

The ac amplifier consists of transformer T1, transistors Q1 through Q4, capacitors C1, C2, C3, and C9, resistors R1, R2, R13 through R15, R17 through R21, and R26. Transformer T1 is used for isolation from the Rate Gyro Package. Capacitor C1 is used for ac coupling of the signal between the base of Q1 and the secondary of T1. Resistors R1 and R17 are used to set the dc bias on the base of Q1. The series combination of R18 and R26 form the emitter load of Q1. With respect to dc, these resistors are referenced to ground through R32, a part of the dc amplifier. The dc drop across R32 varies with

temperature and helps maintain the gain of the ac amplifier fairly uniform over the temperature range. Capacitor C9 is a bypass capacitor used to improve the gain of the ac amplifier. Resistors R13, R14, and R15 constitute the ac feedback within this amplifier. Resistor R14, a sensistor, is used to stabilize the gain of the amplifier over the temperature range of -50°C to $+125^{\circ}\text{C}$ (-58°F to $+257^{\circ}\text{F}$), and resistor R15 is used as a fine gain adjustment. Resistor R2 is an emitter load resistor for Q2. Resistor R19 is the collector load for Q2. Resistor R20 is the base return for Q4. Capacitor C2 acts as a high-frequency bypass at the collector of Q2. Resistor R21 is the emitter load for Q3 and Q4, and C3 couples the output of Q4 to the primary side of T2. The output of the particular rate gyro is coupled into the ac amplifier through T1 and C1.

Demodulator

The demodulator circuit is isolated from the ac amplifier by interstage transformer T2. Transformer T2 also serves to change the single output of Q4 to a signal isolated above ground, which is necessary for demodulator operation. The demodulator consists of transformer T3 and diodes CR1 through CR4. Resistors R3 and R27 are current limiting resistors. Resistor R8 is a null adjustment which balances the system so that zero output is obtained for a no-signal input condition. Capacitor C6 maintains the center tap of T2 at ac ground.

The primary winding, pins 1 and 2, of T3 has a 26-volt, 400 Hz signal applied to it from the inverter. This signal is constant in both amplitude and frequency. The input signal from the rate gyro is amplified by the ac amplifier, coupled through C2 to the primary of T2. Transformer T2 steps the signal up and feeds it to diodes CR1 through CR4. The rectified output of CR1 through CR4 is mixed with the 26 Vac signal in T3 so that, depending on the phase relationship between the rectified peaks and the ac signal, a positive or negative output is obtained.

Rectifier-Filter

The rectifier-filter consists of inductors L1 and L2, and capacitors C4, C5, and C7. Resistors R5, R9, R22, and R29 are the rectifier load. Inductors L1 and L2, and capacitors C4, C5, and C7 form a low-pass filter. They allow the dc sum of the amplitude and phase difference established by the demodulator to be passed to the dc amplifier, and filter the high-frequency ripple component.

DC Current Amplifier

The dc current amplifier consists of transistors Q5 through Q11, capacitors C8, C10, and C11, diodes CR5 and CR6, and resistors R6, R7, R10 through R12, R16, R23 through R25, and R30 through R33. The dc amplifier provides two outputs: one to the Flight Control Computer and the other is a scaled-down value for telemetry. The telemetry output is developed across R16 and provides monitoring of the demodulator while the vehicle is in flight. The output to the Flight Control Computer is developed across R7, R16, and R31.

The dc current amplifier consists of Q5A and Q5B, Q6 and Q8, and Q7 and Q9, with constant current generators Q10 and Q11. Dual transistor Q5A-Q6 and Q5B-Q8 are high input impedance buffer stages. The differential configuration of the current nullifies the ac ripple which is present on the output of the filter. Capacitor C5 provides additional filtering. Capacitors C10 and C11 are parasitic suppressors that prevent high-frequency oscillations; thereby aiding in stabilization of the dc amplifier. Capacitor C8 is a filtering capacitor which attenuates any high-frequency transients appearing on the output. Diodes CR5 and CR6 are temperature compensators for Q10 and Q11, respectively. Resistors R10 and R23 comprise a voltage divider network which establishes a bias voltage for differential inputs to Q5A and Q5B. Resistors R11 and R24 are collector load resistors for Q6 and Q8. Resistors R6 and R25 establish the bias for Q11. Resistors R12 and R30 establish the bias for Q10.

The dc current amplifier, consisting of Q5 through Q11, has two distinct advantages: it improves long term circuit stability and establishes a higher input and lower output impedance for better isolation between the demodulator circuit and the Flight Control Computer. Transistors Q10 and Q11 reflect a low, constant impedance to the load which helps maintain excellent linearity over the range of operation. They also provide a high common mode rejection ratio by having the current return path of one side dependent upon the voltage of the other side.

The operation of the dc amplifier is as follows: If the demodulator receives a modulated signal from the rate gyro phased in such a manner as to cause output B to be positive with respect to output A, the signal received from the filter and rectifier is such as to produce a positive dc potential on the base of Q5A and a negative dc potential on the base of Q5B. The positive potential on the base of

Q5A causes it to start drawing more current, which drives Q6 harder. This action drives Q7 further into the ON state. Transistor Q5A places the voltage on output B, and Q7 acts as a current source from output B. The positive potential is coupled from output B to the base of Q11 through R6, causing Q11 to turn ON. This allows a return path for the current from the load through CR6 and R33 to ground.

The negative potential which is applied to the base of Q5B causes it to conduct less, thereby driving Q8 to cutoff. This, in turn, causes Q9 to conduct less current and the negative signal is impressed on output 1. Therefore, a push-pull dc signal has been produced by referencing output B to output 1. This signal is developed across series resistors R7, R16, and R31.

2-6 COMPARATOR

The comparator circuit (see Figure 2-6) compares the outputs of the command demodulator and reference demodulator. If the difference between these outputs becomes greater than ± 7.4 Vdc, the comparator circuit, by means of relays, will switch the command demodulator out of operation and the standby demodulator into the command position to feed the Flight Control Computer. The comparator consists of two differential amplifier stages, an amplitude sensor, a voltage reference network, a constant current source, and a relay driver. There are three identical comparator circuits in the Signal Processor.

Differential Amplifiers and Constant Current Source

The first differential amplifier stage consists of Q1A and Q1B, R1 through R5, R8 through R11, and R13. The second differential amplifier stage consists of Q4 and Q5, R14 through R20, and C1 and C2. The constant current source stage consists of R6, R19 and R20, R23 through R25, CR4, and Q2 and Q3. Since the functions of each of these stages are closely related, they will be explained collectively. Resistors R1 through R5 act as bridge resistors for the 2 voltages being compared. The differential output from this network is developed across R3 and R10 and is used to drive the bases of Q1A and Q1B in a push-pull manner. The junction of R3 and R10 is returned to a reference voltage developed by Zener diodes CR3 and CR4. The emitters of Q1A and Q1B, via R8, R13, are returned to constant current source Q2. The voltage on the collector of Q2 is near that of the reference diodes and therefore establishes a common mode dc bias for Q1A and Q1B. This

common mode bias is adjusted with potentiometer R20 and in conjunction with transistor Q3, is used to set the trigger voltage of the circuit (nominally ± 7.4 Vdc). The output of the first differential amplifier Q1, is directly coupled to the second differential amplifier Q4 and Q5. Resistors R7 and R12 are feedback resistors to reduce and stabilize the gain of the two differential amplifiers. Resistor R14 is the common emitter resistor for Q4 and Q5. Resistors R17 through R20 form the collector load for Q4 and Q5. Resistors R15 and R16 and capacitors C1 and C2 form a roll-off network to limit the bandpass of the differential amplifiers.

Amplitude Sensor and Voltage Reference Network

The amplitude sensor circuit consists of CR1 and CR2, Q6, R21 and R22, and C3. Resistor R21 and R22 and the emitter-base of Q7 form the collector load for Q6. Capacitor C3 serves as a high frequency and noise bypass to minimize relay chatter. The emitter of Q6 is referenced to a voltage developed by Zener diodes CR3 and CR4 in combination with R26. The base of Q6 is returned to the balanced output of Q4 and Q5 through CR1 and CR2.

Relay Driver Stage

Transistors Q7 and Q8 form the relay driver stage. Transistor Q7 permits phase inversion so that Q8 may be driven directly from Q6. Diode CR5 protects Q8 from breakdown when the relay is deenergized.

Comparator Circuit Operation

The outputs of the reference demodulator and command demodulator are cross connected to the inputs of the comparator circuits. For explanatory purposes, the two demodulator outputs are designated as "A" and "B". High means positive and low means negative. The cross connection serves to place the complementary base drive on both halves of Q1 during normal demodulator operation.

As an example of comparator circuit operation, assume that the high output of demodulator "B" goes negative with respect to the high output of demodulator "A". This causes a negative signal to be applied to Q1B, which turns it OFF. This action causes the collector of Q1B to go positive, thereby driving Q5 toward cutoff. At the same time, Q1A is driven further into conduction, making its collector go more negative. This will drive Q4 further ON.

This disturbs the balance that previously existed on CR1 and CR2 and causes CR1 to turn ON and CR2 to turn OFF. This causes Q6 to turn ON.

When the base of Q6 goes positive, causing it to turn ON, its collector voltage drops and causes the base of Q7 to go negative with respect to its emitter. This causes Q7 to saturate, which in turn drives Q8 into saturation. This supplies a ground to the collector of Q8, completing the return circuit for the relay that Q8 controls. Once the relay has been energized, it will remain energized due to the latching action of a second relay, placing a collector-to-ground dc path on Q8. This action is described in paragraph 2-10.

2-7 RATE SWITCH

The rate switch circuits can abort a flight if the rate gyros indicate excessive gyrations of the vehicle. Output from the rate gyros is an amplitude-modulated signal that is directly proportional to the rate of change of the gyro position. The range of voltage from the rate gyros may be from 0 to 11.312 volts peak to peak. Since there are nine rate gyros in the Rate Gyro Package, there are also nine rate switches in the Signal Processor. One rate switch printed circuit board contains three rate switch circuits. There are three identical rate switch printed circuit boards, one for each channel of the Signal Processor. The rate switch circuit illustrated in Figure 2-7 is typical of each of the nine rate switches.

Pitch and yaw rate switches are identical. Each circuit consists of a voltage divider and filter for the input signal, four-diode quad transmission gates, a differential buffer amplifier, a zener diode reference voltage regulator, a differential amplifier, and a relay switch. A single pitch and yaw rate switch trigger relay is common to both pitch and yaw circuits. The pitch and yaw rate switches have two outputs each.

The roll rate switch has a reference signal isolation transformer, four-diode quad demodulator, a differential buffer amplifier, an emitter-follower, a differential amplifier, a four-diode quad transmission gate, two differential amplifiers, and a relay switch. The roll rate switch has three outputs.

The analog telemetry output is not used in the pitch and yaw rate switches. The second output of both pitch and yaw switches is sent through a relay; when the relay is energized, a signal is applied to the EDS, indicating an abort condition exists. The roll

Control Signal Processor Section II

rate switch telemetry output is a dc analog voltage of the roll gyros, which is fed to the DDAS.

Pitch and Yaw Circuits

The pitch and yaw circuit schematic is shown in Figure 2-7, sheets 1 and 2, respectively. The output from the demodulator is fed directly to the filter through R1 and R34, and to the diode quads CR1, CR2, CR5, and CR6. The filter consists of C1 and C2 and resistor network R13, R14, R21, R22, and R23, and has a 3 db corner at 5 Hz. The diode quads convert the bipolar dc signal to a unipolar positive signal regardless of the phase of the signal from the demodulator.

The output of the diode quads is applied to a differential stage. The differential amplifier, Q1 through Q4, acts as a buffer amplifier with unity gain. The right half of the differential stage establishes a very stable reference voltage with diode CR4 (6.4-volt zener), in the collector of Q3. Potentiometer R31 and resistor R18 form a divider across the zener diode to establish the switch point for the second differential amplifier, Q5, Q6, and Q7.

The second differential amplifier has extremely high gain and is operated from an OFF state to a saturated state by the voltage established by the setting of potentiometer R31. Thus the trigger point of the circuit is set by the dc level at this point. While the voltage across CR4 remains stable, the dc level at CR4 swings up and down with respect to ground. This action ensures a differential mode of operation with minimal drift errors. The output of Q7 is directly coupled to the base of Q8. When Q7 goes from an OFF state to an ON state, Q8 is turned ON and operates a relay on the motherboard.

Two switch points are selectable in the circuit (refer to Table 1-1 for rate switch settings). With relay K2 deenergized, the circuit triggers at the smaller of the two switch points. When a switch point signal is applied to relay K2, relay contacts transfer the switch trigger from the smaller to the larger switch point.

Diode quads CR1, CR2, CR5, and CR6, operating as transmission gates, are matched units to keep temperature drift to an absolute minimum. Transistors in both differential amplifiers are also matched to maintain the drift per stage down to less than 5 mV.

Diode CR4 is a temperature-compensated, 6.4-volt zener diode, operating at 1 mA. CR4 in the yaw and pitch circuits is a type 1N4574A, which has a temperature coefficient of ± 0.03 mV/ $^{\circ}$ C from -55° C to $+125^{\circ}$ C (-67° F to $+257^{\circ}$ F).

Telemetry Output - Telemetry outputs from the yaw and pitch rate switches are brought out after the filter only; telemetry before the filter is the same as a demodulator telemetry output. The telemetry divider output impedance is less than 5 kilohms. Resistors R14, R21, and R22 form a voltage divider to produce a dc output of 1 Vdc for every 2 Vrms into the demodulator. The input to the pitch and yaw rate switch may go as high as 55 V under conditions of maximum signal input. Resistors R1 and R34 divide the output of the demodulator so that with a 45-volt signal, the input to the filter across C1 is 15 V. The input to the diode quad across C2 is 5.0 V, and the telemetry output across R21 is 1.0 V. These voltages are either positive or negative, depending on the phase relationship of the ac inputs into the demodulator. For this reason, C1 and C2 are nonpolarized capacitors. The telemetry linearity is within the stated ± 5 percent of full output.

Relays K1 and K2 are in parallel in the circuit so that if a 28 Vdc switch signal is received, both relays are energized. Relay K2 switches the yaw and pitch trigger points, and K1 switches the roll trigger points.

The dynamic range of the yaw and pitch rate switches is from 0 to ± 10 degrees. The trigger point of the circuit can be adjusted anywhere from 0 to 2.0 Vrms with the potentiometer R31 (or R32). The resolution of the potentiometer is sufficient to permit a setting that is repeatable to less than 10 mV.

Roll Circuit

The roll rate circuit schematic is shown in Figure 2-7, sheets 3 and 4. The roll circuit differs from the yaw and pitch circuits in that it has a demodulator in the front end. This demodulator is required because the roll circuit has to operate over a dynamic range of ± 20 degrees per second; the CSP demodulators begin to saturate above 10 degrees per second and therefore cannot be used. Following the demodulator section, the circuits are similar to the yaw and pitch circuits; therefore this description will treat the demodulator section and other associated circuits not previously described.

The 26 Vrms reference signal is fed to isolation transformer T-1, having a 1 to 1 ratio.

The secondary of T-1 is connected to a four-diode quad demodulator, CR13 through CR16, arranged in such a way that two of them are biased ON during the positive excursion and two are biased ON during the negative excursion of the 400 Hz reference signal. The 400 Hz input signal (0 to 4 Vrms) is fed to alternate pairs in such a way that when the reference and the signal inputs are in phase, a positive output is obtained, and when they are out of phase, a negative output is obtained. This demodulator output is fed to differential amplifier Q17, Q18, Q19, and Q21. The signal from the demodulator is full-wave pulsating dc and requires filtering. Filtering is accomplished with capacitors C16 and C20 in the differential amplifier, which also provide the first corner of the roll circuit filter. The differential amplifier, which acts as a buffer with unity gain, is direct coupled to emitter-follower Q20. This is necessary to keep the telemetry output impedance low (below 5 kilohms) and the collectors of stage Q18, Q19 from being loaded. The output of the emitter-follower is fed to resistive divider R138, R141, and R142.

Resistor R117, across the 0 to 4 Vrms input, is used to reduce the input impedance of the roll rate switch to 12.9 kilohms \pm 3 percent. This value, in parallel with the demodulator, maintains the combined input impedance at 10 kilohms \pm 5 percent.

The telemetry output is obtained across R141. The signal is then fed to diode quads CR17 through CR20, which operate as transmission gates, and convert the bipolar signal to a unipolar dc level that is always positive regardless of the polarity of the signal out of the demodulator. The signal has previously been either positive or negative, depending on the phase relationship of the rms input to the reference 400 Hz.

Differential amplifier Q22, Q23, and Q24 is used to bias the diode quads. This amplifier has high gain and actually switches the bias signal to the quads full positive or negative. The positive signal out of the diode quads is fed to a circuit that is very similar to the yaw and pitch circuits.

Telemetry Output - The telemetry output from the roll rate switch is brought out both before and after the filter. The telemetry output before the filter is obtained with dividers R116, R122, and R123, which are connected directly across the differential output of Q18 and Q19. Although designated as coming from a point before the filter, this output is already subject to the roll-off characteristics of demodulator filter capacitors C16 and C20. These capacitors put the first corner at 30 Hz, while capacitor C13 places the

second corner at 5 Hz with a resultant attenuation of 6 db per octave from 5 to 30 Hz and 12 db per octave above 30 Hz.

The telemetry output after the filter is taken from across R141, which is part of the divider at the input of Q22. The amplitude of the telemetry signal (1.0 Vdc for every 4.0 Vrms at the input) is the same before and after the filter (with modulation below 5 Hz) because the before and after resistor dividers are the same and the voltage gain of emitter-follower Q20 is approximately unity. The telemetry linearity is within \pm 5 percent of full output.

The dynamic range of the roll rate switch is 0 to \pm 20 degrees/second. Potentiometer R150 and R151 can be adjusted to set the trigger point of the circuit anywhere from 0 to 4 Vrms. Two switch points are selectable with K1, although both are set at 4 Vrms. When K1 is energized, the switch point does not change; instead, control is shifted from potentiometer R150 to R151.

The roll circuit has a two-section filter with a 3 db corner at 5 Hz. The capacitive element of the first section forms part of the feedback network of the differential amplifier associated with Q17, Q18, Q19, and Q21. Capacitor C13 forms the second element of the filter.

2-8 WHEEL SPEED

The wheel speed circuits monitor the speed of the nine gyro wheels of the Rate Gyro Package during ground checkout operations and during vehicle flight via telemetry. Each circuit monitors the speed of the gyros contained in the individual groups that make up the Rate Gyro Package. Three gyros in each group or channel measure the deviations of the vehicle in pitch, roll, and yaw. Each channel is monitored by one wheel speed circuit. Three identical wheel speed circuits are contained on one printed circuit board. The wheel speed circuit differs from the other circuits contained in the Signal Processor in two major ways: (1) The wheel speed circuits are not mandatory flight hardware circuits. That is, they are not absolutely essential to the operation of the Signal Processor once the vehicle lifts off and is in flight. (2) The wheel speed printed circuit board contains its own dc power supply and dc regulator.

The wheel speed circuitry is made up of eight major sections. See Figure 2-8. The first section is repeated three times and is referred to as the input section. The next 2 sections are positive and negative input gates. The next section is the

Control Signal Processor Section II

amplifier and relay driver section. The last 2 sections are a dc power supply and dc regulator.

Input Section

The input section consists of 4 stages: a voltage reference stage, an amplifier stage, a differentiating stage, and an integrating and current amplifier stage. Only one of the three sections shall be discussed, since all three are identical in operation except that each section monitors a different channel. The input section that is discussed is labeled number 1.

The voltage reference stage consists of Q1 and Q2, with Q1 being the driver and Q2 establishing the reference voltage. Resistor R1 and the emitter-base of Q3 are the collector load for Q1. Resistor R18 is the common emitter load for Q1 and Q2. Resistor R12 establishes a dc bias for Q1 from Zener diode CR2. Transistor Q2 is biased ON by the reference voltage of Zener diode CR2. The amplifier stage consists of Q3 and collector load resistor R19.

The differentiator stage consists of transistor Q4 with its emitter load resistor R8 and capacitor C3. Diode CR1 serves as a clipping diode, which allows only the positive going signal from the differentiator to be passed into the integrator portion of the next stage. The integrator consists of 2 parts. One part serves as a feedback to Q4; the other serves to produce a driving potential, in tandem with the first part, to Q5. The first part of the integrator consists of C5 and R20. The second part is made up of R13 and C6. The current amplifier stage consists of transistor Q5, potentiometers R3 and R4, and resistor R2. The current amplifier stage is actually an emitter follower.

The input signal to the wheel speed circuits originates from the rate gyros. This signal is fed into the base of Q1, which is normally biased near saturation. The smallest positive input signal drives Q1 into saturation and turns Q3 hard ON. Transistor Q3 switches and forms a very fast rise time to the positive going portion of the input signal. This rise time is differentiated by the action of C3 in conjunction with R8 and Q4. The positive portion of the differentiated signal is fed through CR1 into the integrator. The integrator produces a positive dc level which is proportional to the rate at which it receives energy from the preceding stages. When this dc signal reaches a given level, Q5 operates one of the succeeding input gates.

Positive and Negative Input Gates

The positive input gate is so named because the transistors that make up its input conduct harder when a positive bias is applied to these bases. The positive input gate consists of transistors Q7, and Q12 through Q14, sense transistor Q6, resistors R5, R21, and R27, diode CR3, and capacitor C1. The common emitter resistor for all four transistors is R27, and the common collector load for Q6 is R5. Capacitor C1 slows down the operating response time of the positive input gate. The negative input gate consists of transistors Q24, Q32, and Q34, sense transistor Q21, resistors R33 and R51, and capacitor C13.

If all three rate gyro wheels are up to their nominal speed of 1600 Hz, and all of the integrators are putting out their nominal positive level, Q6 is biased ON by the voltage from reference diode CR2. Potentiometers R4, R25, and R39, on the output of the three input sections, are set to allow the input transistors for the positive input gate to conduct at a preset level when the input frequency deviates by +50 Hz. When Q7, Q12, or Q14 is driven ON, Q6 and Q13 are driven OFF. (Transistor Q13 is normally ON.) When Q13 is driven OFF, its collector goes to ground and causes diode CR3 to become forward biased. This drops the anode potential on CR3 to approximately 1.0 volt and causes Q22 base and emitter voltage to drop. This drop is reflected to the collector of Q25, where it is used to operate relay driver Q26. Transistor Q33 is normally ON, causing the relay to be energized. When the above action occurs, Q33 drives OFF and the relay deenergizes.

The negative input gate operates in the same fashion, but it does so when the dc from the integrator drops due to a reduction in frequency of -50 Hz. The frequency bandwidth of 1600 (+50 Hz to -100 Hz) is intentionally established by the setting of R4, R25, and R39 to the 1650 Hz limit and R3, R24, and R38 to the 1500 Hz limit.

Amplifier and Relay Driver

The amplifier and relay driver section contains: a voltage reference stage consisting of transistors Q22 and Q25 and resistors R34, R35, R40, and R41; an amplifier stage consisting of transistor Q26 and resistor R44; and relay driver transistor Q33. The voltage reference stage has a common emitter load resistor R34. The driving side of the

voltage reference stage has a collector resistor R35. Resistors R40 and R41 establish a bias voltage for Q25. The base of Q26 is connected to the reference voltage from CR2.

When the gyro wheel speeds are at their proper operating point, the potential which is impressed on the base of Q33 is positive and keeps Q33 turned ON. This voltage is positive because the emitter of Q26 is raised with respect to the reference 9.2 volts on the base. This will allow its collector to go positive, thereby driving Q33 into saturation and supplying a ground to energize either relay K25, K26, or K27 (located on mother board). If the gyro wheel speed increases above or decreases below the proper operating speed (by the specific tolerances of plus or minus 50 Hz), the potential which is impressed on the base of Q22 will go close to zero. This will cause Q22 to cut OFF, tending to reduce the potential on the collector of Q25. In turn, Q26 turns OFF, allowing its collector to go to ground. This causes Q33 to turn OFF, and a particular relay, depending on the operating channel being monitored, will deenergize. When the relay deenergizes, it will interrupt the monitoring signal being sent to the DDAS and will indicate a malfunction of 1 of the 3 rate gyros. The circuit is not capable of telling which of the 3 gyros is off frequency. It merely indicates that 1 of the 3 gyros is malfunctioning.

DC Power Supply

The dc-to-dc converter changes IU battery power of 26 to 30 Vdc to a regulated dc using a chopper-rectifier circuit consisting of transistors Q20 and Q23 and resistors R42 and R43. The chopper frequency and output are generated by T1 and rectified by bridge rectifiers CR4, CR5, CR6, and CR7. Capacitor C8 reduces ac transients on the secondary winding of T2. Inductor L1 and capacitor C10, located on the input side of the chopper, are needed to block voltage transients, produced by the chopper, from being fed back to the vehicle battery. The turns ratio of T1 are such that when the vehicle battery voltage reaches 26 Vdc, the output of the bridge rectifier is still more positive than the output of the dc regulator. Resistors R42 and R43 establish a bias for Q20 and Q24 to insure turn-on of the chopper when power is applied.

DC Regulator

The dc regulator consists of 3 stages: a voltage reference stage, a sense stage, and a series regulator. The voltage reference stage is comprised

of transistor Q8, resistors R6, R9, R14, and R16, resistor R15, and diode CR2. Resistor R9 is the base current bias resistor for CR2. Resistor R14 is the common collector load for Q8A and Q8B. Base bias for Q8B comes from the combination of resistors R6 and R16 in series with resistor R15. The resistor varies the regulated output to maintain the trigger point of the circuit constant over the temperature of -50° C to +125° C (-58° F to +257° F). Diode CR2 is the reference voltage diode for the operating circuits of the wheel speed printed circuit board.

The sense stage consists of transistor Q11, resistors R10 and R11, and capacitor C2. Resistor R11 establishes the base bias for Q11. Capacitor C2 and resistor R10 form a fast response network for Q11.

The series regulator consists of driver transistor Q10 and series dropping transistor Q9, resistors R7 and R17, and capacitors C4 and C7. Resistor R7 affords open circuit protection to Q9. Resistor R17 establishes base bias for Q10 and also is a partial collector load for Q11. Capacitors C4 and C7 are filter capacitors.

In operation, voltage sensing transistor Q8B senses any change in output voltage by conducting either more or less heavily, depending on the drop across R6, R15, and R16. This change in conduction is reflected to Q8A. Transistor Q8A conducts heavier or lighter, depending on whether Q8B is conducting lighter or heavier. Transistor Q8A, in turn, regulates the drive on the base of transistor Q11. The bias that Q11 places on Q10 will then regulate the point at which Q9 operates and will oppose any change in rectified output. The voltage drop across Q9 will tend to hold the output of the dc regulator constant at +18 Vdc and establish a regulated output for operation of the wheel speed circuit.

2-9 1600-HERTZ FILTER

There are three 1600 Hz filter printed circuit boards in the Signal Processor. Mounted on each of the printed circuit boards are three separate 1600 Hz filter circuits: one for each of the pitch, roll, and yaw rate gyros associated with one group or channel. The purpose of each of the filter circuits is to isolate the Signal Processor wheel speed circuits from the variable dc signal used during GSE checks to precess the gyros.

Control Signal Processor Section II

Each filter circuit consists of a LC resonant tank, a coupling capacitor, and a bypass capacitor. (See Figure 2-9.) Capacitor C2 and transformer T1 make up the tank circuit, capacitor C1 couples the rate gyro wheel speed signal to the wheel speed circuit, and capacitor C7 bypasses noise to ground. The variable dc precession signal is applied to torquer pin 8 and enters the rate gyro through pin 2. The two remaining filter circuits shown in Figure 2-9 are identical in operation.

2-10 MOTHER BOARD COMPONENT DESCRIPTION

The mother board (Figures 2-2 and 2-10) contains the following components: resistors R1 through R15, capacitors C1 through C15, fuses F1 and F2, meter M1, filter FL1, transducer MT1, connectors J1 through J33, relays K1 through K27, and associated wiring. Each of the resistors on the mother board functions as current limiting resistor for 28 Vdc output signals. Capacitors C1 through C3 and capacitors C10 through C15 reduce noise originating from the power supply and static inverter circuitry. Capacitors C4 through C9 are placed on the outputs of the power supply to prevent the 28 Vdc and 60 Vdc power from becoming modulated by the static inverter outputs. Capacitors C10, C11, and C12 were added to eliminate noise on the GSE line.

Meter M1 is an elapsed time indicator and fuses F1 and F2 protect the meter from possible shorts. Filter FL1 is a RF filter used to attenuate noise on the power input lines generated by the power supply and static inverter circuitry. Filter FL1 attenuates signals from 150 kHz to 25 MHz. Its maximum dc resistance is 0.065 ohm.

Transducer MT1 measures the atmospheric pressure inside the pressurized case of the Signal Processor. This information is relayed to the DDAS. Connectors J8 through J33 provide plug-in capabilities for the printed circuit boards of the Signal Processor. Connectors J1 through J7 are the input and

output connectors for the Signal Processor. Connector J1 carries demodulator signal outputs to the Flight Control Computer; J2 is the EDS output jack; J3 receives 26 to 30 Vdc power from the IU batteries; J4 is the DDAS output; J5 is the Rate Gyro Package input-output jack; J6 receives GSE inputs; and J7 is a test jack for bench checks of the Signal Processor.

When relays K1 through K3, K9 through K11, and K17 through K19 are energized by the rate switch circuits, they send signals through connector J2 to the EDS and through J4 to the DDAS. When relays K25 through K27 are energized by the gyro wheel speed sensor circuits, they send an output to the DDAS.

Relays K4 through K8, K12 through K16, and K20 through K24 are associated with the comparator circuits. The circuit illustrated on Figure 2-10 depicts the roll comparator relay logic. The outputs of the roll command demodulator and the roll reference demodulator are compared and when the algebraic difference exceeds ± 7.4 Vdc, relay K5 receives a ground from the relay driver of comparator Q8 and energizes. The normally open contacts of K5 close and vehicle battery power is applied to K6, K7, and K8. The normally open contacts of K8 close, connecting the collector of Q8 to common, preventing K5 from deenergizing, and thus latching the circuits. When relays K6 and K7 energize, the normally closed contacts of K6 open and the normally open contacts of K7 close simultaneously. This action removes the roll command demodulator from the Flight Control Computer circuit and transfers the roll standby demodulator into the circuit. During flight, a switch to a standby demodulator is permanent. On the ground, the circuit may be unlatched by energizing K4 with a 28 Vdc GSE signal. When relay K5 energizes, a 28 Vdc signal from vehicle battery power is sent to the DDAS, indicating that switching action has occurred in the circuits monitoring roll motion. Since the pitch and yaw channels are identical in operation, the particular relays associated with these channels operate identically to those of the roll channel.

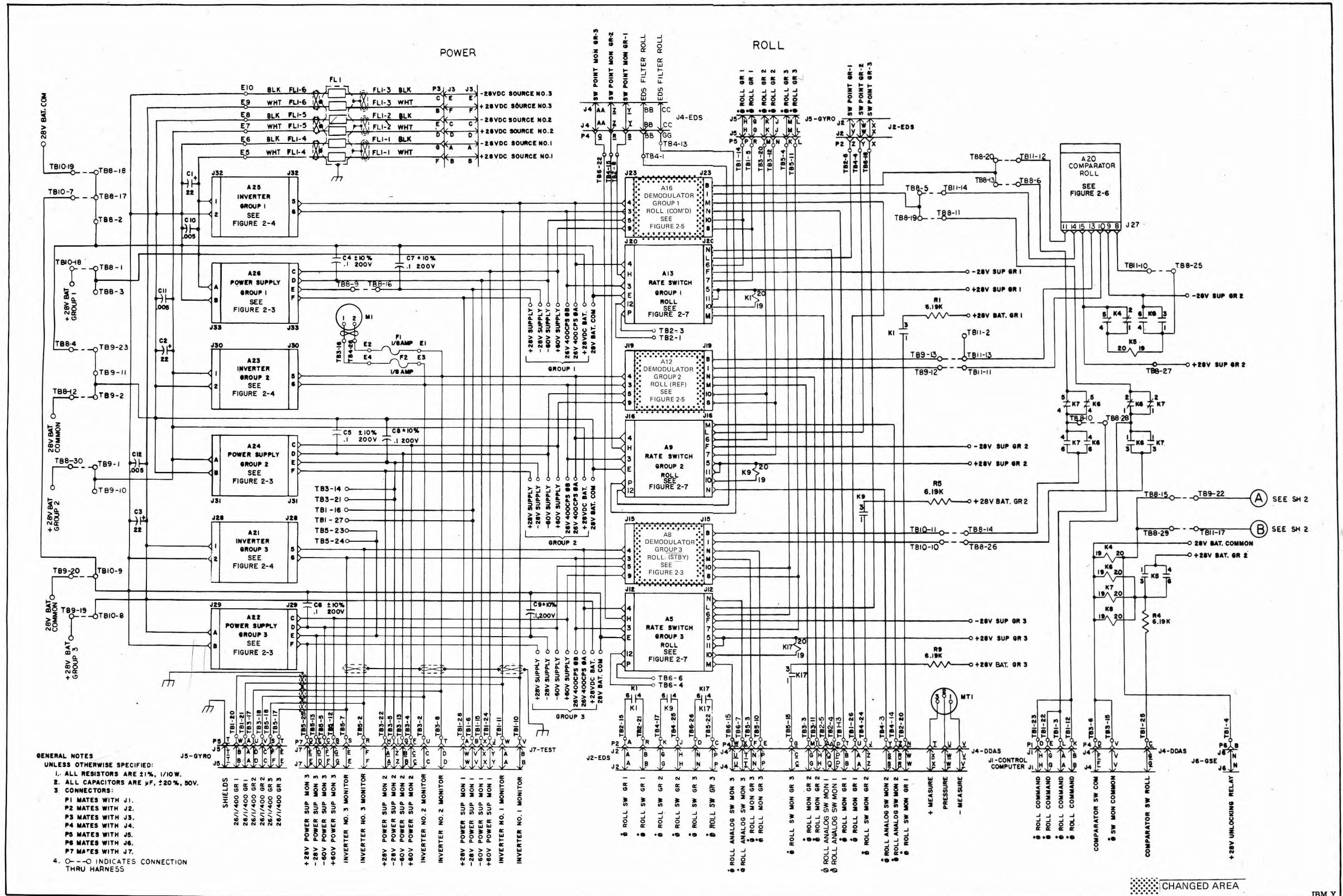


Figure 2-2
Control Signal Processor Schematic Diagram (Sheet 1)

Changed 1 October 1972

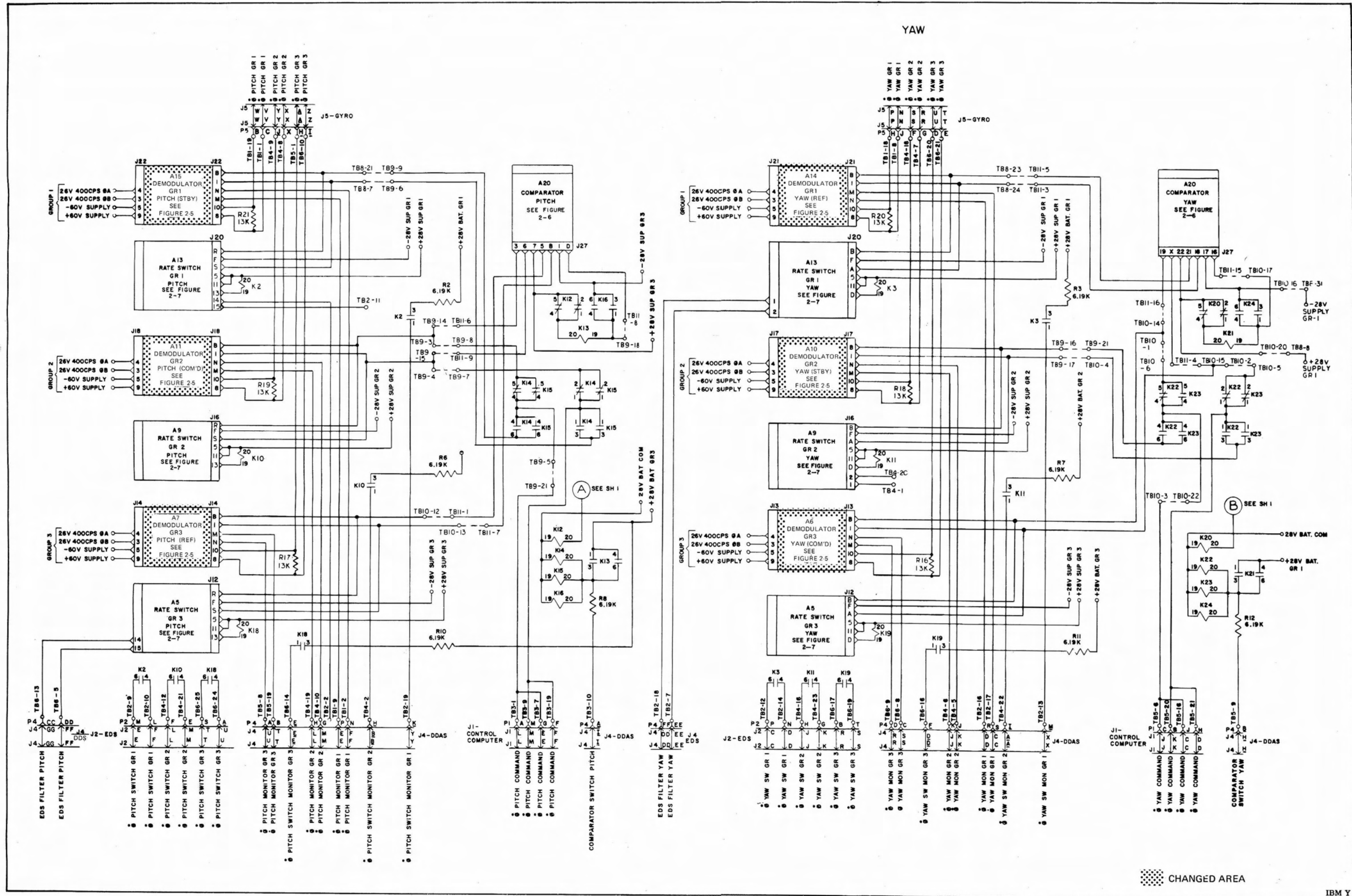
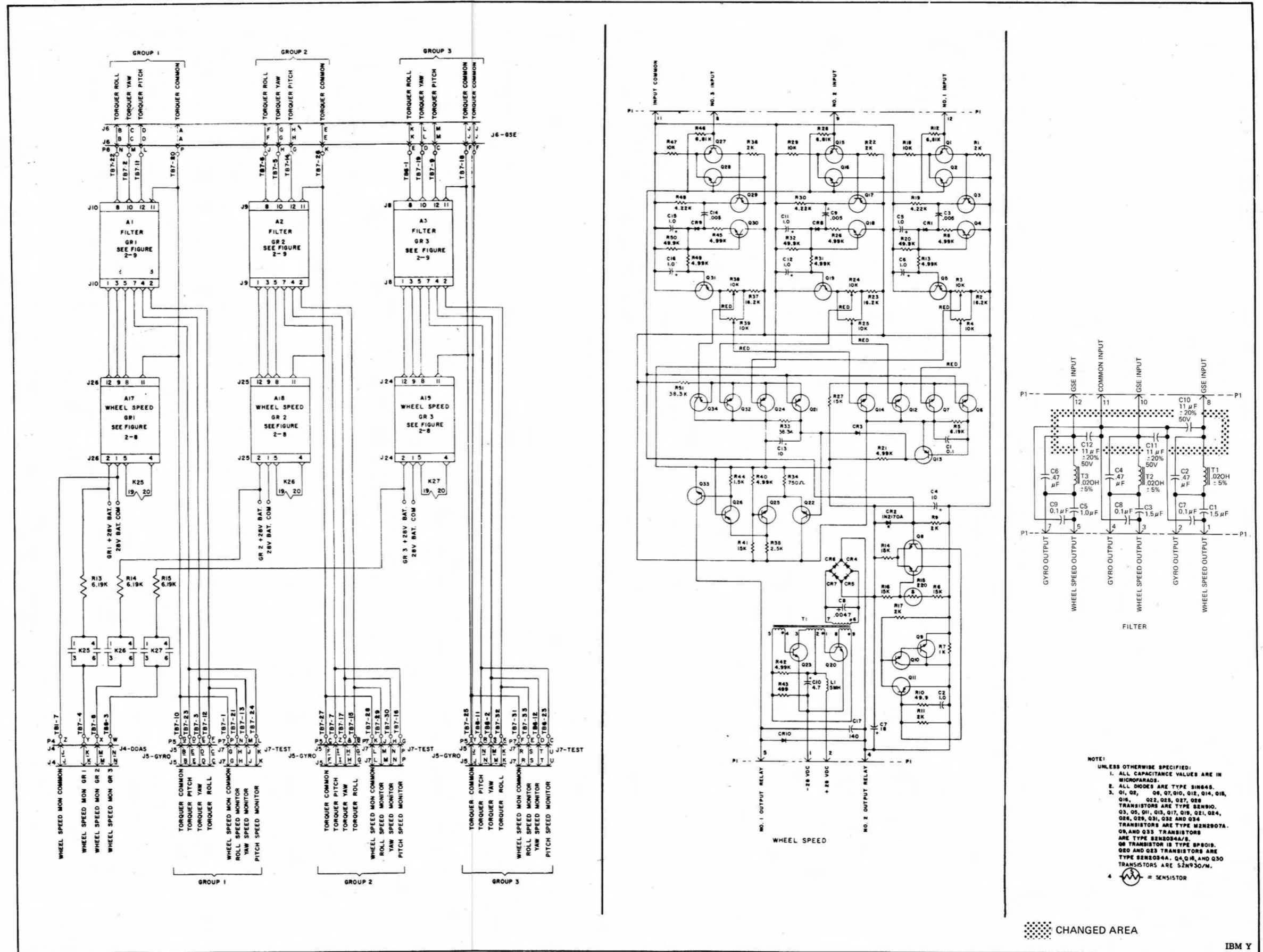


Figure 2-2
Control Signal Processor Schematic Diagram (Sheet 2)

Changed 1 October 1972

IBM Y



Changed 1 October 1972

Figure 2-2
Control Signal Processor Schematic Diagram (Sheet 3)
2-21/2-22

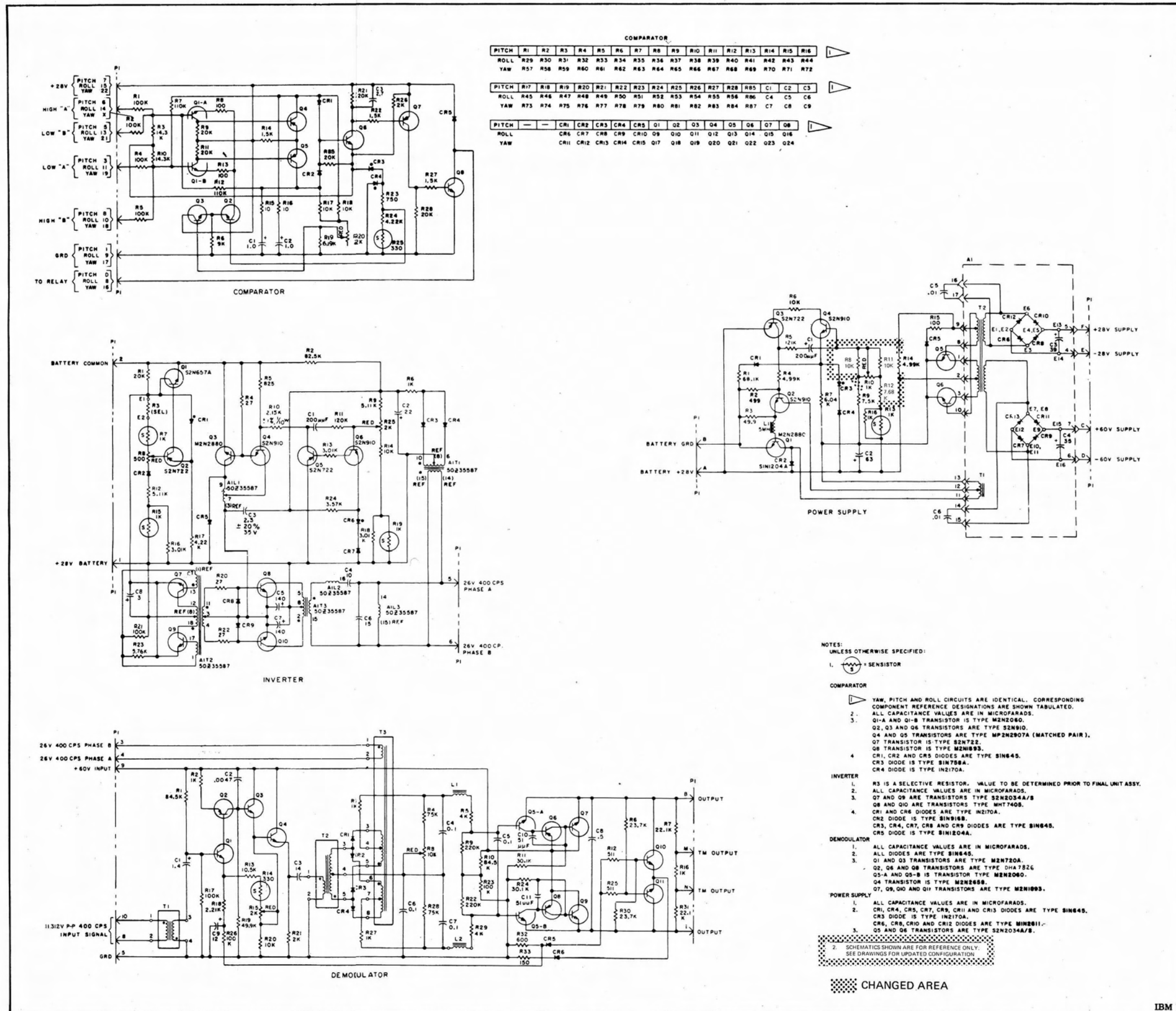
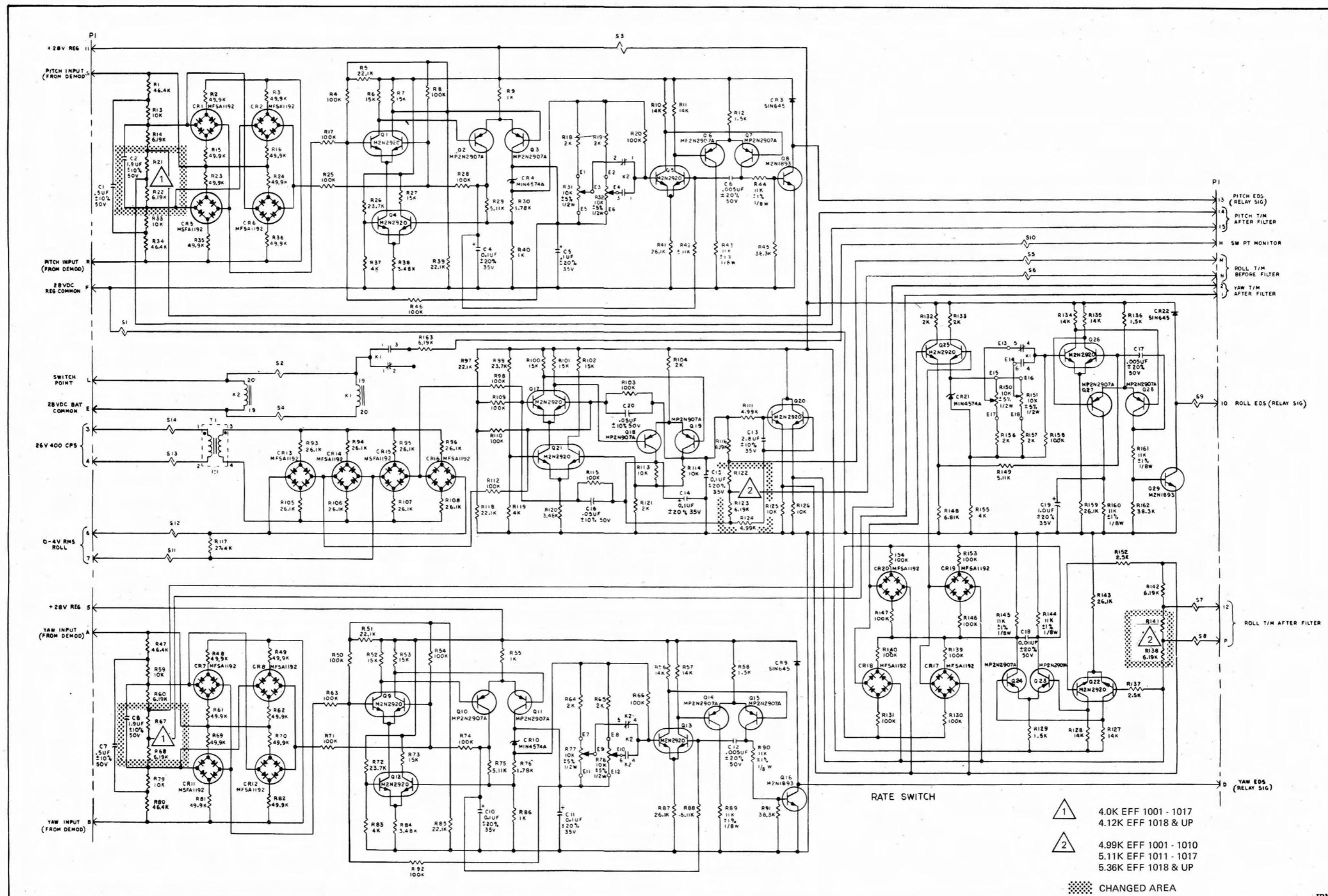


Figure 2-2
Control Signal Processor Schematic Diagram (Sheet 4)

Changed 1 October 1972

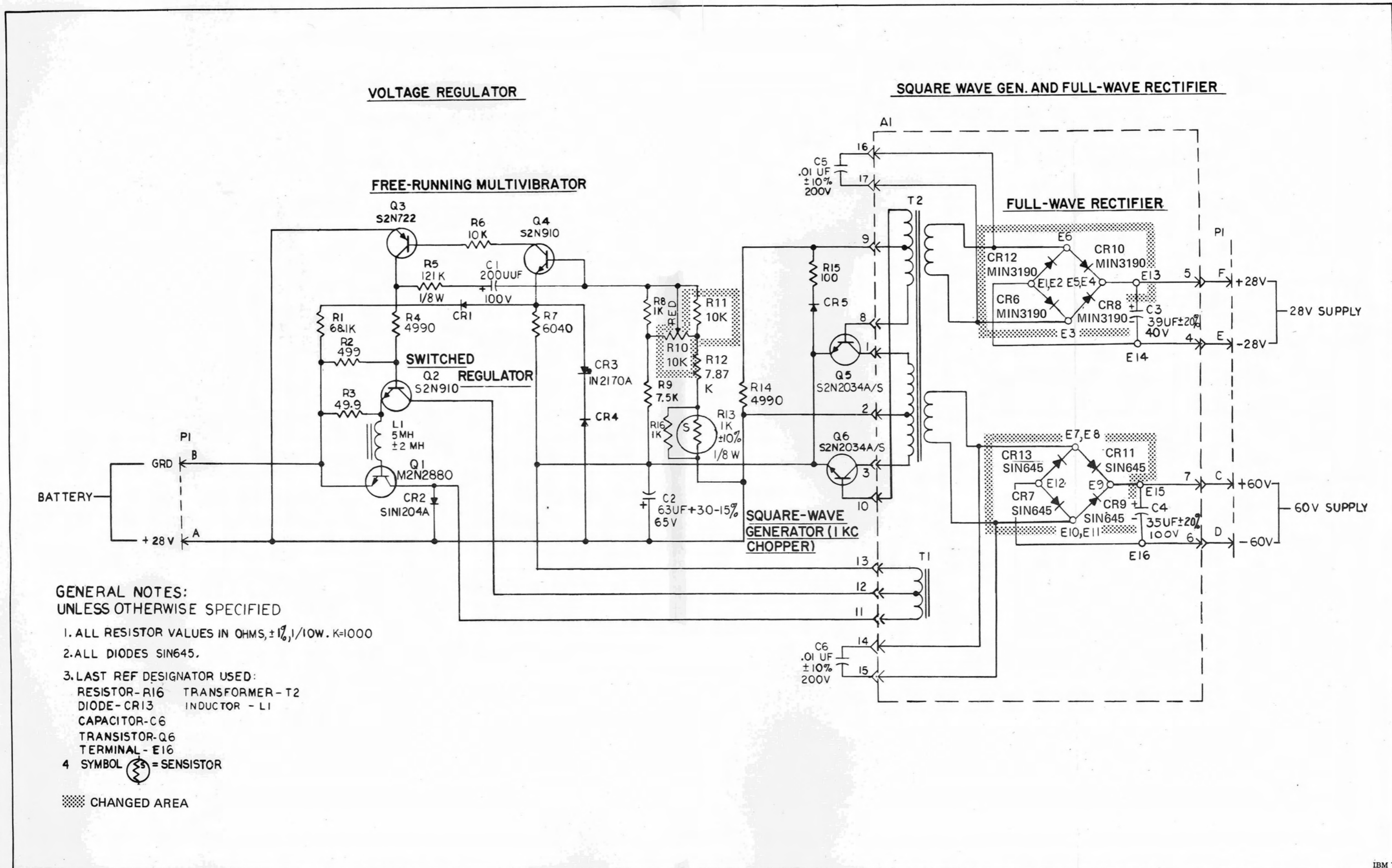


IBM Y

Figure 2-2
Control Signal Processor Schematic Diagram (Sheet 5)

Changed 1 October 1972

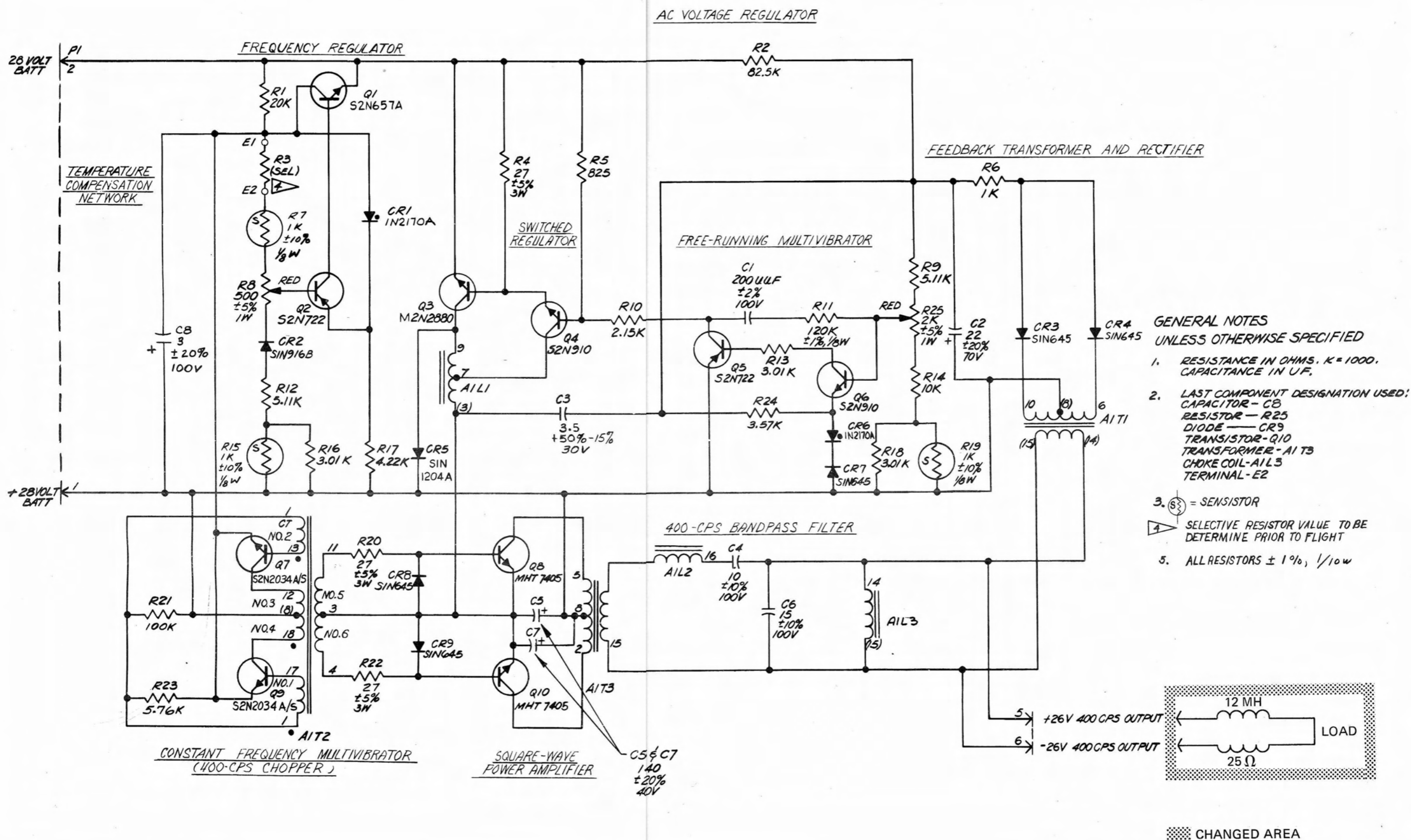
2-25/2-26



IBM Y

Figure 2-3
DC Power Supply Schematic Diagram
2-27/2-28

Changed 1 October 1972

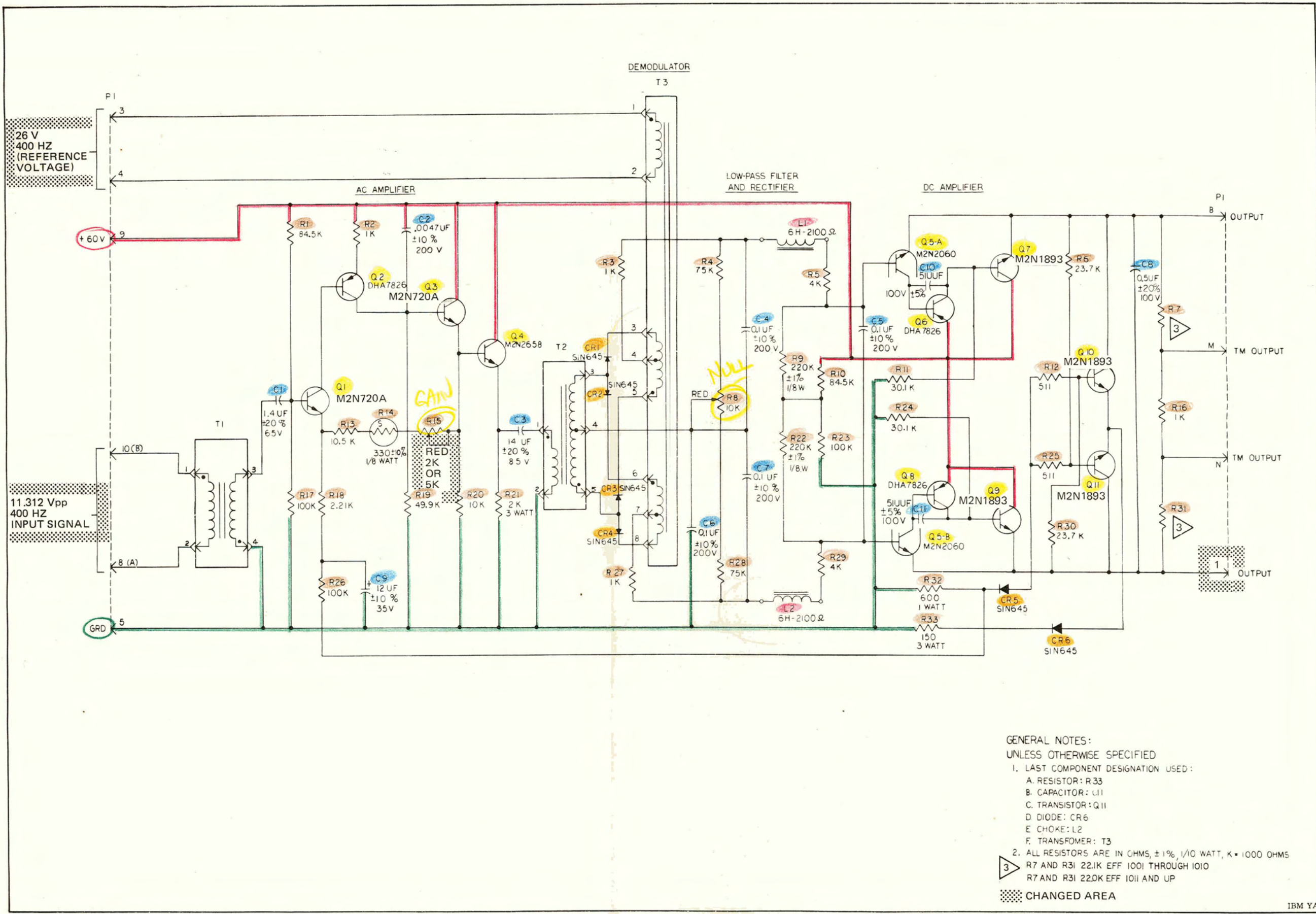


IBM Y

Figure 2-4
Inverter Schematic Diagram

Changed 1 October 1972

S/N 1082
S/N 2003
S/N 20



GENERAL NOTES:
UNLESS OTHERWISE SPECIFIED

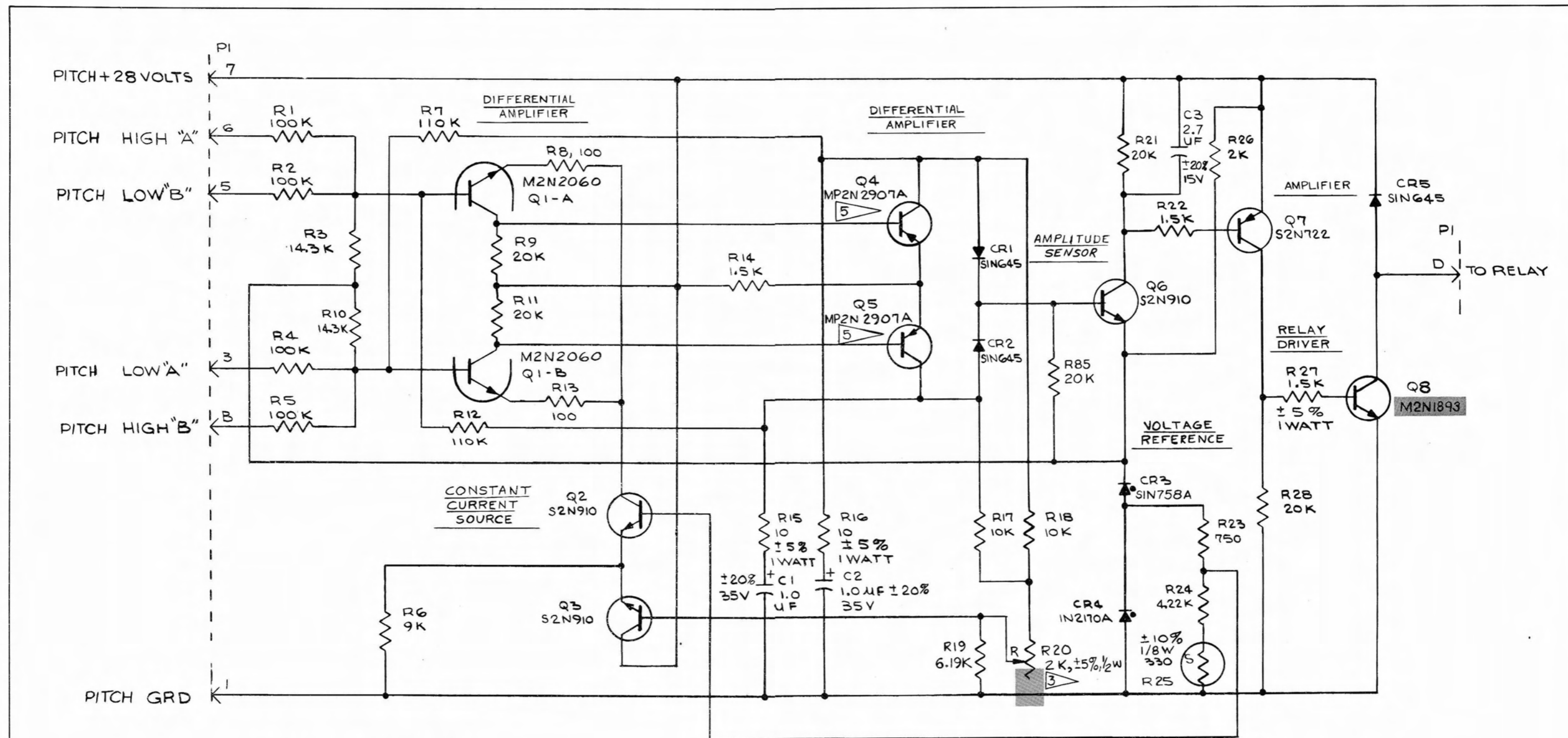
- LAST COMPONENT DESIGNATION USED:
 - A. RESISTOR: R33
 - B. CAPACITOR: C11
 - C. TRANSISTOR: Q11
 - D. DIODE: CR6
 - E. CHOKE: L2
 - F. TRANSFORMER: T3
- ALL RESISTORS ARE IN OHMS, ±1%, 1/10 WATT, K = 1000 OHMS
R7 AND R31 22.1K EFF 100I THROUGH 1010
R7 AND R31 22.0K EFF 1011 AND UP

CHANGED AREA

IBM YA

Change 1 October 1972

Figure 2-5
Demodulator Schematic Diagram
2-31/2-32

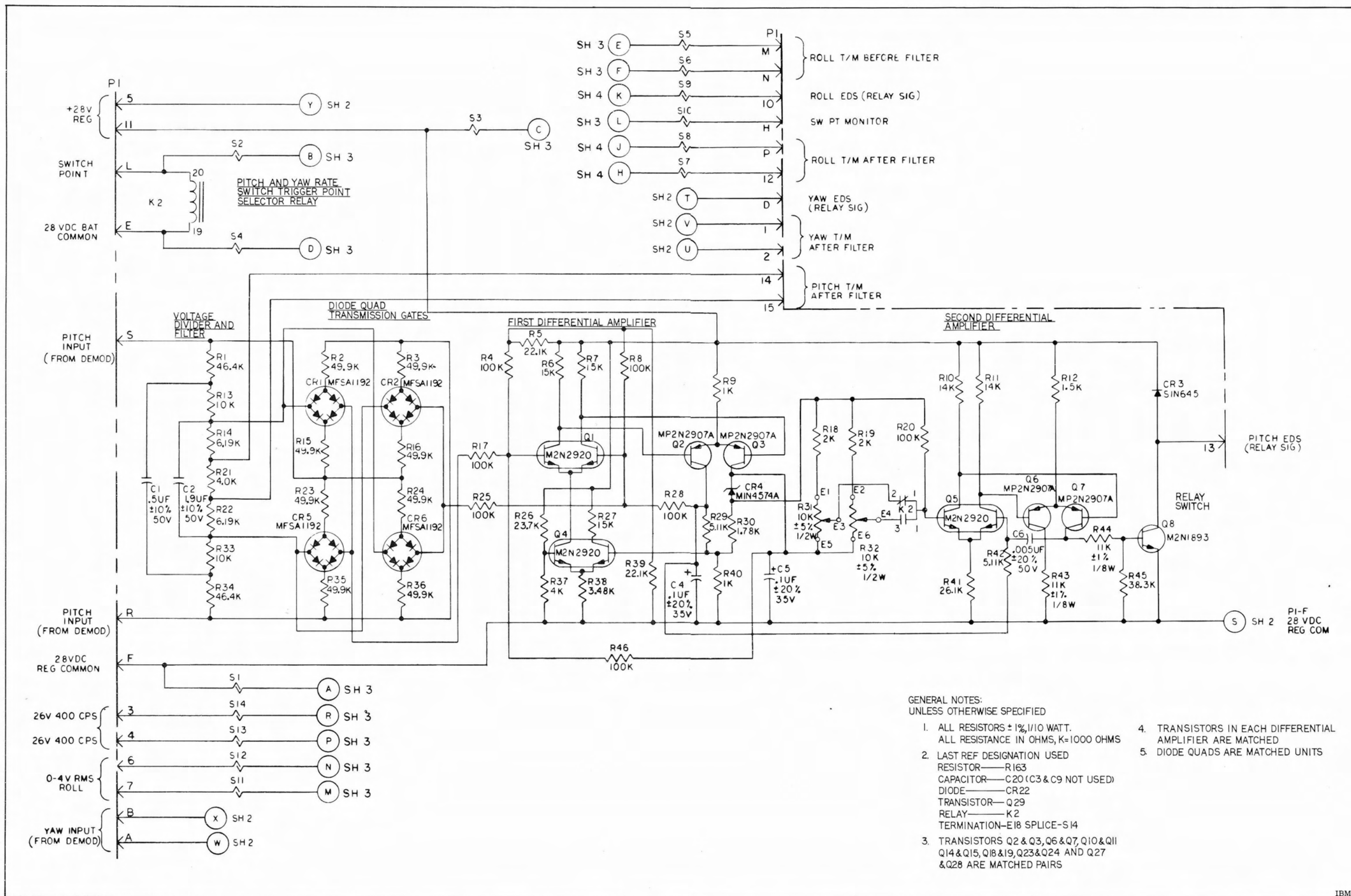


REFER TO FIGURE 2-2 SHEET 4 FOR
PIN CONNECTION NUMBERS AND
REFERENCE DESIGNATORS OF OTHER
TWO COMPARATORS

- GENERAL NOTES:
UNLESS OTHERWISE SPECIFIED:
1. LAST COMPONENT DESIGNATION USED:
A. RESISTOR: R87
B. CAPACITOR: C9
C. TRANSISTOR: Q24
D. DIODE: CR15
E. TERMINAL: E6
 2. ALL RESISTORS ARE IN OHMS, $\pm 1\%$, 1/10 WATT, K=1000 OHMS.
GREEN LEAD NOT USED.
 4. = SENSOR
 5. TRANSISTORS Q4 & Q5, Q12 & Q13, AND Q20 & Q21
ARE MATCHED PAIRS.
- Changed Area

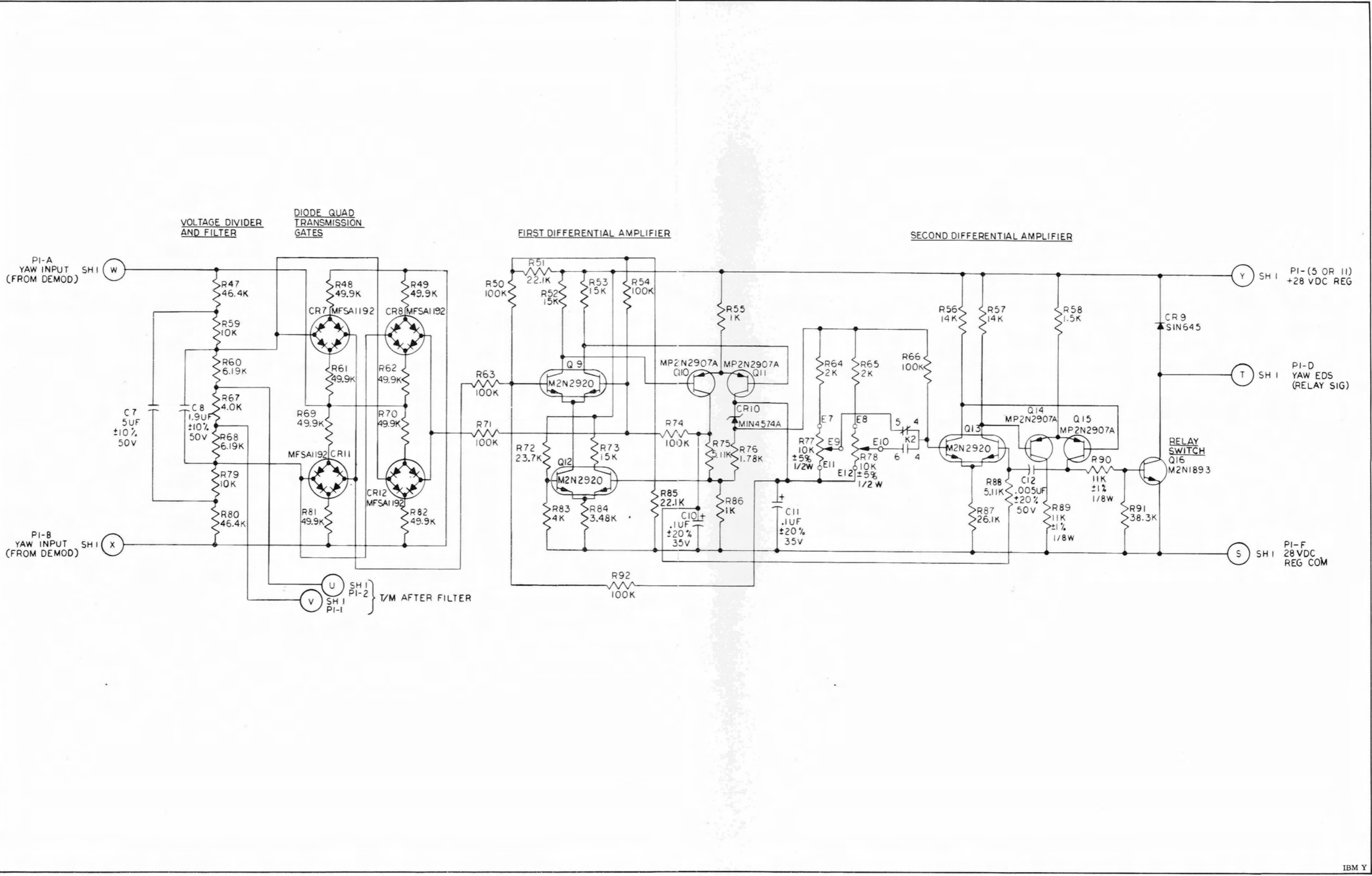
IBM YA

Figure 2-6
Comparator Schematic Diagram
2-33/2-34



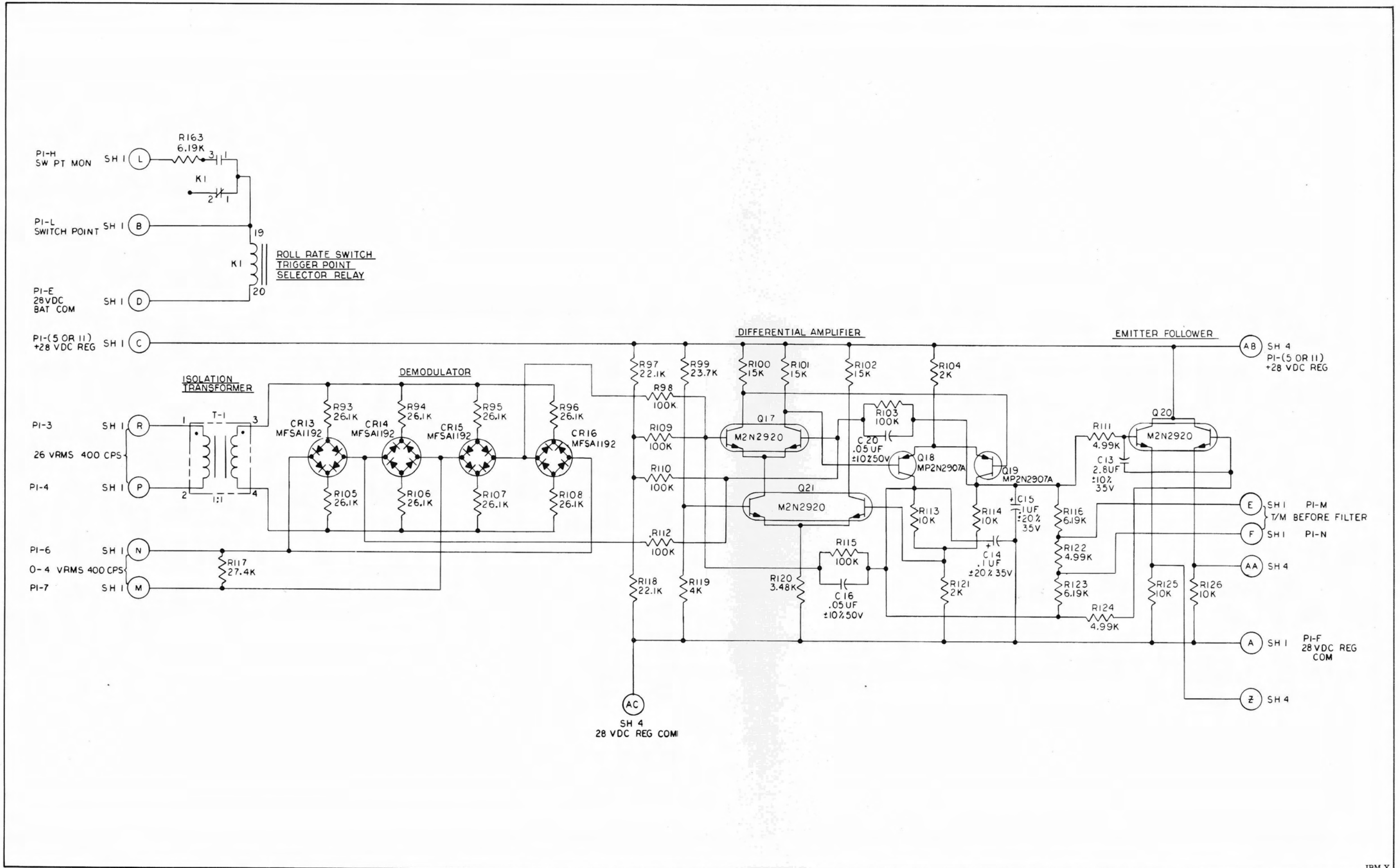
IBM Y

Figure 2-7
Rate Switch Schematic Diagram (Sheet 1)
2-35/2-36



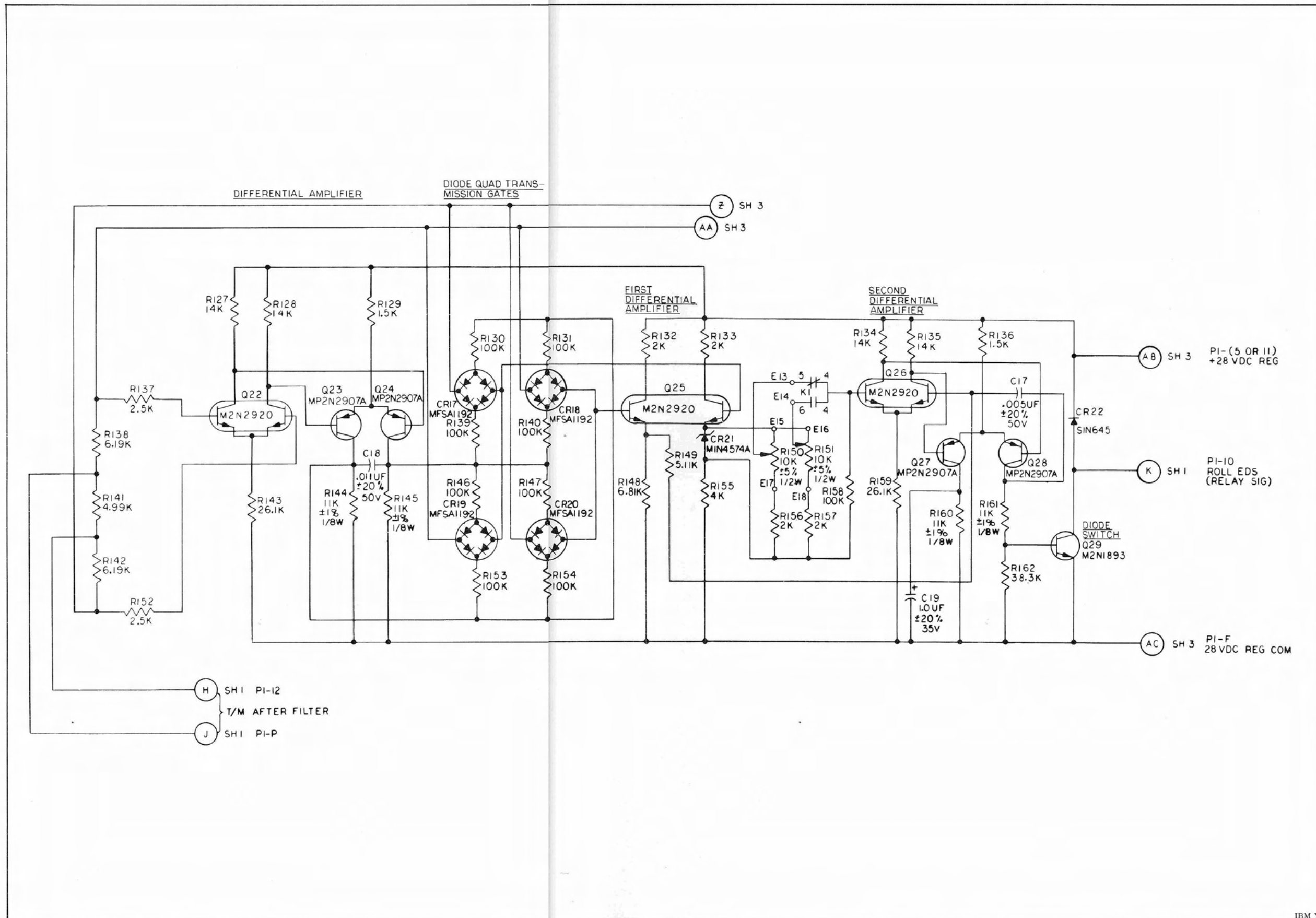
IBM Y

Figure 2-7
Rate Switch Schematic Diagram (Sheet 2)
2-37/2-38



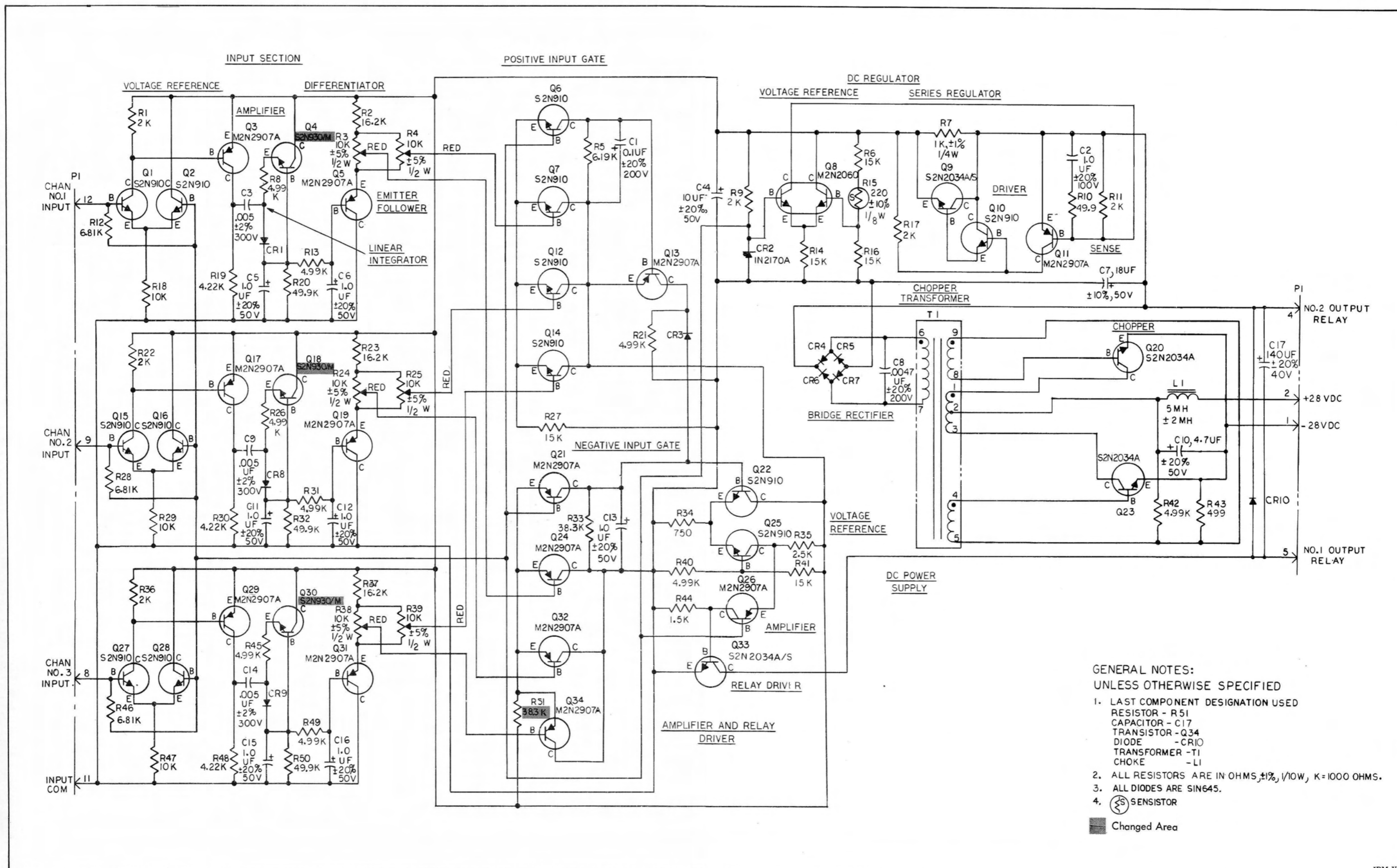
IBM Y

Figure 2-7
Rate Switch Schematic Diagram (Sheet 3)



IBM Y

Figure 2-7
Rate Switch Schematic Diagram (Sheet 4)
2-41/2-42



IBM YA

Figure 2-8
Wheel Speed Schematic Diagram
2-43/2-44

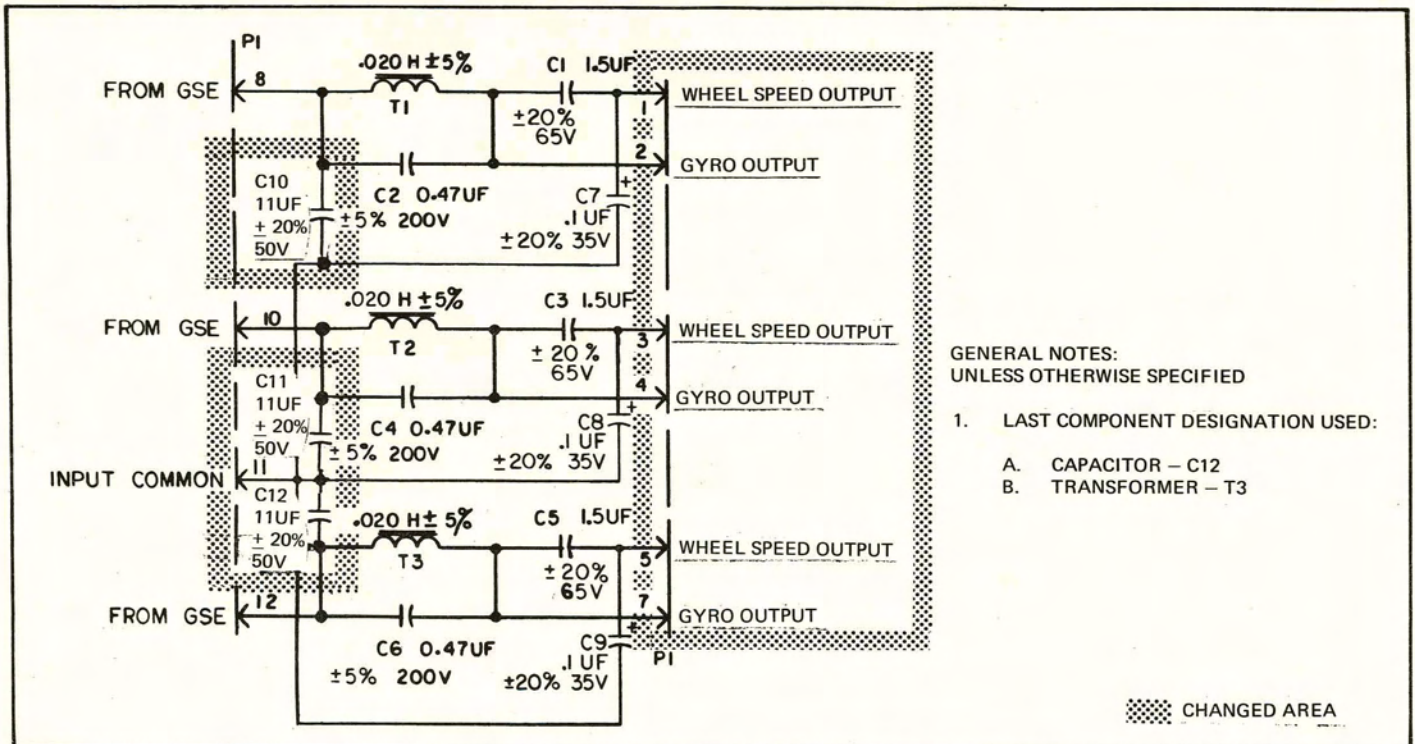


Figure 2-9. 1600-Hertz Filter Schematic Diagram

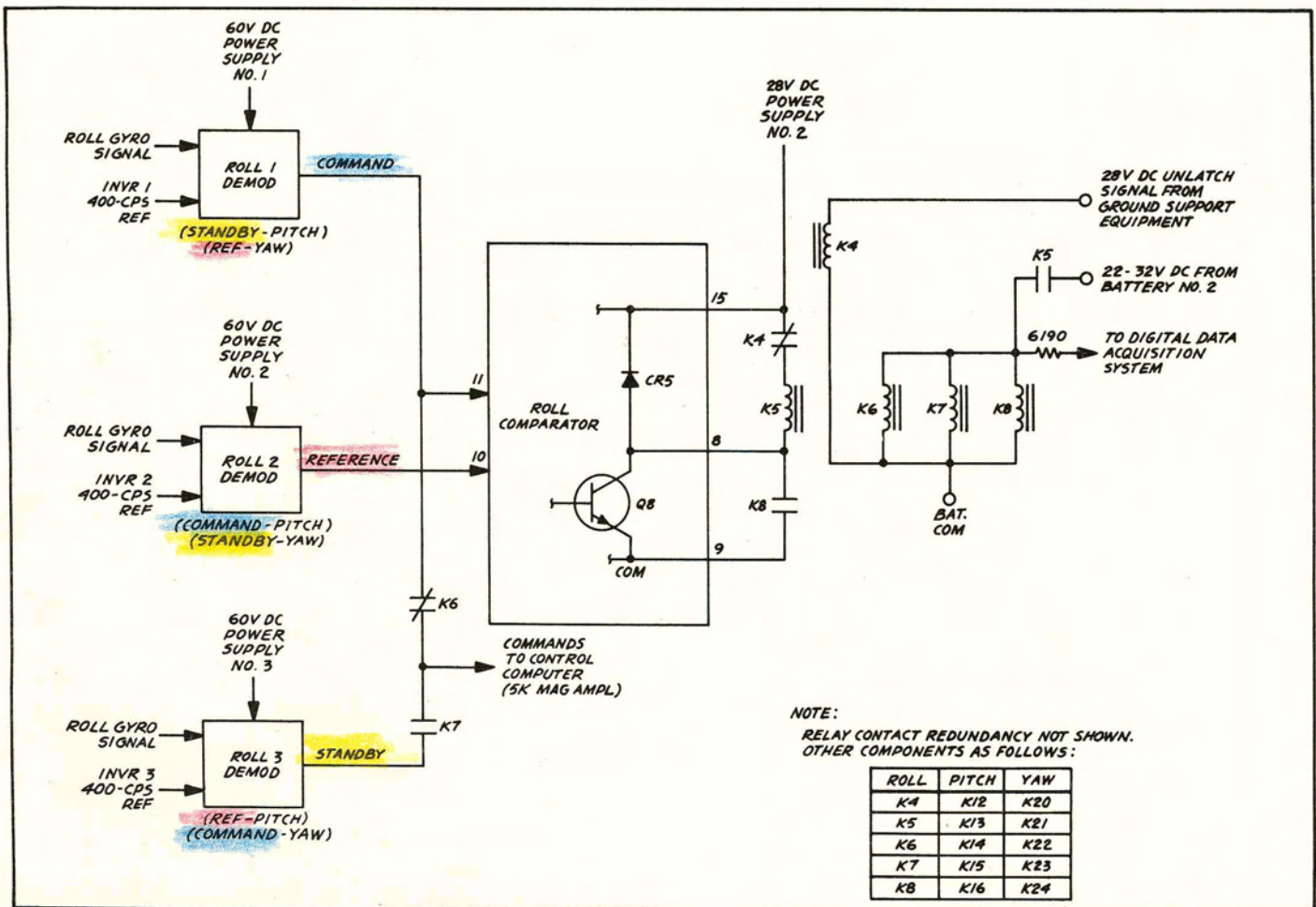


Figure 2-10. Relay Logic Schematic Diagram

SECTION III

PREVENTIVE MAINTENANCE AND REPAIR

3-1 PREVENTIVE MAINTENANCE (Not Applicable)

3-2 REPAIR

All repairs on the Control Signal Processor will be accomplished by component replacement. If failure analysis determines repair is possible, the component should be returned to the manufacturer for repair.

IBM®

Space Systems Center
Huntsville, Alabama

Printed in USA

