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HIGH VOLTAGE NANOSECOND PULSE GENERATORS.(U)
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RESEARCH AND DEVELOPMENT TECHNICAL REPORT

DELET-TR-77-2641-4

LEVEL III

A066803

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HIGH VOLTAGE NANOSECOND PULSE GENERATORS

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July 1979

Fourth Interim Report for Period 1 Jul 78 - 30 Apr 79

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This report covers the work performed during the period 1 Jul 78 to 30 Apr 79 to develop high voltage nanosecond pulse generators. Effort was concentrated on the Task III pulser, which requires a burst of square wave, 100 ns wide pulses, operating at the 1.3 kV level. The load is an electroptic CdTe crystal. The technical approach combined a pair of wide bandwidth triodes, for charging and discharging the crystal capacitance, with high speed VMOS as grid drivers. The pulser was constructed and tested. Results show that voltage output and waveforms, with a capacitive load to simulate the crystal, meets all requirements.

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LIST OF FIGURES

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I - INTRODUCTION

This report covers work during the period 1 July 1978 to 30 Apr. 1979 on Contract DAAB07-77-C-2641 to develop an IFF Pulser. The work is being performed by Cober Electronics in Stamford, Connecticut for the U.S. Army Electronics Command, Ft.Monmouth, New Jersey. The work is directed towards fulfilling the requirements of Task III Technical Guidelines entitled "High Voltage Nanosecond Pulse Generators" dated 18 December 1978. Listed below are the requirements for Task III.

Task III Requirements (IFF Pulser)

Peak Voltage on Load (both Preamble & IFF)	:	1.3 kV
Load Capacitance	:	30 pf
IFF Pulsewidth on Load(50%)	:	70 ns
IFF Pulse Rise Time on Load (10 to 90%)	:	30 ns max.
IFF Pulse Fall Time on Load (90 to 10%)	:	30 ns max.
Preamble Pulsewidth on Load (50%)	:	approximately 1 us
Preamble Pulse Rise Time on Load (10 to 90%)	:	30 ns max.
Preamble Pulse Fall Time on (90 to 10%)	:	30 ns max.
Jitter	:	1 ns max.
Volume	:	1200 cm^3 max.
Weight	:	3 kg max.
Input Battery Voltage	:	28 V
MTBF	:	10^7 burst operations

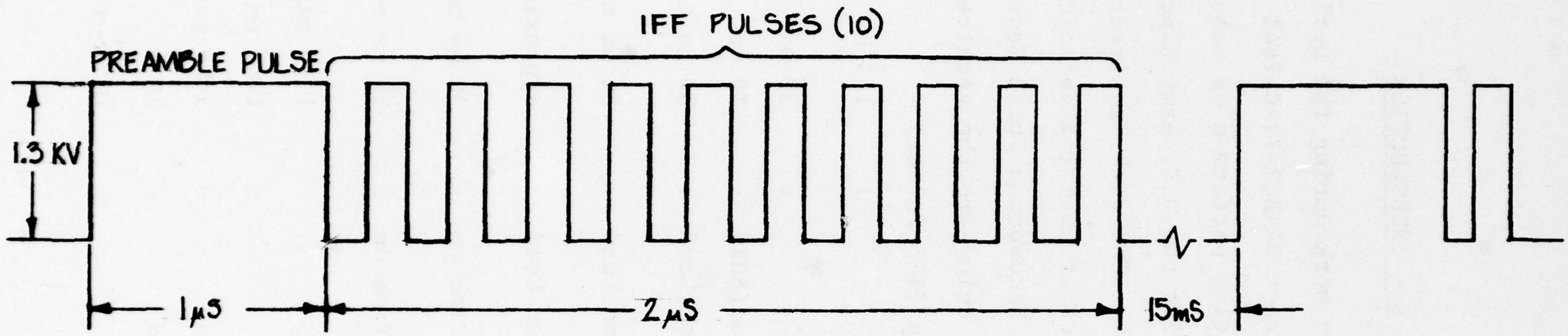


FIGURE 1

VOLTAGE ON CdTe CRYSTAL

2566-X4

A typical burst, including the preamble pulse is shown in Figure 1.

TASK III

The original approach in realizing the design objectives of this task is shown in Figure 2.

Machlett ML-8538 tubes were to be used as the charge and discharge elements. Power to operate the filaments of these tubes as well as the bias supplies (2) and 75 volt supply were to be obtained from suitable windings of two 20Kc inverter supply transformers. A typical inverter is shown in Figure 3. This circuit arrangement was used in powering the discharge tube. A similar transformer-inverter was provided to power the charge tube. Winding 5 (75 volt winding) was omitted in this transformer.

Finned anode radiators were found to be necessary to help dissipate filament heat.

Power to operate the charge and discharge tubes was to be obtained from two adjustable Venus supplies. External 60 cycle power supplies were used in the development of the breadboard unit because of added flexibility in changing the output voltage. Schematics of the positive and negative power supplies are shown in Figure 4.

Long delivery of the Machlett ML-8538 made it necessary to switch to Eimac Y-540 tubes.

The original design concept was based on differentiation of the trigger pulse as it passed through the input transformer.

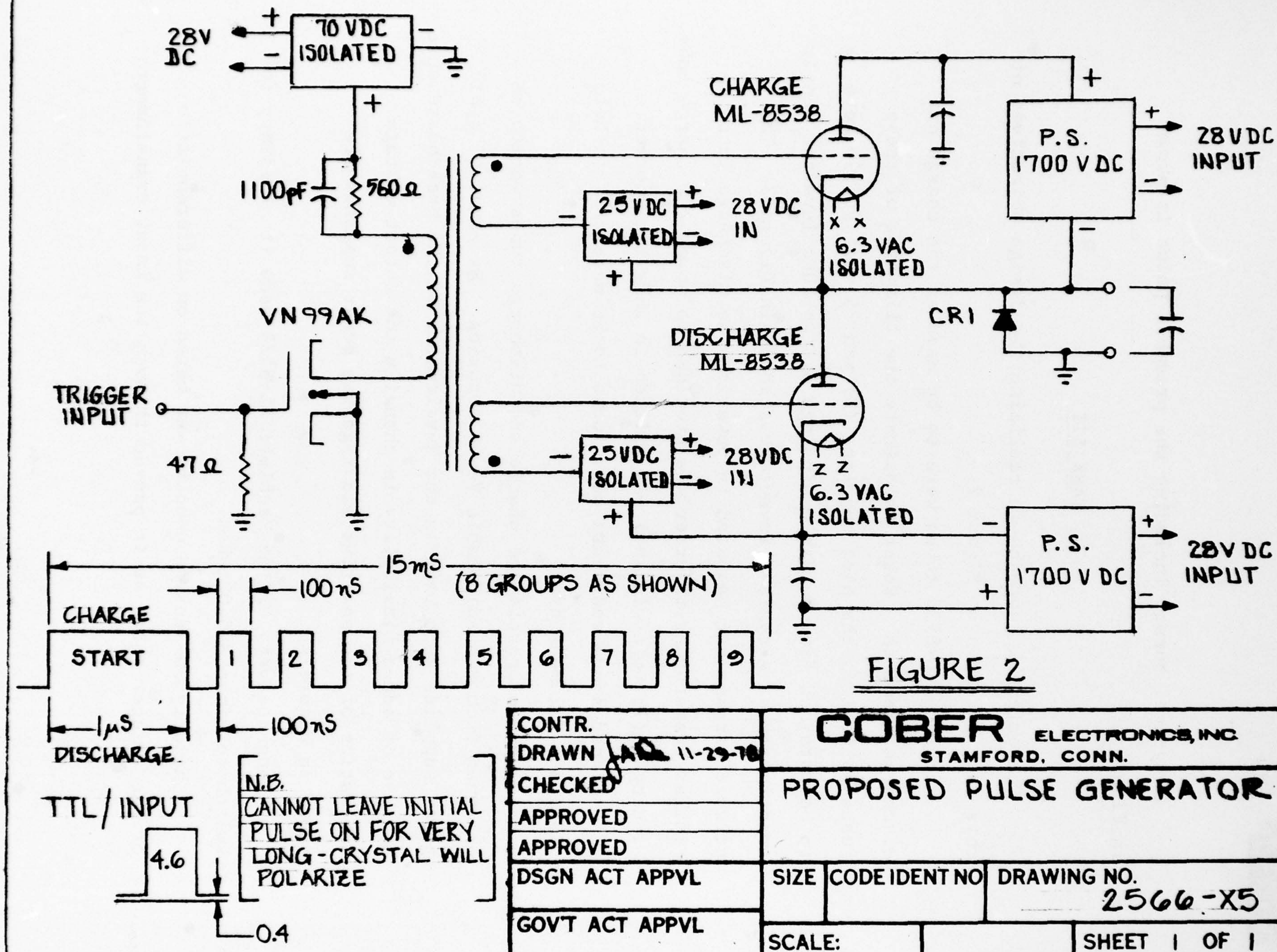

28V DC
70 VDC ISOLATED
1100pF
560 Ω
VN99AK
TRIGGER INPUT
47 Ω
CHARGE ML-8538
DISCHARGE ML-8538
25 VDC ISOLATED
28 VDC IN
6.3 VAC ISOLATED
P. S. 1700 V DC
28 VDC INPUT
CR1
15mS
100nS
(8 GROUPS AS SHOWN)
CHARGE
START
1 2 3 4 5 6 7 8 9
1μS
100nS
DISCHARGE
TTL/INPUT
4.6
0.4
N.B. CANNOT LEAVE INITIAL PULSE ON FOR VERY LONG - CRYSTAL WILL POLARIZE
CONTR.
DRAWN 11-29-78
CHECKED
APPROVED
APPROVED
DSGN ACT APPVL
GOV'T ACT APPVL
COBER ELECTRONICS, INC
STAMFORD, CONN.
PROPOSED PULSE GENERATOR
SIZE
CODE IDENT NO
DRAWING NO. 2566-X5
SCALE:
SHEET 1 OF 1

FIGURE 2

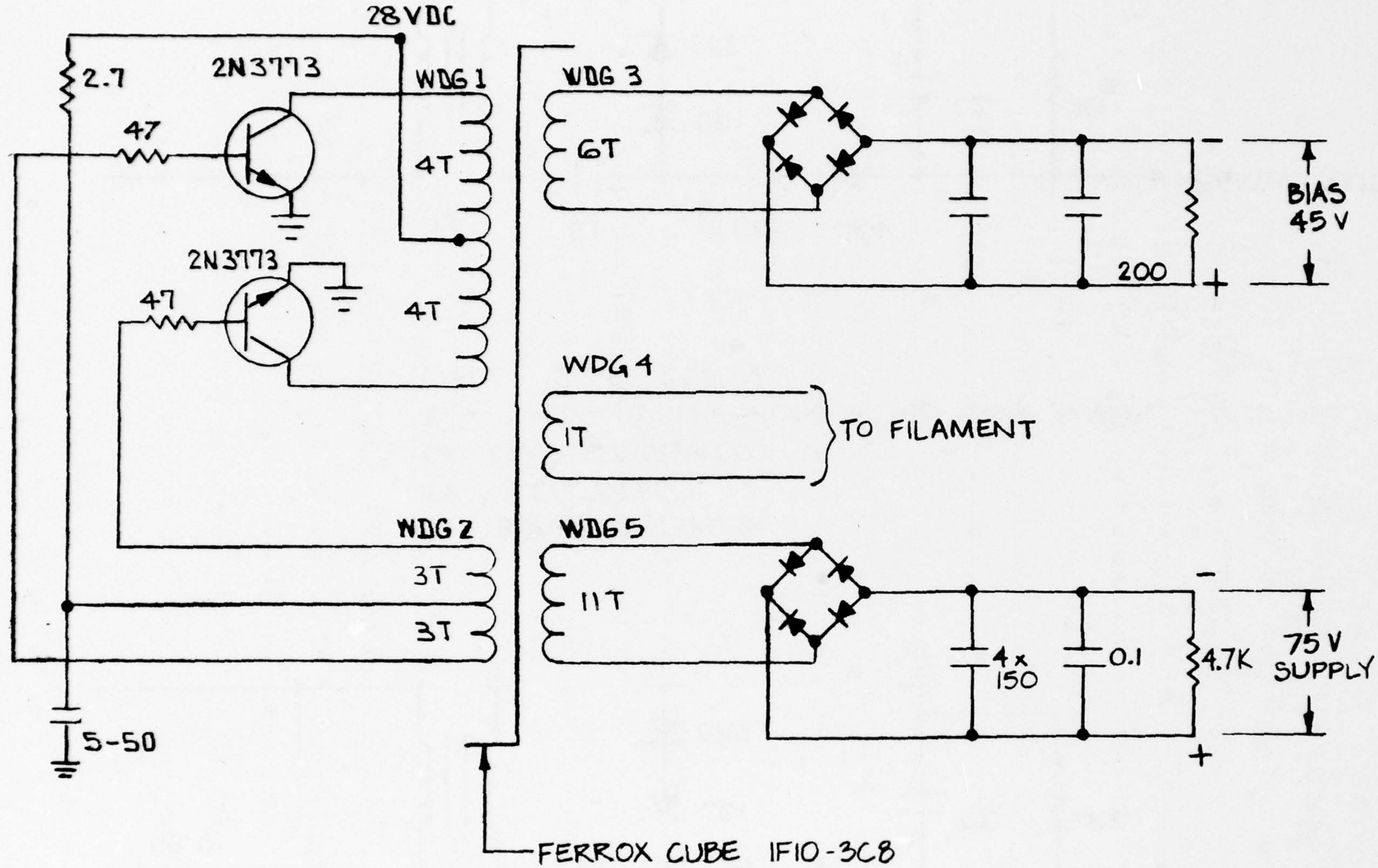
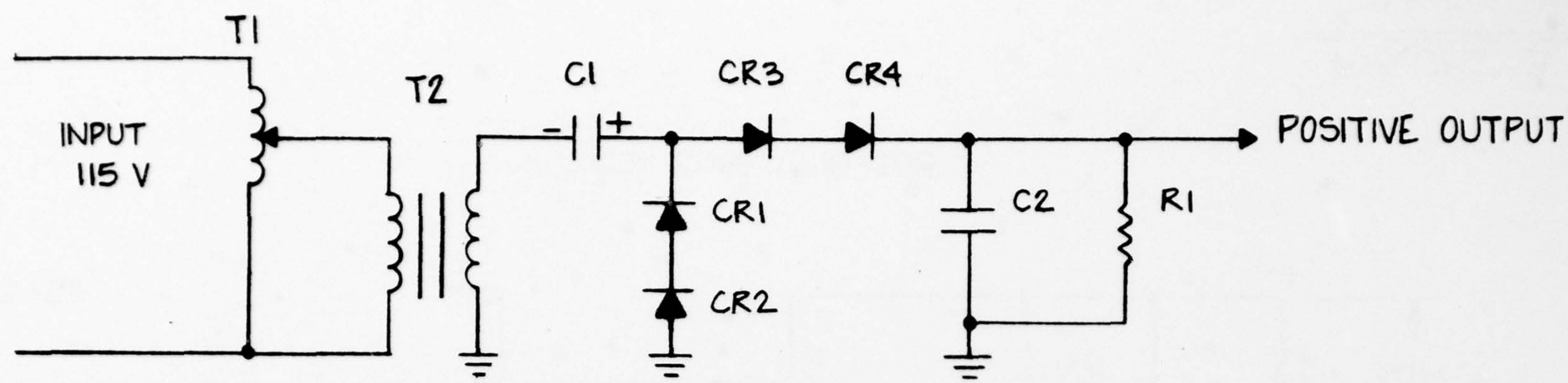


FIGURE 3

2566-X6



T1 - SUPERIOR, TYPE 21
T2 - U.T.C., R43C
CR1-CR4 - EDI, EH400
R1 - 1 MEG. (2 SERIES CONNECTED 510 K, 2 W)
C1 & C2 - 2 μF, 2500 V

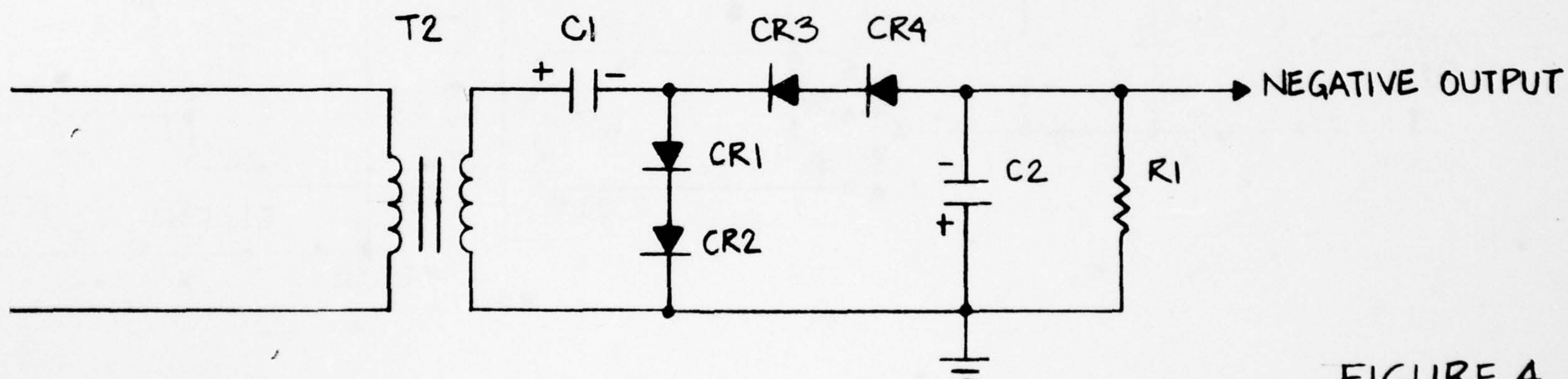


FIGURE 4

2566-X7

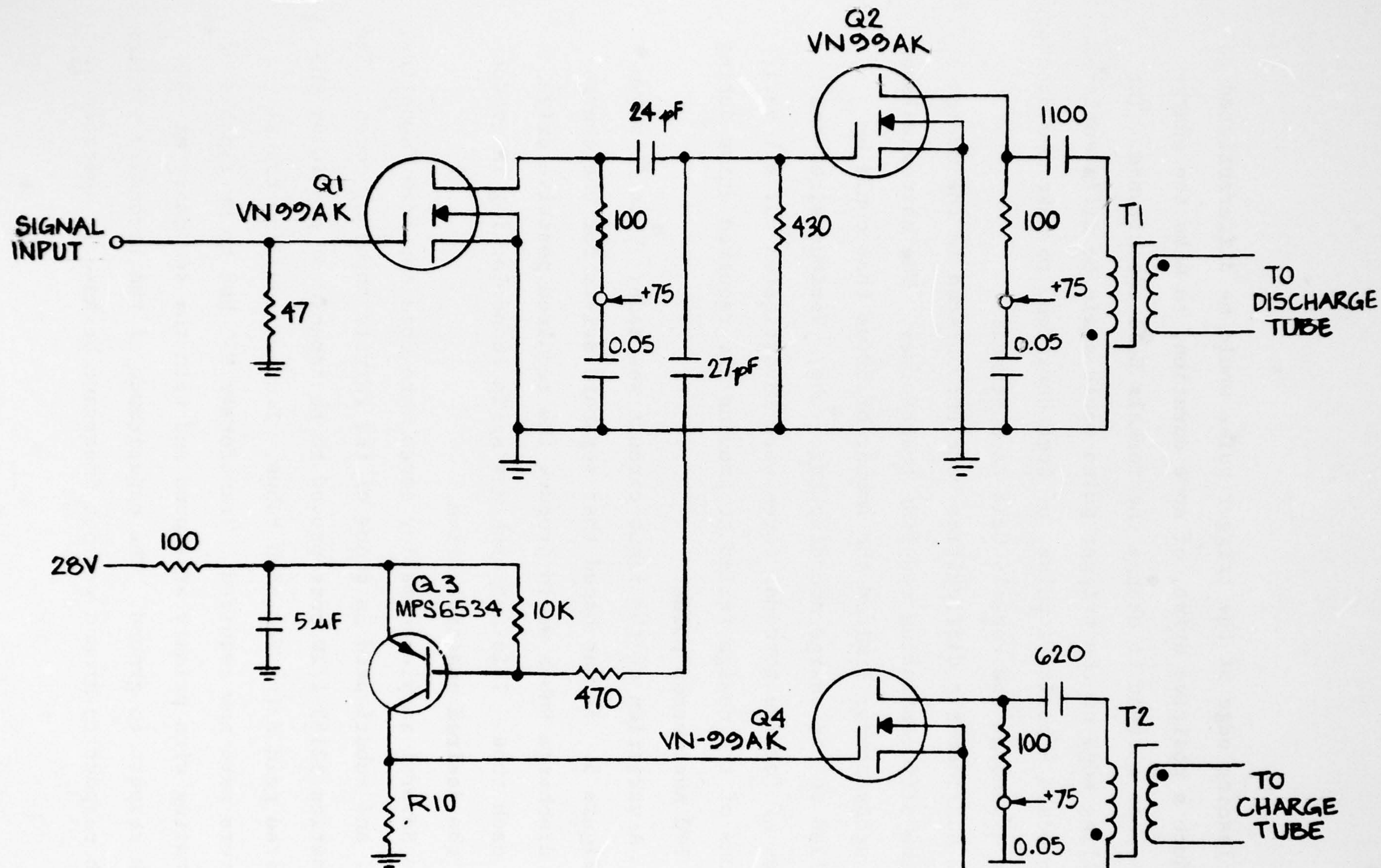


FIGURE 5

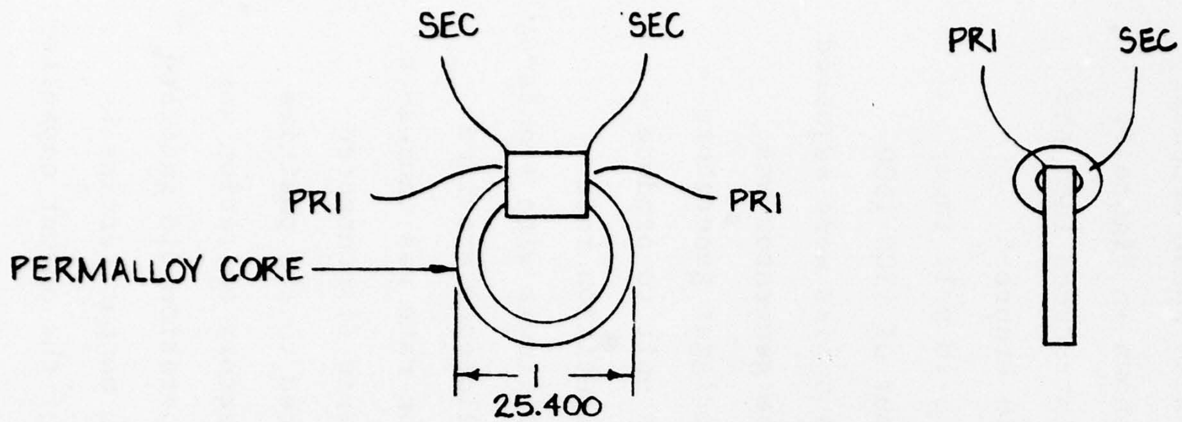
2566-X8

The leading edge of the trigger pulse would be differentiated to produce a positive drive, of some duration, to make the charge tube pass current to charge the Pockels Cell capacitance. The trailing edge of the trigger pulse would again be differentiated to produce a positive pulse, of some duration, to make the discharge tube discharge the Pockels Cell capacitance.

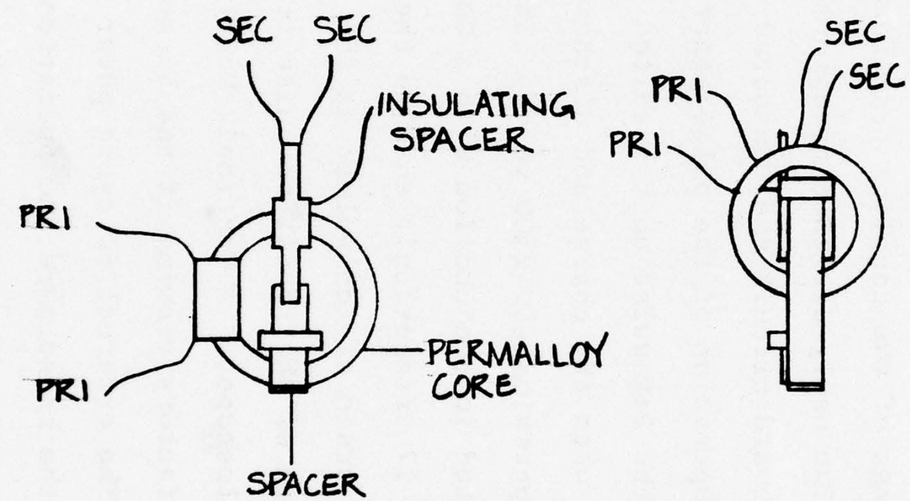
Considerable difficulties were encountered in the design of the differentiating coupling transformer. The narrow pulses, 100 nanoseconds, limited the amount of drive that could be applied to the charge and discharge tube. Various sizes and types of ferrite toroidal cores were investigated but all variations of the design failed to provide the required drive during the 100 nanosecond pulse.

A variation of the input circuit was made. This is shown in Figure 5. It was hoped that separate drives for the charge and discharge tubes would produce the required positive drive for each tube. This approach was again found lacking in producing the desired positive drive.

Several sample permalloy cores were obtained from Magnetics, Inc. and substituted in place of the ferrite toroidal cores. The Magnetics 52143-1/2D core proved to be capable of providing the desired grid drive for both tubes. Two new coupling transformers were now required. Transformer T-1 had to be capable of operating with primary at ground and with the secondary at -3KV with respect to ground. The capacitance of the secondary winding with respect to ground was not important because it operated at



TRANSFORMER T1



TRANSFORMER T2

FIGURE 6

2566-X9

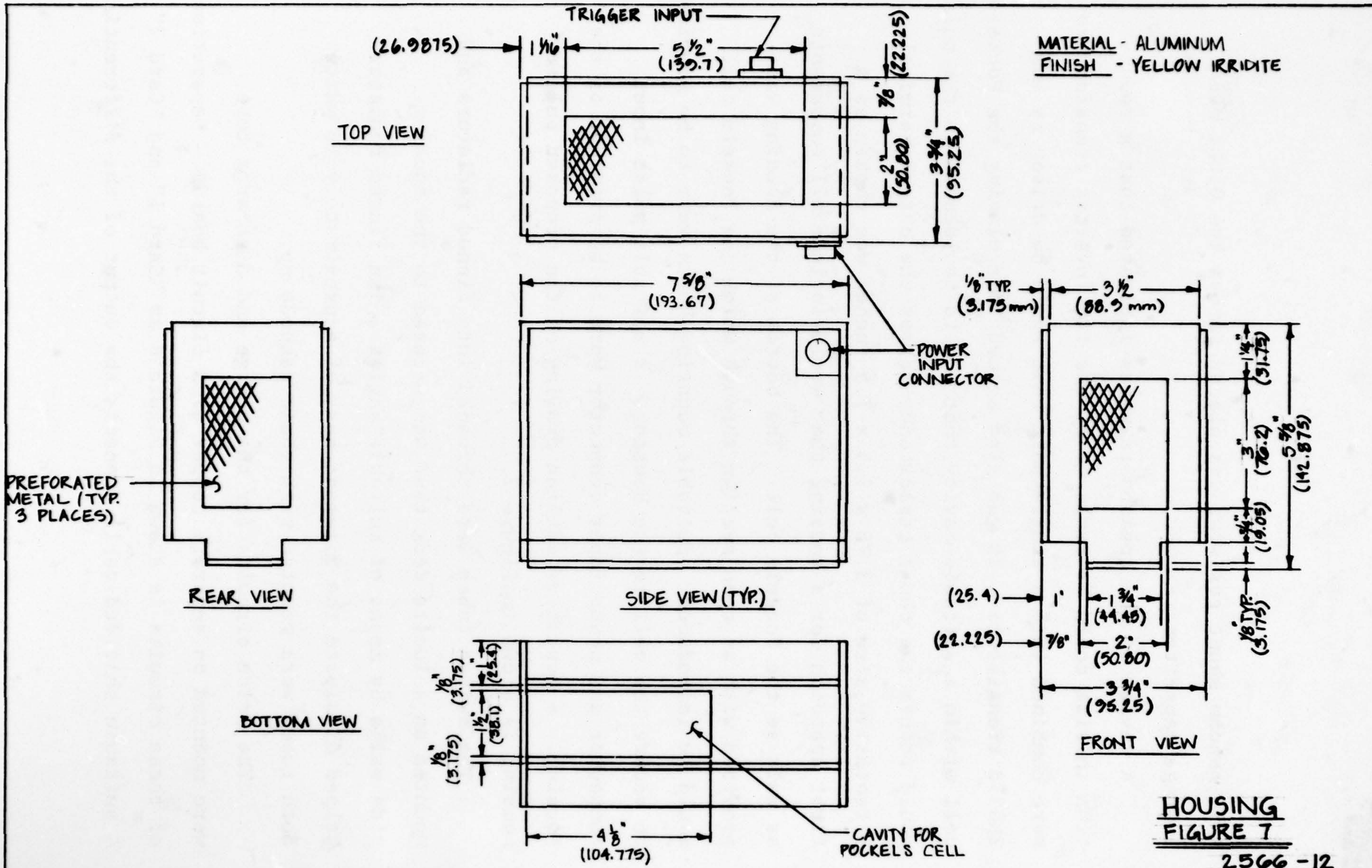
power supply potential. The output terminals of the negative power supply were shunted by .002 microfarads.

Transformer T-2, which operates the charge tube, requires a secondary winding which must have as little capacitance to ground as practical. This requirement may be realized by winding the primary close to the core with a spaced donut secondary. Drawings of the coupling transformers are shown in Figure 6.

The newly designed transformers were introduced into the breadboard circuit and connected as shown in Figure 5.

Operation of the pulse generator with a 10 volt input from the Datapulse unit resulted in an output of 1300-1500 volts when the charge and discharge power supplies were adjusted for approximately 2500 volts. The Datapulse generator was operated in conjunction with a Cober P-27 trigger generator. The P-27 trigger unit enabled the Datapulse unit to produce a pulse train of ten pulses at the desired repetition rate. Viewing of the resulting pulse train was difficult with standard oscilloscopes. A Tektronix Model 466 Oscilloscope provided satisfactory viewing if the burst repetition rate was increased.

The external 60 cycle power supplies were disconnected from the breadboard and operation was shifted to the positive and negative Venus power supplies. Satisfactory operation was observed with the Venus power supplies. Operation did indicate that a bleeder would be required across the output terminals in order to speed up the discharge period of the output capacitor.



HOUSING
FIGURE 7

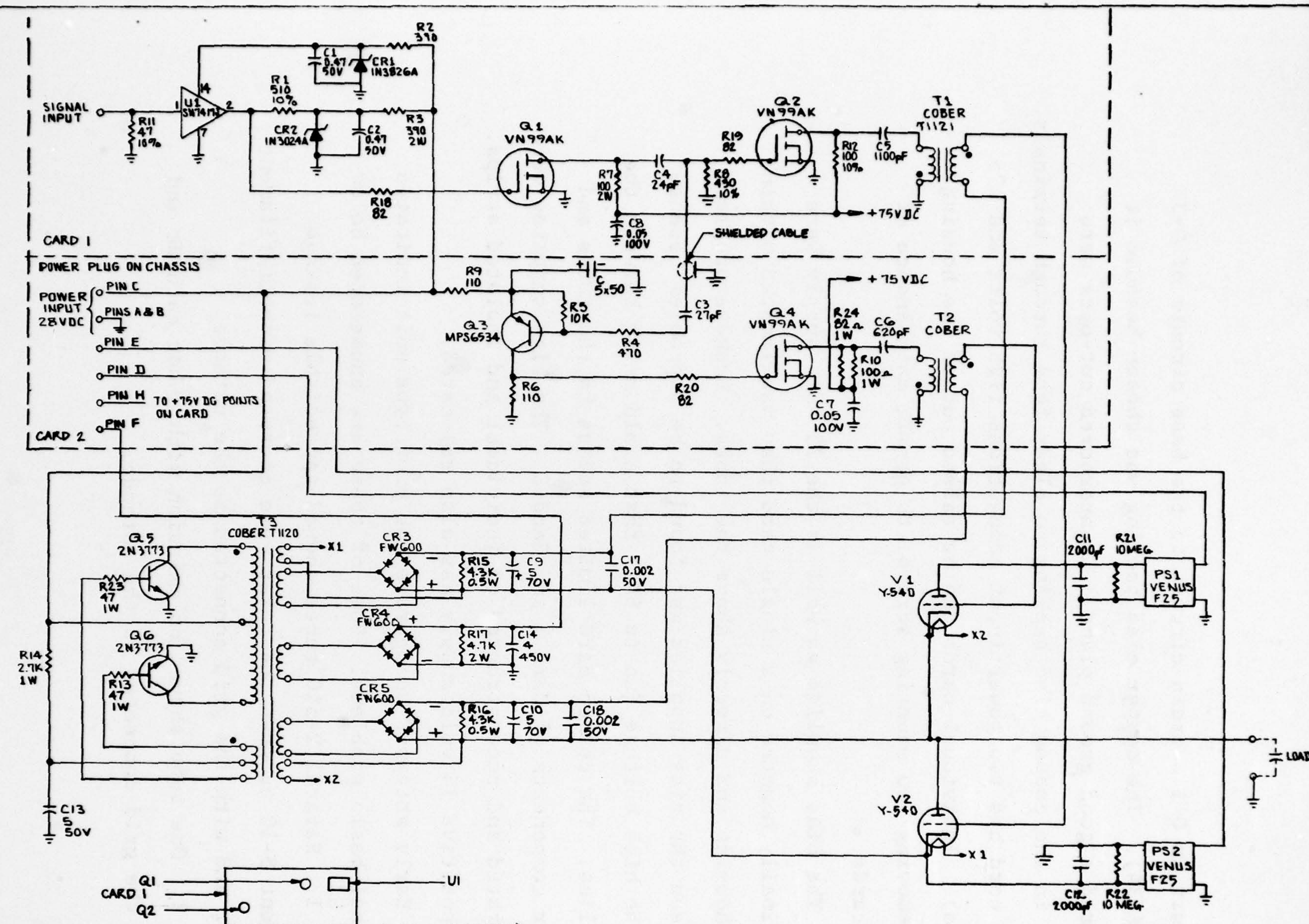
2566 -12

A 10 mehohm shunt resistor was placed across the 0.002 mfd storage capacitor.

A review of the breadboard units indicated that a reduction in size could be realized if the two inverter transformers were combined into a single unit that would be driven by two 2N3773 transistors. It was also agreed that placing the Pockels cell within a suitable cavity that was to be located in the pulser would reduce the shunt capacitance across the output terminal. A tentative size of 3.75 x 5.5 x 7.5 inches was chosen as a first approach for a housing that would include all components as well as the Pockels cell. The bottom of the housing was provided with an open section through which the Pockels cell would be introduced. Suitable mounting holes were to be provided to secure the cell to the housing. A suitable pulse input connector and power input connector were to be provided on the housing. A tentative outline drawing of the proposed pulser housing is shown in Figure 7.

The switch tubes were threaded into finned radiators and mounted on a lucite deck that was secured to the housing side walls by means of suitable angles. The finned radiators helped dissipate the filament heat of approximately 10 watts. Both tubes were mounted with their cathode up.

The drive circuits for the charge and discharge tube were mounted on separate copper clad circuit boards. Separation of these circuits is shown in Figure 8 as "Card 1" and "Card 2". A suitable shielded cable connects the output of the differentiating



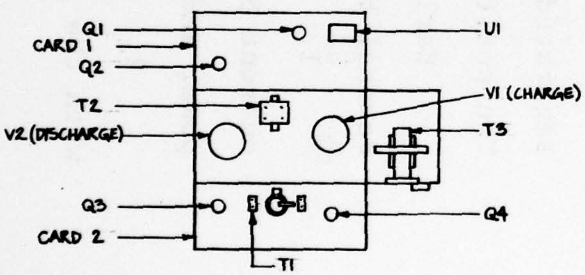


FIGURE 8

NOTES:
1. UNLESS OTHERWISE NOTED;
   A.) ALL RESISTORS ARE IN OHMS, 1/2W.
   B.) ALL CAPACITORS ARE IN μF.

CONTR.	COBER ELECTRONICS, INC. STAMFORD, CONN.		
DRAWN JAQ 2-13-79			
CHECKED	SCHEMATIC DIAGRAM 1300 VOLT PULSE GENERATOR		
APPROVED			
APPROVED			
DSGN ACT APPVL	SIZE C	CODE IDENT NO 28909	DRAWING NO. 2566-X3
GOV'T ACT APPVL	SCALE:		SHEET OF

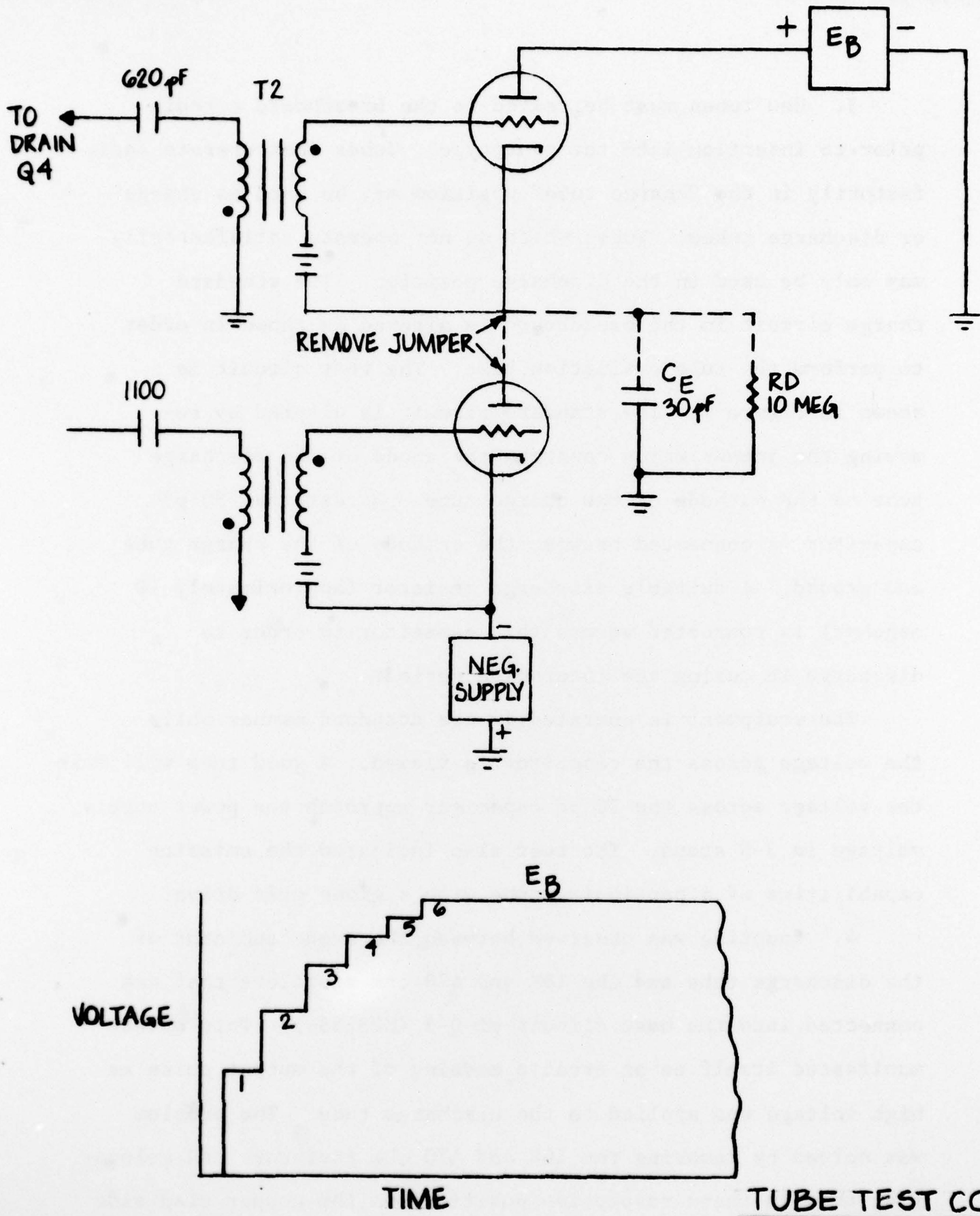
circuit in Q-1's drain circuit to the base circuit of Q-3 (MPS6534). The copper clad backing was chosen because it offered a good ground plane. Counterbored cut-outs were made in the copper clad backing to clear feed through terminals. Each card had two power input connections (+28 volts and +75 volts). Individual cards can be raised out of the housing by removing two mounting screws, to permit maintenance of the cards.

The bias supplies as well as the 75 volt supply were originally mounted on a single card that was located within the housing and directly above the tubes. Leakage problems between the bias supplies was found to be a problem because of the high voltage (up to 6KV) that could exist between the supplies. The common card limited access to the tubes and other components of Card 1 and Card 2. The bias supplies were separated and reconstructed on individual and isolated strips. The positive 75 volt supply was also relocated.

Early attempts to operate the prototype unit indicated several basic problems. Some of these are enumerated below:

1. Several Y-540 tubes showed appreciable leakage current 5-10 ua when the tubes were operated without filament power and with the grid connected to the cathode.

2. One tube showed no emission with a hot cathode and with the grid connected to the cathode.

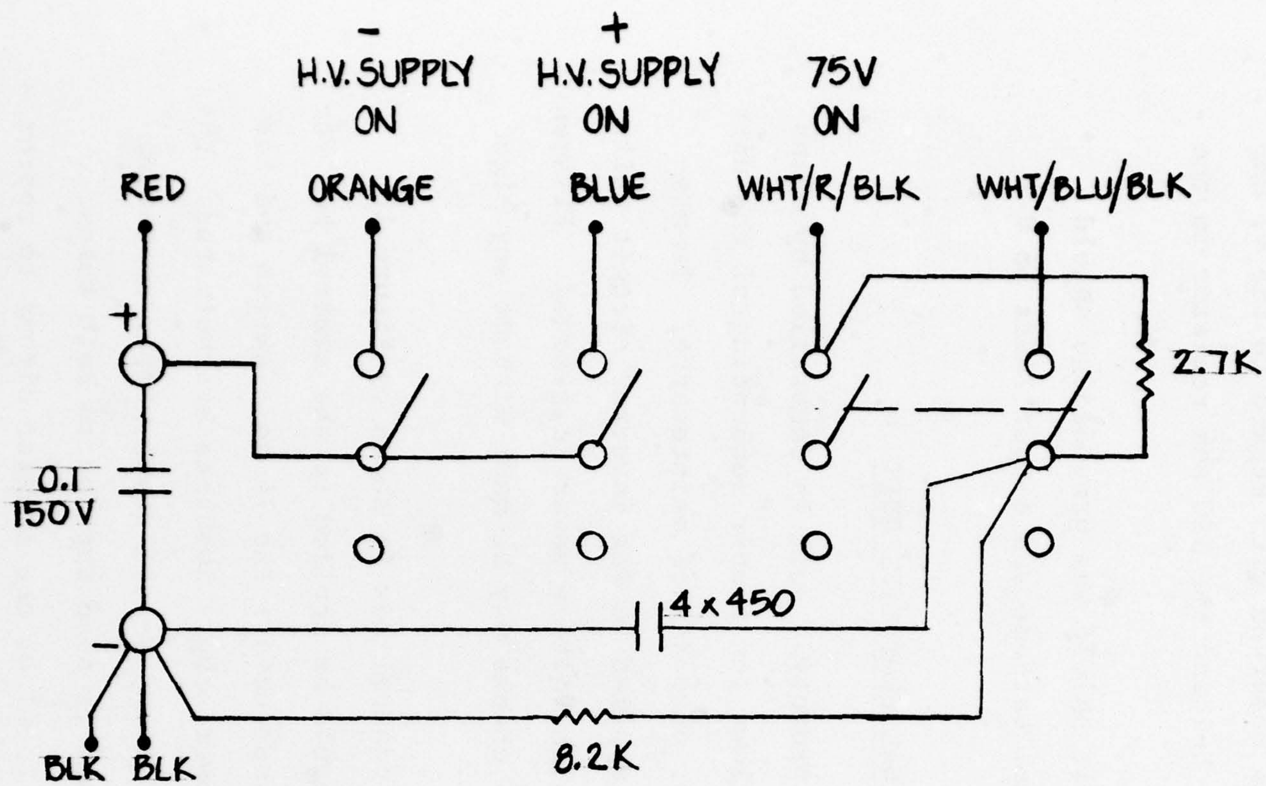


TUBE TEST CCT
FIGURE 9
2566-X10

3. New tubes must be tested in the breadboard circuit prior to insertion into the prototype. Tubes that operate satisfactorily in the "charge tube" position may be used as charge or discharge tubes. Tubes which do not operate satisfactorily may only be used in the discharge position. The standard charge circuit in the breadboard is altered as shown in order to perform the tube evaluation test. The test circuit is shown in Figure 9. The standard circuit is altered by removing the jumper which connects the anode of the discharge tube to the cathode of the charge tube. An external 30 pf capacitor is connected between the cathode of the charge tube and ground. A suitable discharge resistor (approximately 10 megohms) is connected across this capacitor in order to discharge it during the interpulse period.

The equipment is operated in the standard manner while the voltage across the capacitor is viewed. A good tube will make the voltage across the 30 pf capacitor approach the power supply voltage in 3-5 steps. The test also indicated the emission capabilities of a particular tube with a given grid drive.

4. Coupling was observed between the anode radiator of the discharge tube and the 10K and 470 ohm resistors that are connected into the base circuit of Q-3 (MPS6534). This effect manifested itself as an erratic modeing of the output pulse as high voltage was applied to the discharge tube. The problem was solved by removing the 10K and 470 ohm resistors and relocating them in their respective positions on the copper clad side



PIN A - BLK
PIN B - BLK
PIN C - RED
PIN D - BLUE
PIN E - ORANGE
PIN F - B/W/RED
PIN H - B/W/PURPLE

CONTROL BOX
FIGURE 10
2566-X11

of the card.

A similar effect was observed with regard to the 47 ohm resistor in the input to U-1 and the 510 ohm resistor in the output of U-1 (pin 2).

A brass electrostatic shield was provided to shield U-1 and Q-1 from the bias, cathode and output leads on V-1 (charge tube).

FINAL PROTOTYPE UNIT

Power to the final prototype unit is controlled by means of a switch box which allows for proper sequencing of the unit and adds flexibility for purposes of maintenance. Twenty-eight volt power may be applied to the inverter circuit while 75 volts power and all high voltage power is removed. Filament voltage and bias voltage checks may be made without any high voltage hazard.

A schematic of the control box is shown by Figure 10.

Power (28 volts) should be applied to the control box for approximately 30-45 seconds before the 75 volt switch and the positive and negative power supply switches are actuated. This allows the cathodes of V-1 and V-2 to reach proper operating temperature. Bias voltage is also applied to both tubes.

U-1 raises the TTL level of the trigger signal to approximately 12 volts in order to provide a suitable gate for Q-1. The output of Q-1 is differentiated by C4 and R-8. The trailing edge of the signal (positive going) is applied to the gate of Q-2. The negative going drain signal of Q-2 is coupled to T-1 through

C-5 where it is inverted and applied to the grid of V-2 (discharge tube).

The differentiated leading edge of the negative going drain of Q-1 is applied to the base of Q-3. The signal in the collector circuit of Q-3 is inverted with respect to its base signal. The resulting positive voltage across R-6 is applied to the gate of Q-4 to produce a negative going drain which is in turn coupled through C-6 to the primary of T-2. The negative signal that is applied to the primary of T-2 is inverted and applied to the grid of V-1 (charge tube).

An outline drawing of the prototype unit is shown in Figure 7.

A protective outer cover is provided in the prototype unit. It may be removed readily be removing eight 6-32 machine screws.

Each circuit card may be lifted from the housing by removing two 6-32 screws which secure the circuit card to the housing side panels. An insulating baffle is provided beneath each card and care should be taken to replace this baffle in its proper position before the circuit cards are secured in place.

Voltage adjusting access holes are provided and labeled for each high voltage power supply.

Each Y-540 tube is threaded into its cooling radiator. The filament, cathode and grid leads must be carefully unsoldered before any attempt is made to remove the tube.

The collectors (outer shells) of the 2N3773 inverter transistors are at +28 volts with respect to the housing.

Care should be exercised to prevent grounding of these points. The prototype unit may be operated continuously for approximately 5 minutes without the need of external cooling. Operation beyond this time will require an external cooling fan that should be directed at the collectors of the 2N3773 transistors.

A hanging lead is provided in the Pockels cell well to permit connection to the turret terminal on the top surface of the cell.

III. CONCLUSIONS

A prototype of the Task III pulse generator has been constructed and tested without the final Pockels cell.

Initial tests indicate that it will meet the output voltage requirement of Task III.

The size of the prototype exceeds the initial goal of 1200 cm^3. The pulser housing has a volume of 2500 cm^3 with an allowance of approximately 500 cm^3 for internal mounting of the Pockels cell.

A further reduction in size is possible if the circuit cards (2) are combined into a single card.

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