

GIT/EES Project No. A-2889

94 GHz EIA MODULATOR INSTRUCTION MANUAL

By

G. M. Conrad, D. S. Ladd, and J. C. Butterworth

Prepared for

FGAN

By

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

April 1982

TABLE OF CONTENTS

<u>SECTION</u>	<u>TITLE</u>	<u>PAGE</u>
1	GENERAL INFORMATION.....	1
1.1	SCOPE OF MANUAL.....	1
1.2	TRANSMITTER DESCRIPTION.....	1
2	INSTALLATION AND HOOK-UP.....	3
2.1	INSTALLATION.....	3
2.2	HOOK-UP.....	3
3	PRINCIPLES OF OPERATION.....	4
3.1	GENERAL DESCRIPTION.....	4
3.2	CONTROL CIRCUITRY.....	4
3.3	DRIVER STAGE.....	4
3.4	FOCUS CONTROL.....	5
3.5	COLLECTOR CURRENT MONITOR.....	5
3.6	HEATER SUPPLY.....	5
3.7	HIGH VOLTAGE POWER SUPPLY MODIFICATIONS.....	6
4	STABILITY.....	7
4.1	PULSE TO PULSE.....	7
4.2	INTRAPULSE.....	7
5	OPERATING INSTRUCTIONS.....	8
5.1	OPERATING FEATURES	8
5.1.1	BEAM CURRENT METER.....	8
5.1.2	AUTOMATIC WARM-UP DELAY.....	8
5.2	TURN ON PROCEDURE.....	9
	APPENDIX A: SCHEMATIC DIAGRAMS.....	10

SECTION 1
GENERAL INFORMATION

WARNING

THIS EQUIPMENT EMPLOYS VOLTAGES THAT ARE
EXTREMELY DANGEROUS AND MAY BE FATAL.

EXTREME CAUTION MUST BE EXERCISED

1.1 SCOPE OF MANUAL

This manual describes the installation and operation of a modulator for a 94 GHz focus Electrode Controlled Extended Interaction Amplifier VKB 2449 (EIA). This modulator employs a variable pulse width, saturated push-pull driver circuit which delivers the required drive pulse to the EIA. The radio frequency (RF) pulse produced by this driver circuit results in a minimum of frequency modulation with fast rise and fall times. Section 3 describes the circuits in the modulator. Pulse stability is discussed in Section 4. Section 5 contains operating instructions and procedures to ensure proper operation. Appendix A includes schematic diagrams of the modulator and high voltage power supply control circuit modifications.

1.2 TRANSMITTER DESCRIPTION

The transmitter consists of the control console and the modulator box. Connecting cables allow power and pulse width control signals to be passed from the control console to the modulator box. A rack mountable control console provides the operating controls and enables the selection of pulse width, pulse repetition frequency and high voltage level. The modulator box contains two high voltage supplies, the driver circuit, and the EIA. The modulator box is to be mounted in a suitable location within the limits of the control cable and accessible to waveguide connections for the EIA. Table 1 lists the characteristics of the 94 GHz EIA transmitter.

TABLE 1. TRANSMITTER CHARACTERISTICS

<u>PARAMETER</u>	<u>SPECIFICATION</u>
Output Frequency	94 - 95 GHz
Output Power	1 kW
RF Pulse Width	35 ns - 1 μ s
Maximum PRF	20 kHz
RF Pulse Rise and Fall Times	10 ns
Maximum Duty Factor	.004
Input Power	220 VAC 47 - 63 Hz

SECTION 2
INSTALLATION AND HOOK-UP

2.1 INSTALLATION

The control console is designed to be mounted in a standard 19-inch rack. The modulator box should be installed in the desired location within the limits of the 50-foot connecting cable. The cable is terminated with 24-pin connectors at each end.

2.2 HOOK-UP

Plug the cable connector in at each cable end between the modulator and control console. With the POWER switch in the OFF position, plug the ac line cord into a 220 Vac, 47-63 Hz, power outlet. The modulator may be powered with 110 Vac by changing the jumper as indicated on the 28 Volt, 4 amp power supply in the control console.

Locate the two BNC connectors, labelled CURRENT MONITOR and INPUT PULSE, on the modulator box. The CURRENT MONITOR connector will allow monitoring of the EIA peak collector current. The output should be terminated in a 50 Ω cable and load. The maximum observed voltage should be 1.0 V which represents 650 mA collector current for the EIA (refer to Varian TEST DATA FOR EXTENDED INTERACTION AMPLIFIER for the device being used). The calibration factor for the CURRENT MONITOR is 650 mA/V when terminated with a 50 Ω load. The INPUT PULSE connector is the input for the pulse drive circuit.

Locate the two BNC connectors labelled PRF TRIGGER and PULSE OUT, on the control console. The PRF TRIGGER connector is the input for a TTL compatible, positive-going pulse of the required PRF (less than 20 kHz). The PULSE OUT connector is for external synchronization. To insure proper operation, the INPUT PULSE should be driven only from the MODULATOR PULSE CONNECTOR at the rear of the control console.

Locate the output flange of the EIA. Remove the plastic cover and connect the required waveguide to ensure proper power dissipation and a VSWR of less than 2.0. The EIA must be driven by a suitable RF source of the proper frequency and power level connected to the input waveguide flange.

SECTION 3 PRINCIPLES OF OPERATION

3.1 GENERAL DESCRIPTION

The purpose of the modulator is to provide a pulse for the EIA ranging from approximately 35 ns to 1 μ s in duration. An amplified RF pulse with a minimum of phase modulation is produced by supplying a flat top voltage pulse to the grid of the EIA. The flatness of this pulse is entirely dependent on the saturation characteristics of the driver tube.

3.2 CONTROL CIRCUITRY

The internal operation of the control circuitry is governed by two relays and a set of contacts inside the BEAM CURRENT meter. The meter and relays are de-energized when the modulator is in the OFF mode. The relay and meter contacts are shown in the OFF mode in the Power Control Circuit schematic, Appendix A.

When the ON/OFF switch is set to ON the +5 Vdc and +28 Vdc power supplies are energized. The 28 Vdc energizes the time delay relay (RL1) which initiates the two minute time delay. When the two minute time delay is completed, relay RL1 is energized and the STANDBY light turns on. When the RADIATE switch is pressed, relay RL2 is energized, turning the radiate light on and providing 28 Vdc to the high voltage power supply.

The BEAM CURRENT METER must have power applied from the 110 Vac input tap of the line transformer in the 28 Vdc power supply to switch the internal contacts associated with the maximum and minimum settings on the front of the meter. Contacts 11-12 and 14-15 are normally closed when no over-maximum condition exists. Contacts 21-22 and 24-25 are normally closed when no under-minimum condition is present.

3.3 DRIVER STAGE

Referring to the drawings in Appendix A, the pulsed TTL output of the control console is coupled via a 50 Ω coaxial cable to the PRE-DRIVER stages located on two printed circuit boards in the modulator. The final output of the PRE-DRIVER stage is generated by two VMOS power FETS (IVN 6000). The

PRE-DRIVER is transformer-coupled to the hard-tube driver, consisting of tubes V_1 and V_2 . The PRE-DRIVER pulse turns-on tube V_1 , which places a positive 3 kV (with respect to bias) pulse on the Focus Electrode (grid) of the EIA. This produces a grid-cathode voltage for the EIA of approximately zero. The end of the pulse is signaled by the PRE-DRIVER which turns off tube V_1 and turns on tube V_2 in a push-pull fashion, thereby removing the 3 kV pulse on the grid of the EIA and returning it to its cut-off bias condition.

3.4 FOCUS CONTROL

The Modulator drawing in Appendix A shows that the Zener string between the plate of V_1 and the cathode of the EIA provides an offset voltage to compensate for the plate-cathode voltage drop and to adjust the focus voltage. Rotation of the 10 position switch (located under the EIA mounting plate) shorts a section of the string, providing voltage steps in 4 to 10 volt increments.

3.5 COLLECTOR CURRENT MONITOR

From the Collector Pulse Isolation circuit and Modulator circuit drawings in Appendix A, note that the printed circuit board for the collector current monitor is located behind the EIA. The peak and average collector current monitor functions are on this circuit board. A 2:16 turns ratio transformer supplies the 50 Ω CURRENT MONITOR output. This output requires a 50 Ω termination for correct calibration as discussed in Section 2.2. The average dc collector current is monitored through the 170 K resistor and the BEAM CURRENT METER. The Collector Current (I_{CS}) is compared against the total high voltage supply current to set a safe operating range for the body current.

3.6 HEATER SUPPLY

The Heater Power Supply drawing shows that both Y690 tubes and the EIA have approximately 14 volts peak-to-peak applied by a switching oscillator circuit. A toroidal transformer encapsulated in insulation material makes up a low capacitance coupler between the oscillator and all three tubes.

The oscillator frequency is approximately 20 kHz. The heater supply printed circuit board is located in the modulator and is supplied by 28 Vdc when the ON/OFF switch is set to ON. The LM 317 regulator allows the output voltage to the filaments to be set at 6.3 V RMS.

3.7 HIGH VOLTAGE POWER SUPPLY MODIFICATIONS

For external control of the high voltage, the variable resistor RP1 was removed from the -22 kV unit, and a modified resistor network was placed in the CONTROL CONSOLE.

During turn-on, the -22 kV power supply was found to overshoot the maximum allowable voltage by approximately 20%. To solve this problem, a 10 μ f capacitor was added to the reference voltage circuit to create a three second start-up time with no overshoot. In addition, to ensure this capacitor was fully discharged when going to STANDBY, a diode (1N914) was added to discharge the 10 μ f capacitor.

SECTION 4 STABILITY

4.1 PULSE TO PULSE

The principal source of pulse instability is the advanced high voltage -22 kV power supply, which has a slow (1 Hz) variation of as much as 20 V peak-to-peak. The ripple on the EIA cathode at the power supply switching frequency is approximately 5 V peak-to-peak.

4.2 INTRA PULSE

Both the EIA grid-cathode voltage and the cathode-body voltage affect the RF power and phase during the top of the pulse. V_1 is driven to saturation, effectively clamping the grid to the cathode. The combined ripple and drop of the grid-cathode voltage is less than 10 volts.

The two .0025 f 30KV capacitors, one from cathode-to-body (C_{RB}) and the other from cathode-to-collector (C_{KC}), allow separation of the body and collector pulse currents. The droop of V_K is determined only by the body intercept current and can be calculated by

$$\Delta V_K \approx \frac{I_B \tau}{2500} \text{ Volts}$$

where:

$$I_B = \text{Body current (mA) and } \tau = \text{Pulse width (ns)}$$

The droop was confirmed by measuring the RF frequency variation of an extended interaction oscillator (EIO) supplied by Varian. When phase pushing factors are established for an EIA, phase characteristics for the entire Modulator Amplifier can be determined.

SECTION 5 OPERATING INSTRUCTIONS

5.1 OPERATING FEATURES

5.1.1 BEAM CURRENT METER

The maximum and minimum pointers for the BEAM CURRENT METER should be set for a small range of average beam current. If the duty factor of the peak beam current exceeds its nominal value, the BEAM CURRENT METER will indicate that the average collector current is too high. The control circuit will automatically switch to standby, turning off the high voltage power supplies, and the OVER-CURRENT light will illuminate. Appropriate steps such as reducing the PRF, pulse width, or peak beam current should be taken to reduce the average beam current. The STANDBY/RESET switch must be pressed to cancel the OVER-CURRENT condition.

If the minimum-pointer for the BEAM CURRENT METER has been set to some value other than zero, the modulator will automatically switch to STANDBY when the average current decreases below this value and the under-current light will illuminate. The overload circuit is not activated in this case. To switch to radiate once a lower limit on the beam current meter has been set, press the RADIATE switch once again.

In order to insure that the EIA body current remains within proper limits, a collector pulse isolation circuit is incorporated. In the event of an arc or excessive body current being drawn from the -22 kV power supply, the collector pulse isolator circuit deenergizes a fault relay in the control console which returns the modulator to standby. The indication will be the extinguishing of the radiate light.

5.1.2 AUTOMATIC WARM-UP DELAY

A delay of two minutes has been built into the CONTROL CONSOLE to assure that the EIA and hard tubes have the proper warm-up time before high voltage is applied. A time delay relay on the control circuit board sets the minimum required time.

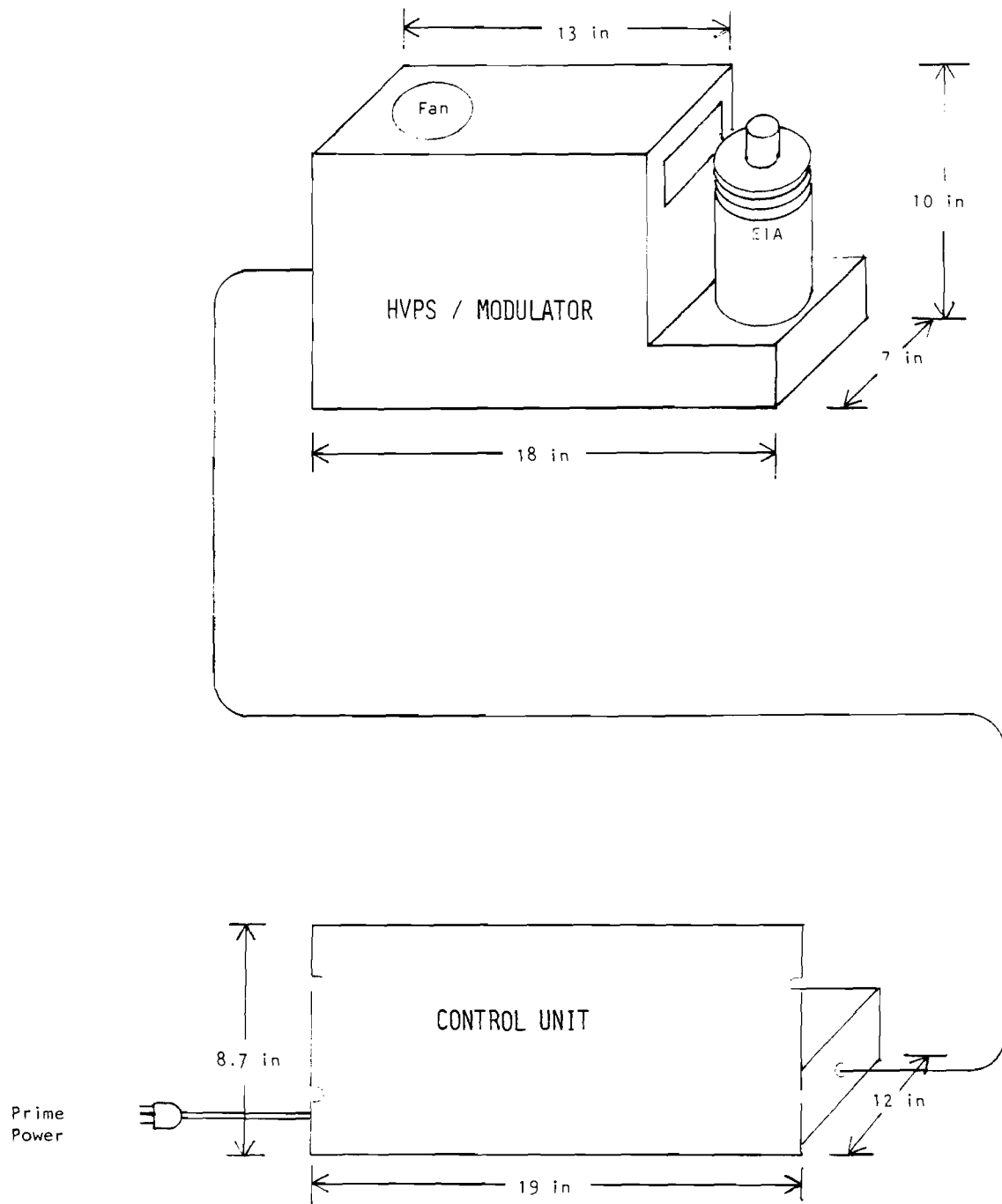
5.2 TURN-ON PROCEDURE

- a. Insure that all connections as described in Section 2.2 are securely in place.
- b. Set the Beam Voltage Control on the control console to the minimum (counter clockwise).
- c. Turn POWER ON/OFF Switch to ON position. The orange ON light should be on. The green STANDBY/RESET light will illuminate AFTER A TWO MINUTE DELAY.
- d. Set the minimum set point to $0\mu\text{A}$ on the BEAM CURRENT METER, and the maximum set point to $80\mu\text{A}$ on the BEAM CURRENT METER.
- e. Set the PULSE WIDTH to the desired position.
- f. Press the RADIATE switch. The red RADIATE light should illuminate. If the radiate light fails to illuminate, check the interlocks.
- g. While monitoring the RF, set the Beam Voltage adjust potentiometer on the Control Console until the RF is maximized. If there is no RF at this point, refer to Principles of Operation (Section 3).
- h. IMPORTANT! Bracket Beam Current per Section 5.1.1.
- i. Adjust Focus Control for maximum RF Power (Section 3.4).

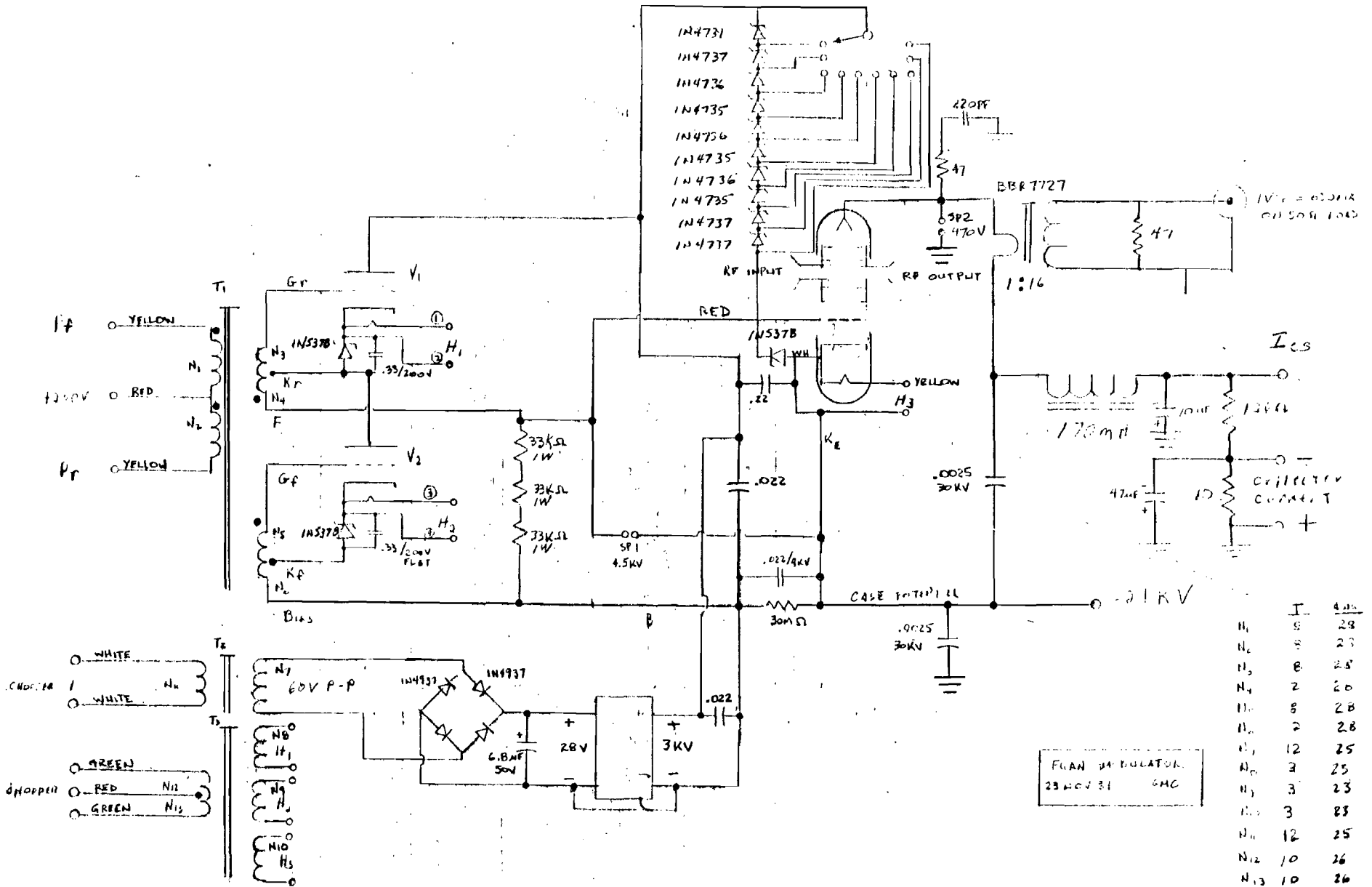
APPENDIX A

MODULATOR SCHEMATICS

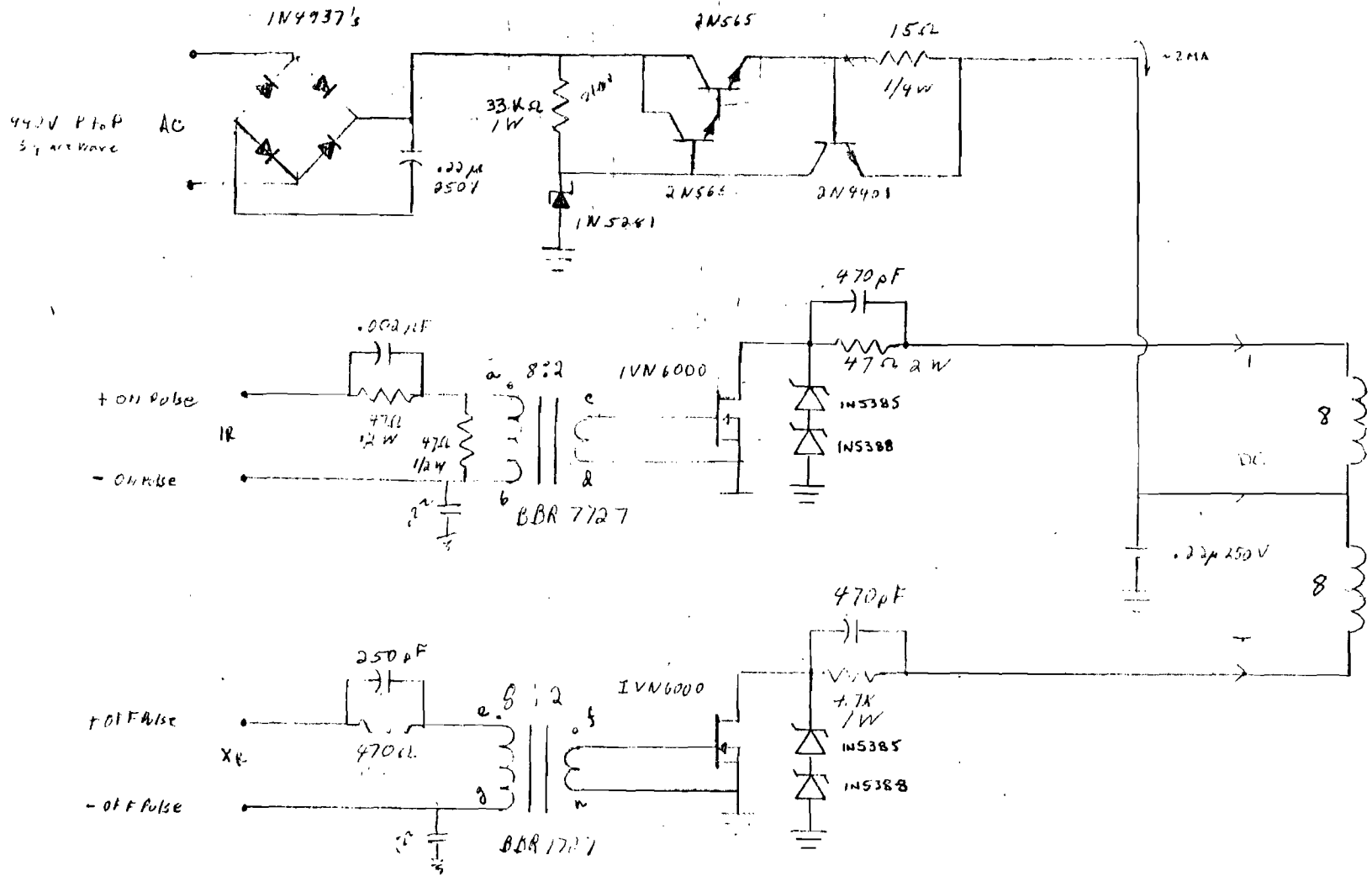
<u>FIGURE</u> <u>NUMBER</u>	<u>TITLE</u>	<u>PAGE</u>
A-1	MODULATOR AND CONTROL UNIT.....	11
A-2	MODULATOR AND H.V. INTERFACE CIRCUIT.....	12
A-3	MODULATOR DRIVER CIRCUIT.....	13
A-4	PRE-DRIVER AND +70 V SUPPLY.....	14
A-5	COLLECTOR PULSE ISOLATION CIRCUIT.....	15
A-6	PULSE CONTROL CIRCUIT.....	16
A-7	PRF LIMITED SIGNAL GENERATOR.....	17
A-8	POWER CONTROL CIRCUIT.....	18
A-9	FILAMENT CHOPPER SUPPLY.....	19
A-10	DRIVER POWER SUPPLY.....	20
A-11	CABLING DIAGRAM.....	21



A-1. Modulator and control unit.

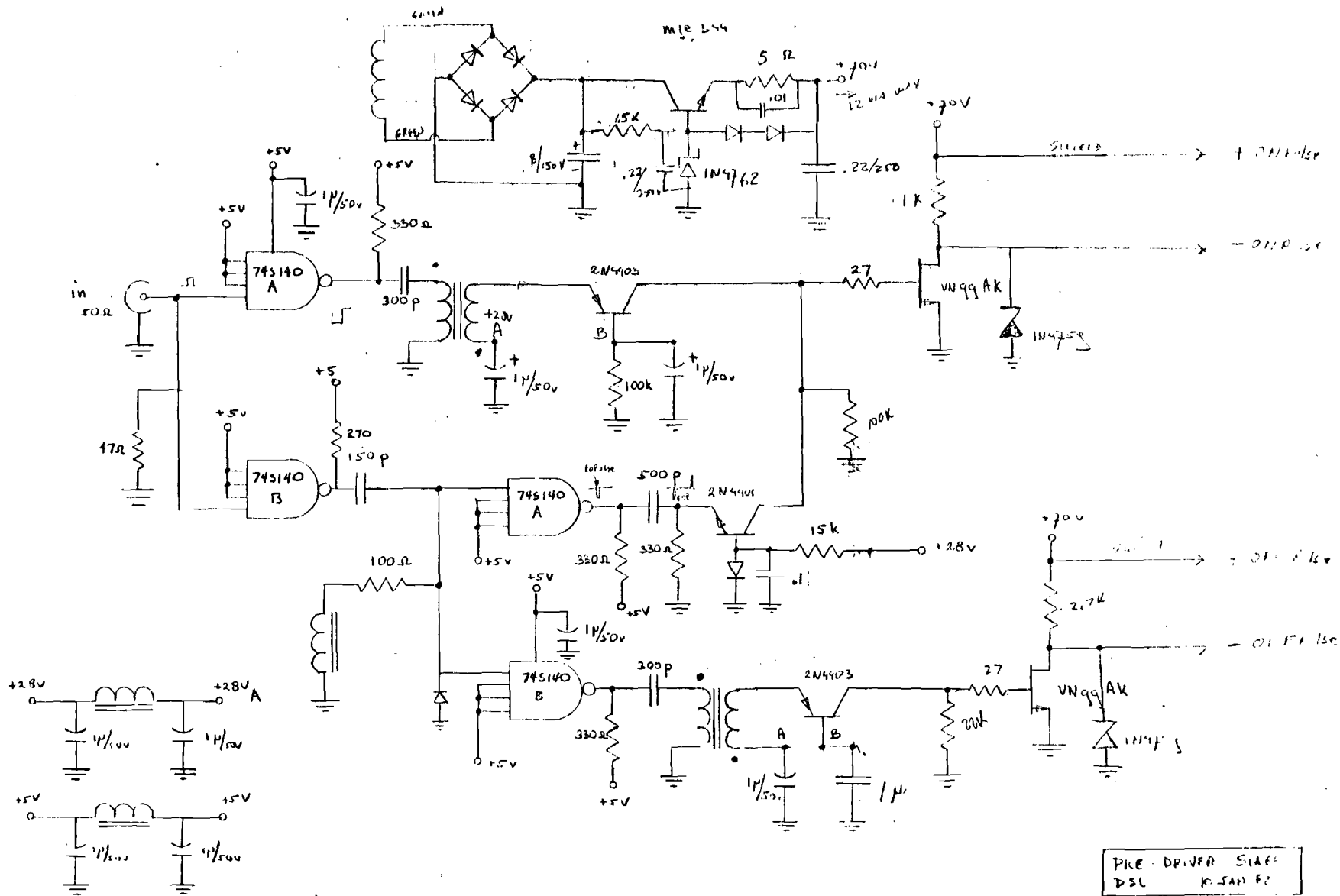


A-2. Modulator and H.V. interface circuit.



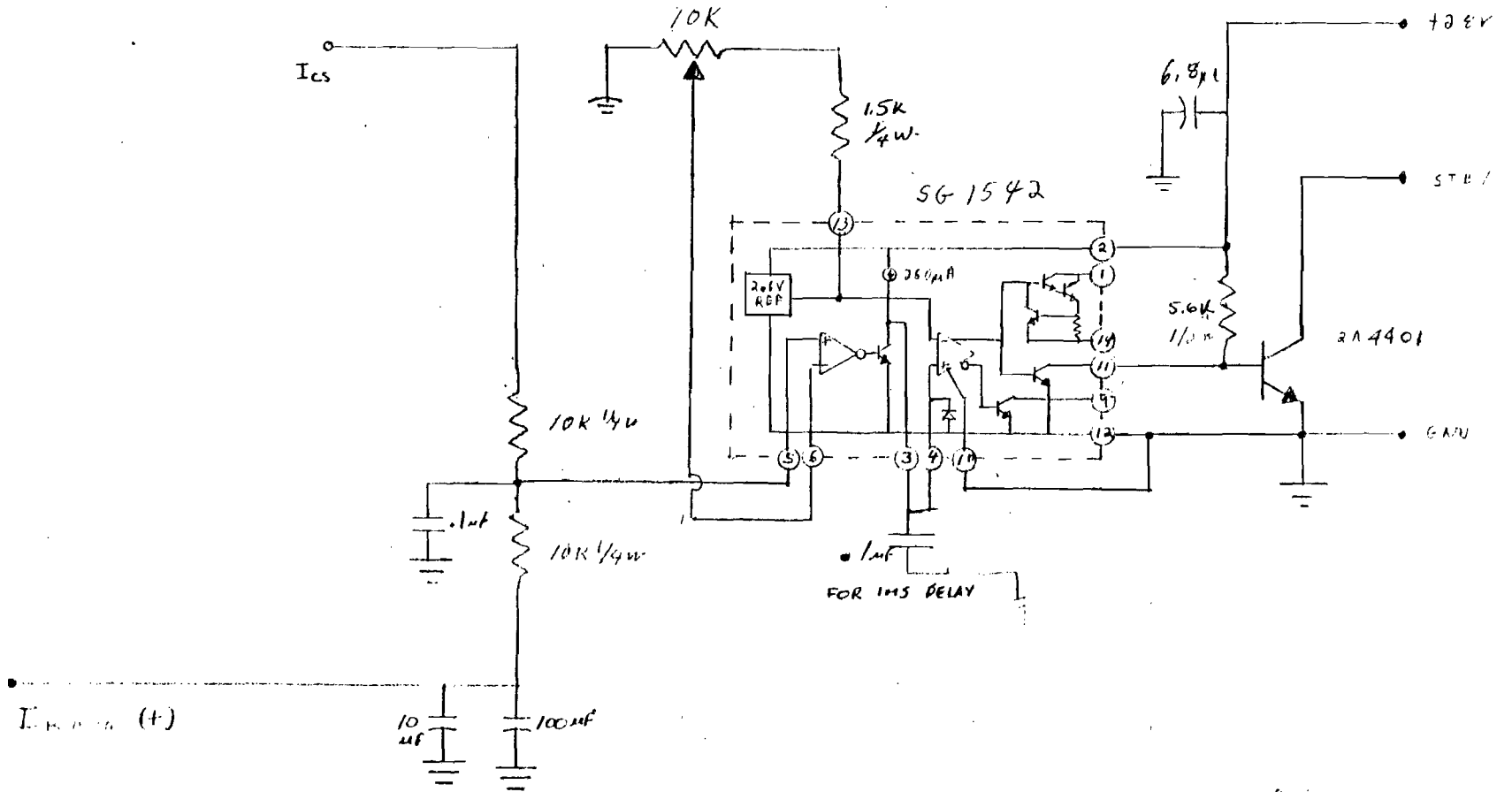
Part of DP 088 (1A) 1000

A-3. Modulator driver circuit.



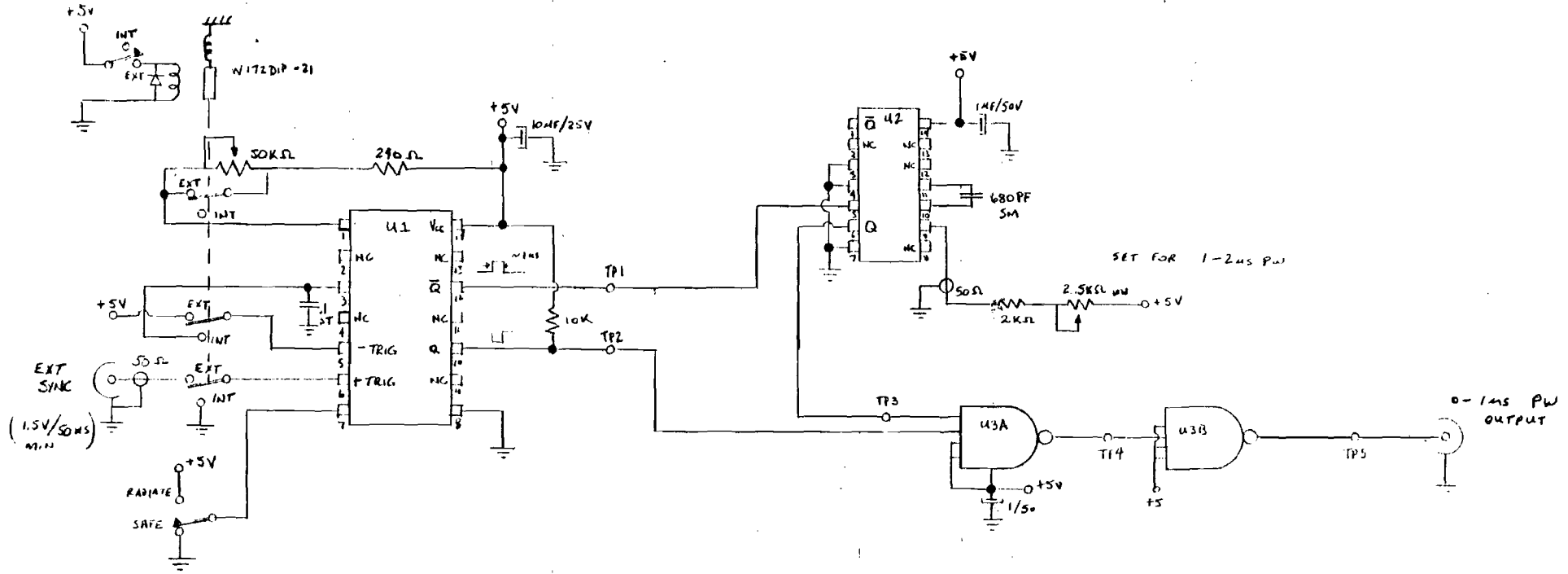
A-4. Pre-driver and +70 V supply.

NRL
current
source



Collector Pulse
Isolation Circuit

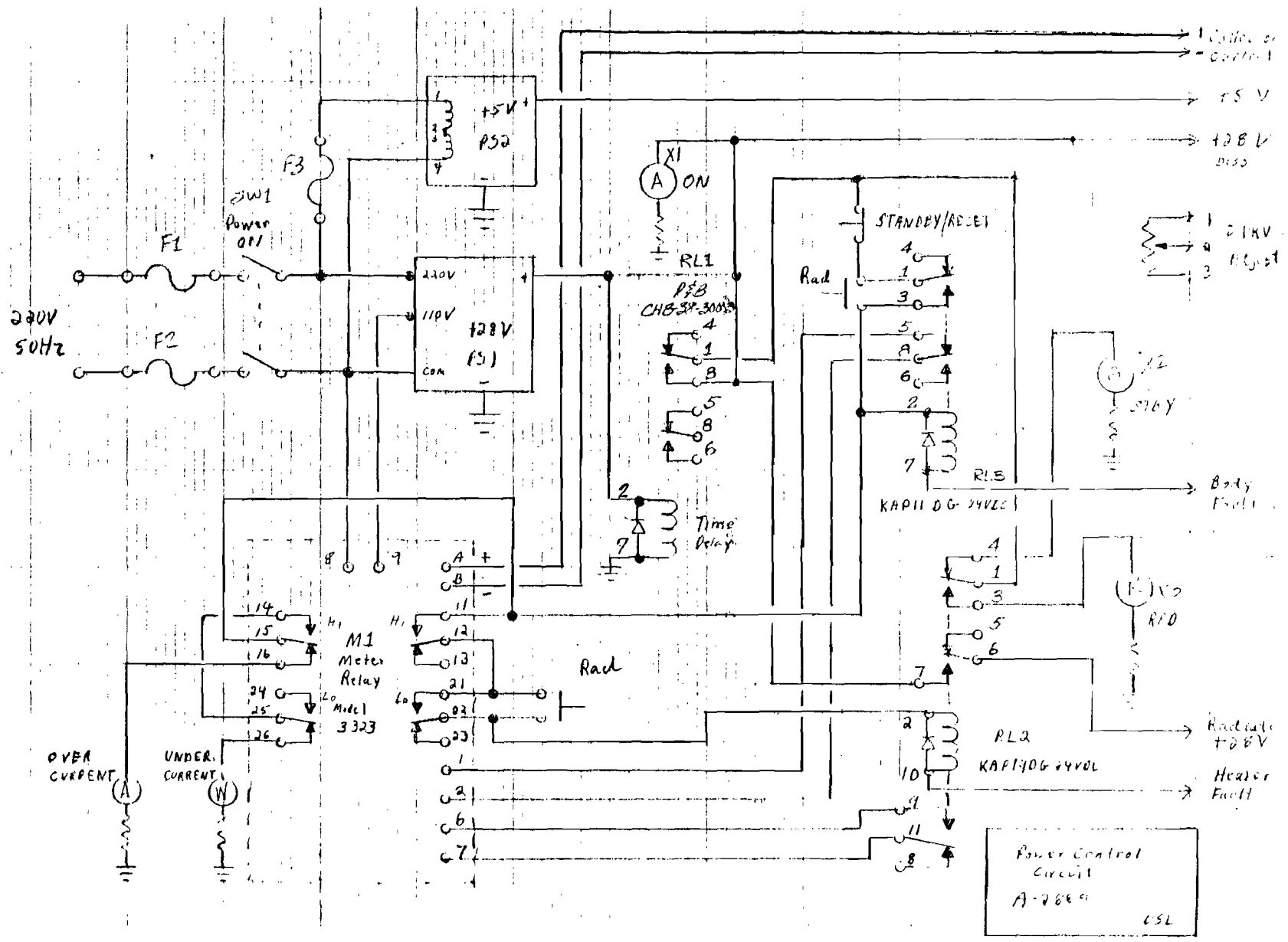
A-5. Collector pulse isolation circuit.



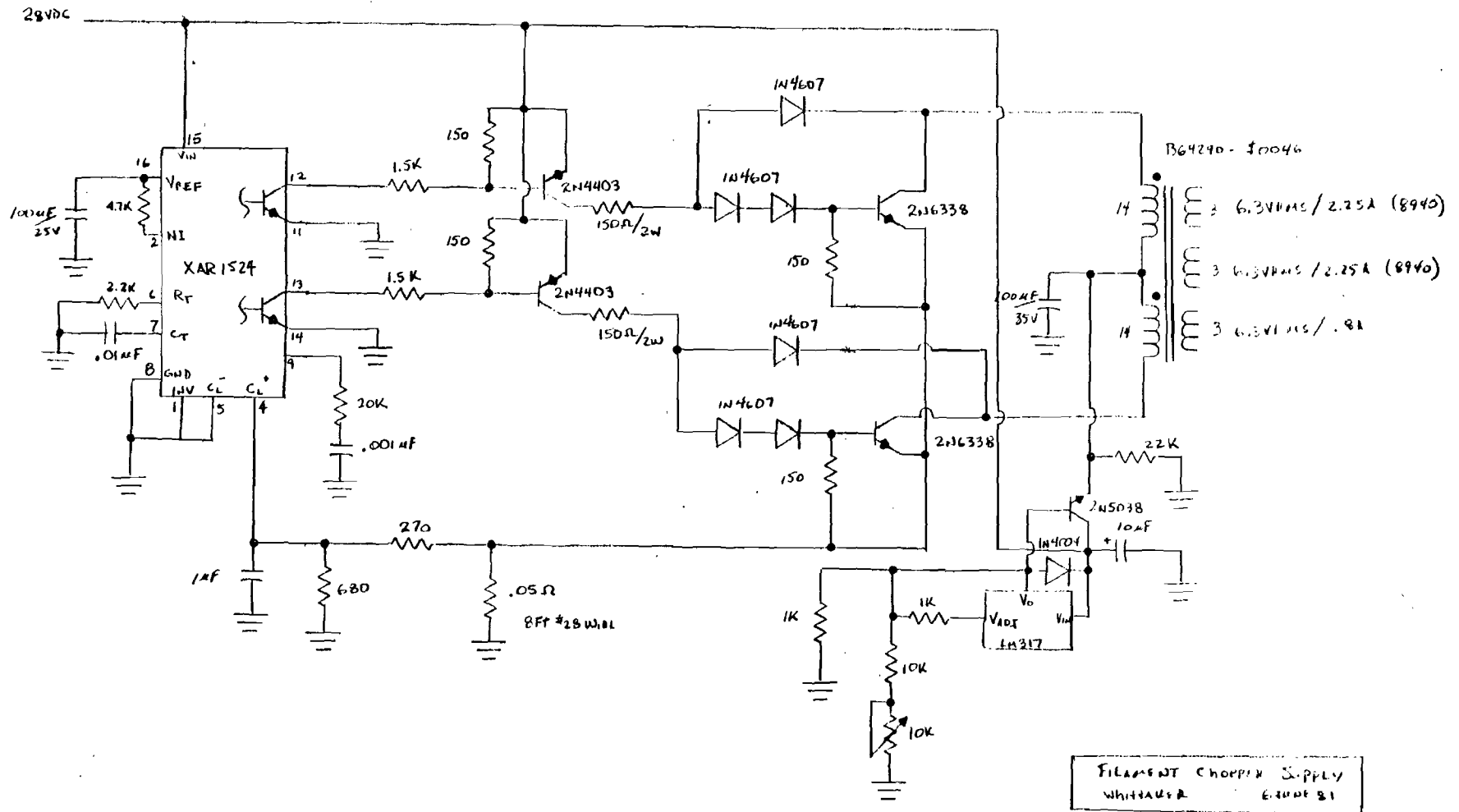
- U1 : 555
- U2 : 74121
- U3 : 74140

PRF - LIMITED SIGNAL GENERATOR
GHC 28 JUL 81

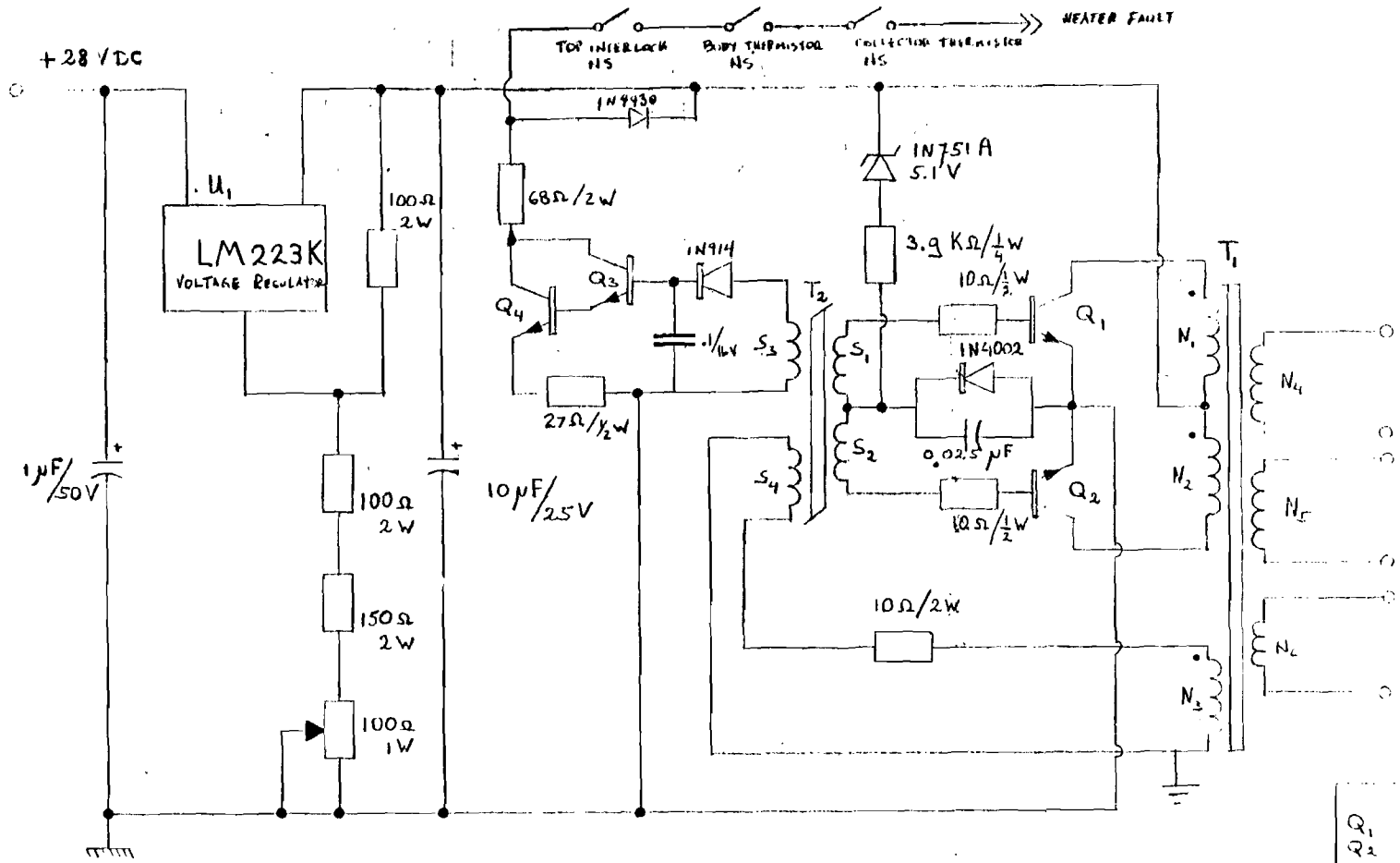
A-7. PRF limited signal generator.



A-8. Power control circuit.

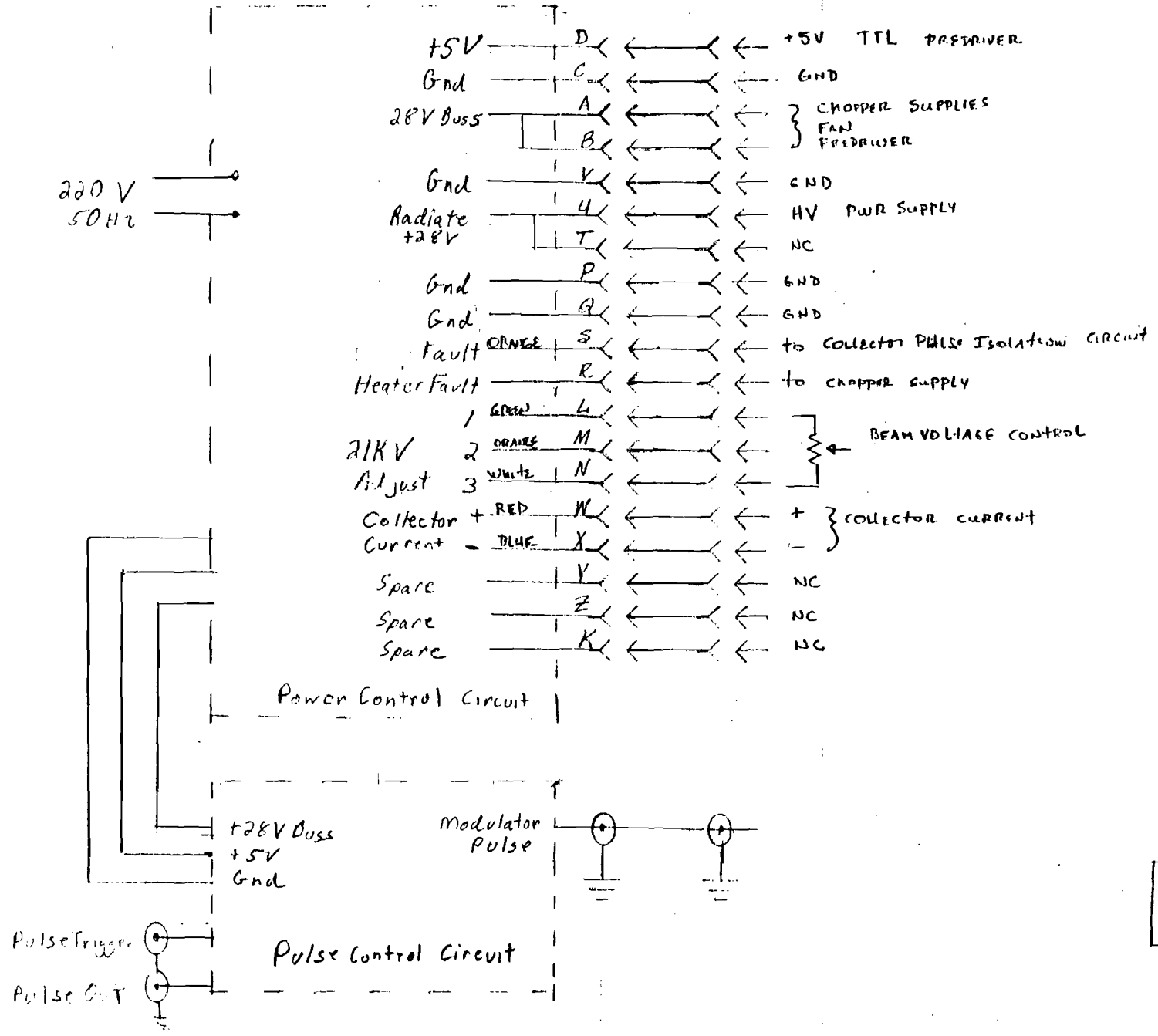


A-9. Filament chopper supply.



Q ₁	- 2N5002
Q ₂	- 2N5002
Q ₃	- 2N4501
Q ₄	- 2N3440
U ₁	- LM223K
T ₁	F152-1-06 BOBBIN CORE
N _{1,2}	10 T # 20 AWG
N ₃	3 T # 20 AWG
N ₄	75 T # 25 AWG
N ₅	43 T # 25 AWG
T ₂	MAG INC # 80614-ID(MA)
S _{1,2}	(BIFILAR WOUND) 21 T # 30
S ₃	- 21 T # 30
S ₄	- 21 T # 30
RALPH	10414 81
TECH.S.D	G.M.C.
	11404 81

A-10. Driver power supply.



BASIC CABLING DIAGRAM
GACC 1 FEB 62

A-11. Cabling diagram.