APOLLO ENGINEERING MEMORANDUM AP-M #4636

11 January 1965
Revision A

TO: Distribution

FROM: Mr. P. Grant

SUBJECT: THE POWER SUPPLY AND COMMON CIRCUITS OF THE ELECTRONIC COUPLING
            DATA UNIT. (Paper III)

This is the third of a series of papers describing the electronic CDU. The
original issue of this memo broadly described three alternatives for supplying
logic power, 4 VDC, to the digital section of the electronic CDU. Since that
time a choice has been made making that memo obsolete. This memo is intended
to supercede the original memo and explain the 4 VDC supply which will be
independent, and of different design, from that of the computer's 4 V supply.
In addition, this memo will present and explain common circuits of the electronic
CDU. An hour long talk to support this memo will be given on Tuesday,
January 19 at 9:00 AM in the SAT Conference Room.

It may be recalled from the original memo that the Block I AGC 3 VDC supply
had an inherent draw back in that if the driver transistor of the supply failed
shorted, 28 VDC would be applied to the 3 V logic elements. This disadvantage
is overcome in the electronic CDU supply by design. Refer to the enclosed
schematic. The theory of operation is as follows: A free-running multivibrator
whose natural frequency is 11.5 K CPS is slaved to the 25.6 K PPS pulse train
developed in the ECDU but dependent on the 51.2 K PPS clock pulse train from
the computer. The 12.8 K CPS output of the multi drives the power switch. The
power switch output level is determined by the series regulator which generates
a DC level proportional to the difference between the 4 V output and a pre-
determined reference. This regulated DC level (approximately 21 V) is the level
to which the power switch will drive. The amplitude modulated 12.8 K CPS square
wave from the power switch is transformer coupled to the rectifier and filter
where the desired output of 4 VDC is developed with better than 1% regulation
for line and load variations.

The digital logic system for a five axes ECDU consumes between 2.5 and 3.0 amps
maximum from the 4 VDC supply. For completeness the average power consumption
of the analog modules from the +28 VDC source are listed on a separate sheet at
the end of this memo.

The operational amplifier shown in Figure 3 is used throughout the ECDU as an analog computing device. Its function is to adjust the amplitudes of the input voltages by the factor $\frac{Z \text{ feedback}}{Z \text{ input}}$, algebraically sum these adjusted voltages at the summing junction and invert the result. Thus, the basic analog computing operations of amplification, attenuation, summing and inverting are accomplished. Power amplification is also provided, the output impedance being approximately 0.1 ohms. The open loop response of gain and phase shift versus frequency is graphically presented in Figure 5. With feedback and input resistors of 25 K, B+ equal to 28 VDC, and a 800 CPS input frequency, the amplifier begins to saturate with an input signal of 8.2 V RMS. A breakdown of the number of operational amplifiers used per module for a one axis IMU system is given below.

$$\begin{aligned}
&\text{Quadrant Selector Module } \text{-------- 6} \\
&\text{Main Summing Amplifier Module } \text{------ 2} \\
&\text{Coarse Module } \text{-------------- 1}
\end{aligned}$$

The accuracy of the ECDU is dependent upon many factors one of which is the level to which error detection is possible. Voltage level detection is accomplished by the Schmitt trigger circuit shown in Figure 4A. The Schmitt's triggering level is set by the input resistors (in Figure 4A, it's the 3.9 K resistor). The trigger levels are listed below for reference.

NOMINAL SCHMITT TRIGGER VOLTAGES
(Measured at output of emitter followers)

	Min.	Nom.	Max.	
Fine Ternary Level (Fine Schmitt) IMU	180	200	210	mv P-P
Fine Ternary Level (Fine Schmitt) TRUNN	180	200	210	mv P-P
High Ternary Level (2-speed Schmitt)	3.2	4.0	4.2	v P-P
5V Coarse Ternary Level (Coarse Schmitt)	1.25	1.33	1.4	v P-P
Ambiguity Detect (Ambig. Schmitt)	6.0	7.0	9.0	v P-P
4V Coarse Ternary Level	1.26	1.4	1.54	v P-P

Fine and Coarse Ternary Levels include dead zones of 1 to 2 bits.

The circuits operation is as follows: The 2N914 transistor is normally on providing a voltage across its 56 ohm emitter resistor which is common with the 2N2980 emitter and provides bias to keep the 2N2980 off. Hence, all the current through the 68 K base resistor of the 2N2980 transistor flows through the diode portion of the 2N2980 and through the 1 K resistor to ground. The base-emitter junction of the first transistor of the 2N2980 is used only as a diode with no connection to the collector. Both base-emitter junction voltages in the 2N2980 are matched to within 5 mv with similar temperature coefficients. The result of using these matched junctions is stable trigger voltages with temperature variation. Triggering is accomplished when the input voltage rises beyond the trigger level

and back biases the diode of the 2N2980 and allows the base of the 2N2980 transistor to rise toward the 6.2 V zener voltage. When the emitter bias of the 2N2980 transistor is overcome, it fires and causes the 2N914 to turn off and the output to rise to 6.2 V. When the input voltage decreases to below the trigger level the reverse happens and the output voltage returns to approximately 0 volts. Hence, the output of the Schmitt is always a positive going pulse.

The analog switch and driver configuration shown in Figure 4B is used extensively throughout the electronic CDU. The input to the driver (enabling function) is normally high keeping the driver saturated and the base of the switch starved for current and the switch off (or open). When a ground is applied to the input, the driver turns off and its collector (and base of the switch) rises toward +28 VDC allowing the switch to become AC saturated and on (or closed).

Don't miss the next exciting chapter which is entitled "The Fine System of the ECDU".
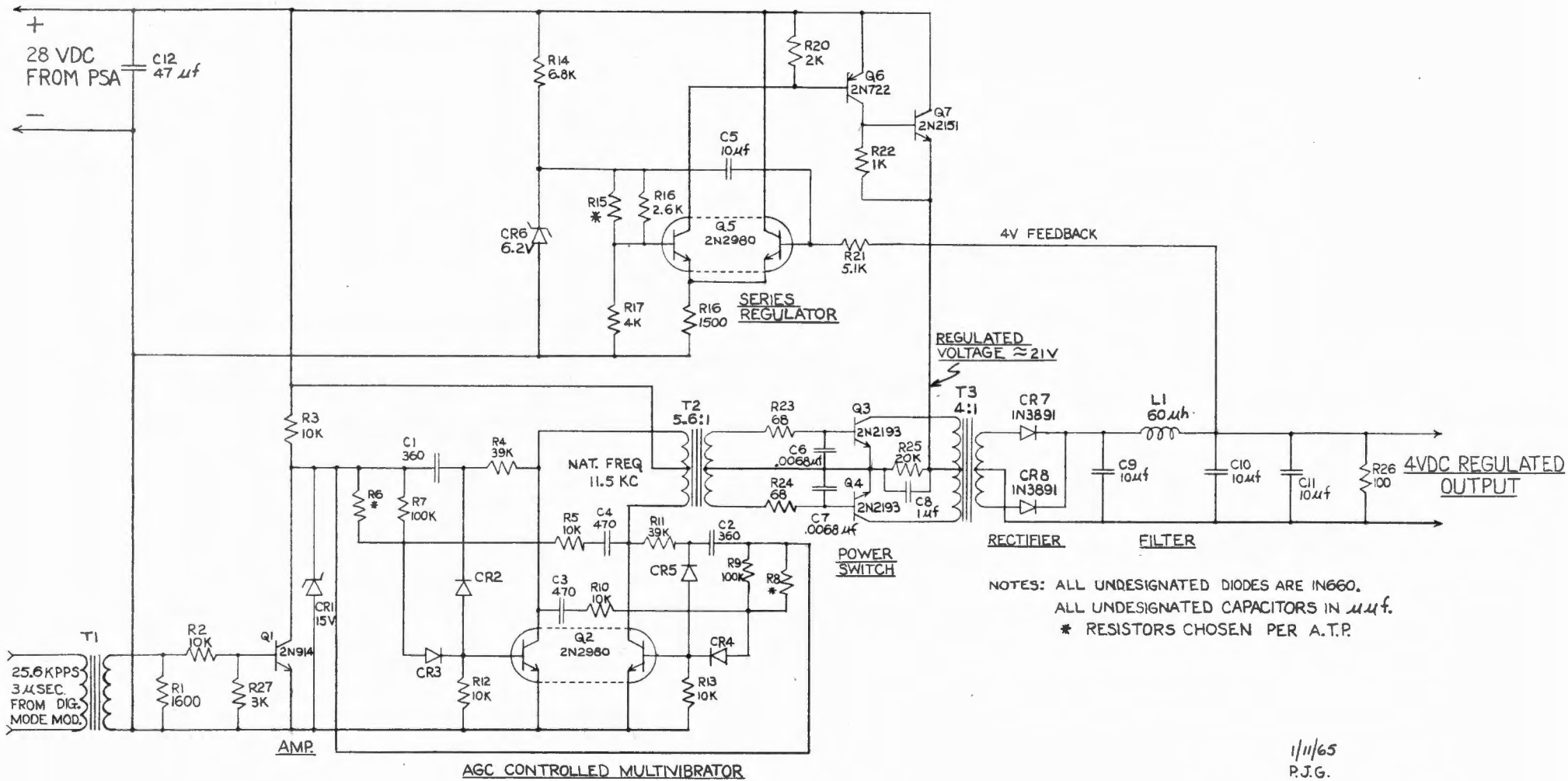

P. Grant
Digital Systems Group
Apollo Engineering

PG/np

ELECTRONIC CDU 4VDC POWER SUPPLY

+
28 VDC
FROM PSA
−

C12 47 μf

R14 6.8K

R20 2K

Q6 2N722

Q7 2N2151

R22 1K

C5 10μf

R15 *

R16 2.6K

CR6 6.2V

Q5 2N2980

R21 5.1K

4V FEEDBACK

R17 4K

R16 1500

SERIES REGULATOR

REGULATED VOLTAGE ≈ 21V

R3 10K

C1 360

R4 39K

NAT. FREQ 11.5 KC

T2 5.6:1

R23 68

Q3 2N2193

T3 4:1

CR7 1N3891

L1 60μh

C6 .0068μf

R25 20K

C9 10μf

C10 10μf

C11 10μf

R26 100

4VDC REGULATED OUTPUT

R6 *

R7 100K

R24 68

Q4 2N2193

CR8 1N3891

R5 10K

C4 470

R11 39K

C2 360

C7 .0068μf

C8 1μf

POWER SWITCH

RECTIFIER

FILTER

CR5

R9 100K

R8 *

CR1 15V

C3 470

R10 10K

Q2 2N2980

CR4

NOTES: ALL UNDESIGNATED DIODES ARE 1N660.
ALL UNDESIGNATED CAPACITORS IN μμf.
* RESISTORS CHOSEN PER A.T.P.

CR3

R12 10K

R13 10K

T1

25.6 KPPS 3 μ SEC. FROM DIG. MODE MOD.

R2 10K

Q1 2N914

R1 1600

R27 3K

CR2

AMP.

AGC CONTROLLED MULTIVIBRATOR

1/11/65
P.J.G.

ELECTRONIC COUPLING DATA UNIT
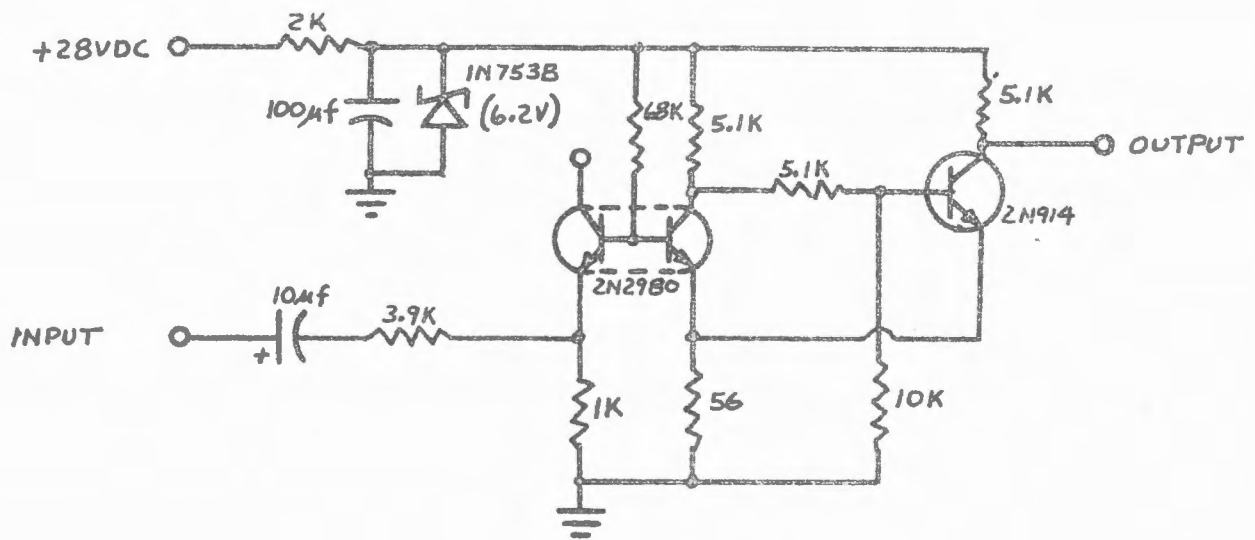
FIVE AXES SYSTEM POWER REQUIREMENTS (APPROXIMATE)

Module	# Mod. Required Per 5 Axis System	Current/ Module	Power In Watts
Analog Mode (Formerly the Analog	1	20 ma	.56 W
Interrogate Mode Module)	1		
D/A Converter	5	27	3.78
Coarse System	4	46	5.15
Quadrant Selector	5	48	6.71
Main Summing Amplifier	5	58	8.12
		199 ma	24.32 W

Digital Logic @ 4 VDC 2.8 amps   11.2

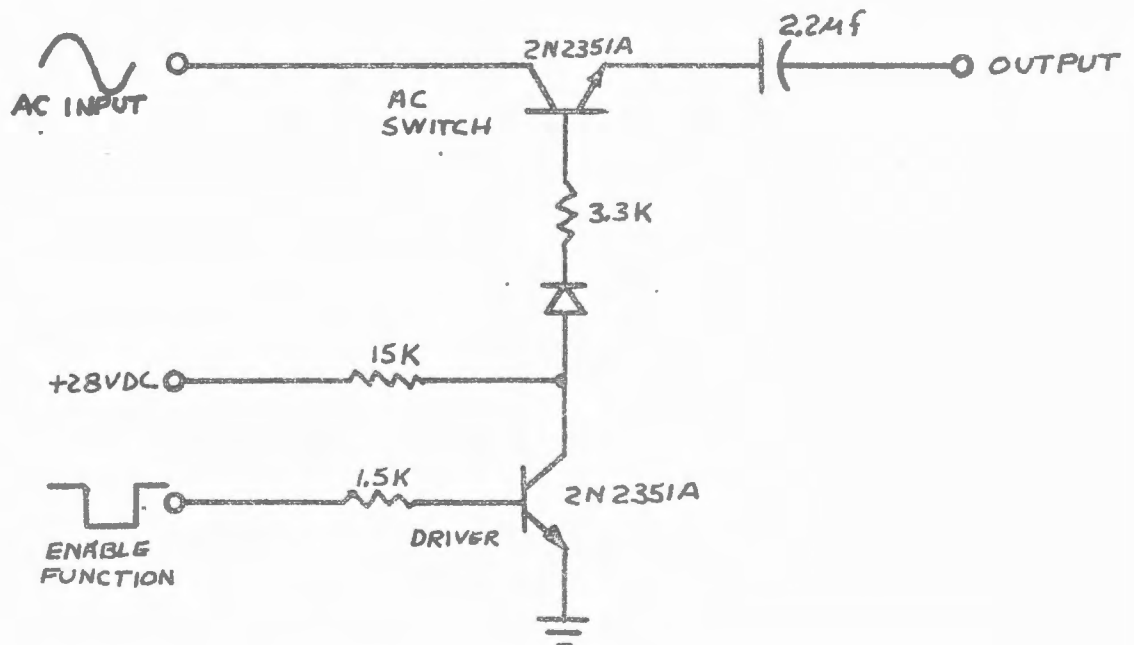   Total Power Consumption for 5 axes system   35.5 W
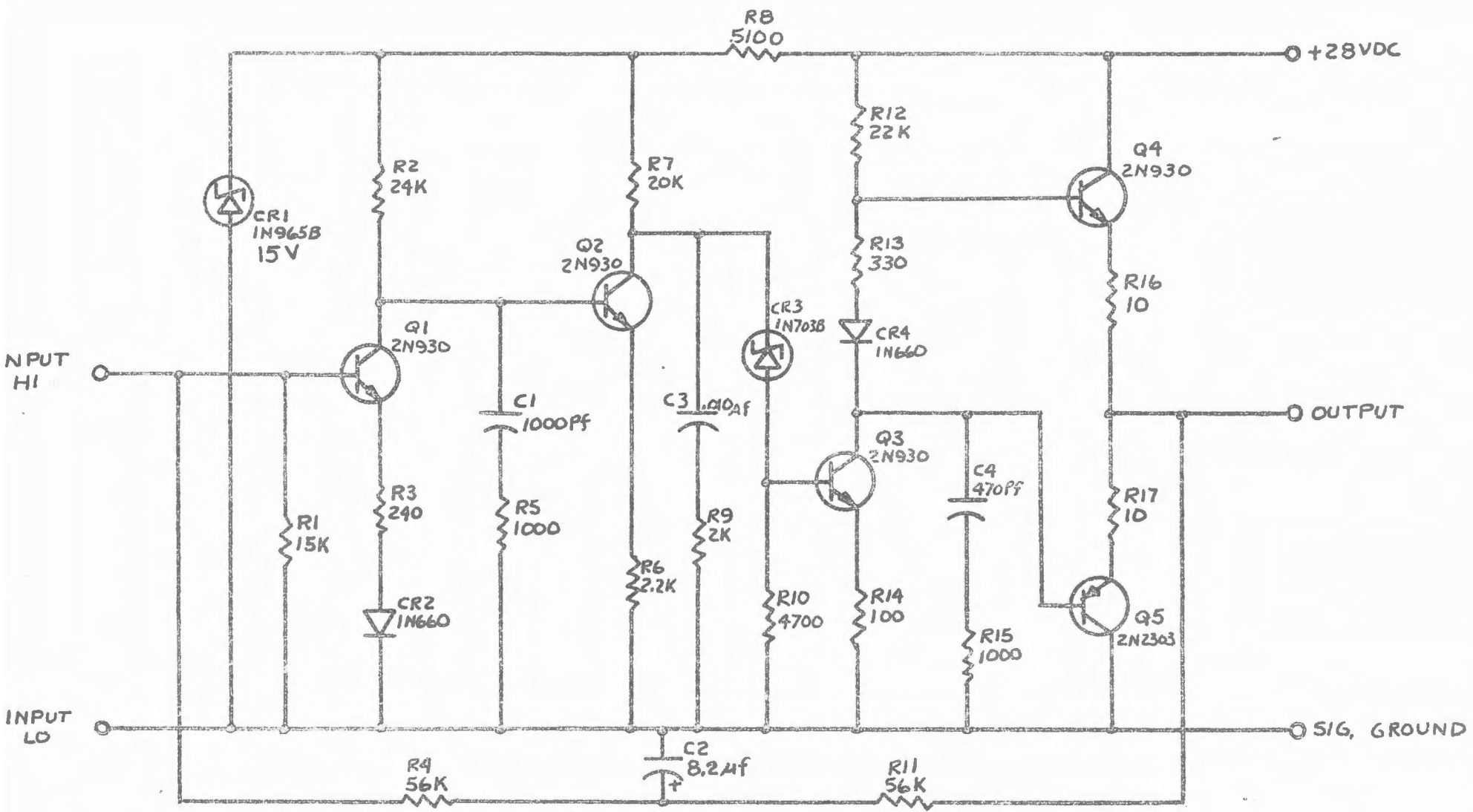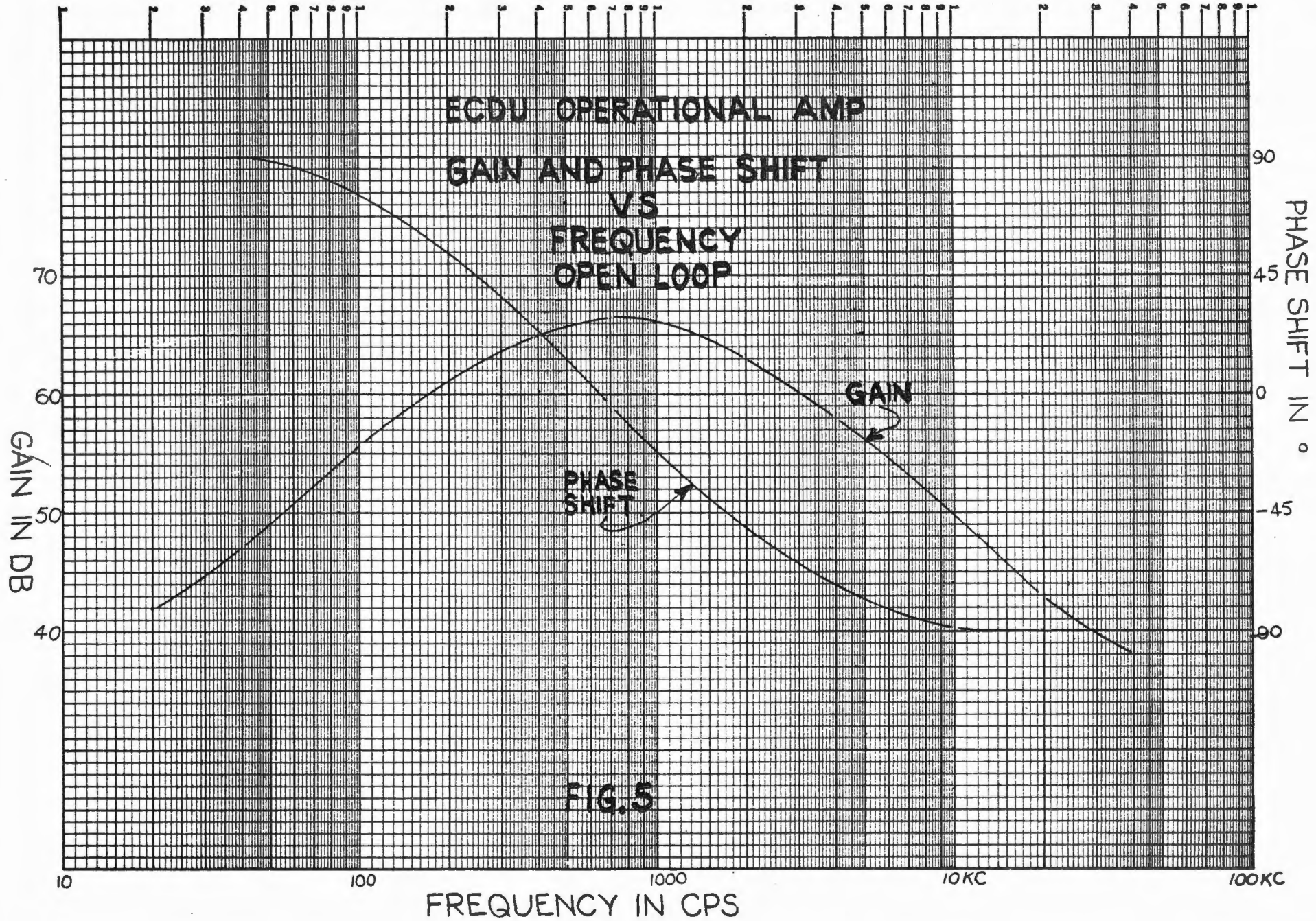
OPERATIONAL AMPLIFIER - ECDU

FIG. 3

SCHMITT TRIGGER

FIG. 4A

SWITCH AND DRIVER CONFIGURATION

FIG. 4B

ECDU OPERATIONAL AMP
GAIN AND PHASE SHIFT
VS
FREQUENCY
OPEN LOOP

FIG. 5

GAIN IN DB

PHASE SHIFT IN °

FREQUENCY IN CPS

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