DESIGN AND CONSTRUCTION OF A HIGH-SPEED SYNCHROSCOPE

by

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INTRODUCTION

The cathode-ray oscillograph is one of the most versatile electronic instruments which has ever been developed as an aid to investigators of natural phenomena, and is a time saving, accurate method for observing the characteristics of both electrical and mechanical devices. Fundamentally, the oscillograph provides a means of plotting a visual curve on a fluorescent indicating screen. The coordinates of the curve are usually of the orthogonal or Cartesian type, and, in the conventional instrument, the horizontal axis represents time. Instantaneous values of any quantity which can be converted into an electrical potential, the amplitude of which will vary according to the variation of that quantity, are plotted along the vertical axis of the screen.

The indicating pointer or element is an electron beam having negligible inertia. Therefore, the instrument may be used to plot rapidly changing quantities which cannot be plotted with a mechanical system of indication. Another advantage of the electronic beam type of indicator element is that it cannot be seriously damaged by the application of over-voltage on the deflection system. Furthermore, the indicator requires a negligible amount of power for operation. Thus, phenomenon under observation is not burdened with a load which might disturb its operating characteristics.

From the foregoing description of an oscilloscope it can be seen that the uses of such an instrument are almost unlimited. A little thought will disclose hundreds of ideas for specialized applications. A few of the more general uses are the study and testing of the operation of radio receivers, transmitters, welding circuits, transmission lines, electronic control devices, circuit breakers, ignition coils, and other electrical devices. An oscillograph may also be used to advantage in the study of vibrations, properties of metals, and dynamic mechanical unbalance. Production testing applications even include fast and accurate adjustment of watches and musical instruments. Not to be overlooked are uses in the field of internal combustion engines, where detonation studies and pressure-volume curves can be plotted.

In recent years with the advent of television, radar, Geiger-counters, and other types of electronic instruments and circuits which generate or make use of sharp voltage or current pulses, there has been an increasing demand for instruments capable of faithfully reproducing these waveforms.

The unit which was constructed has wide-band amplifiers and driven sweeps with timing markers to cope with waveforms which have steeply rising wave fronts and which may or may not be continuously recurrent at a definite rate. By an unique switching arrangement the unit becomes a conventional oscillograph.

DISCUSSION

The oscillograph was built for relay rack mounting. The three power supplies and filament transformers were contained in two units while the indicator unit comprises another unit. With the relay rack mounted on wheels the oscilloscope readily becomes a portable unit.

The bottom unit in the relay rack, which is Unit 1, consists of the 4000 volts d-c power supply which supplies a plus and minus 2000 volts d-c for accelerating the electrons in the cathode-ray tube. This provides a trace of maximum intensity with the 5CP1 cathode-ray tube which was used. The bottom unit also contains the 400 volts d-c supply for the X-axis and Y-axis final amplifiers. A conventional condenser input filter was used. A regulated supply has been found to be unnecessary for the final amplifiers because of the use of constant current tubes. Also, the bottom unit contains the filament supply for the cathode-ray tube and for some of the tubes in the indicator unit.

The middle unit, Unit 2, contains a 200 milliampere 250 volts d-c regulated power supply. This is a degenerative type in which a 6SJ7 amplifier tube and a VR-105 voltage regulator tube in conjunction with their associated circuits control the grid bias on three parallel 6Y6 tubes which are placed in series in the supply line and thus determine the voltage drop that occurs across the 6Y6 tubes. The controlled drop across the 6Y6's subtracts from the variable d-c input voltage to give a constant output voltage of 250. In addition, Unit 2 contains the remainder of the filament supplies for the indicator unit. Unit 2 is also the main switching unit for the entire oscilloscope. Plate I shows the circuit diagram of the switching arrangement. Unit 2 contains the master power switch as well as the switch for the high-voltage supply. It also contains four fuses mounted on the back of the chassis, one for the filament transformers, one in the primary of the plate transformer of each of the three power supplies. The unit also contains a thermal-type relay which delays closing the primary circuit of any of the plate supplies for about 40 seconds. This gives the filaments of all the tubes more than sufficient time to heat before the plate voltages are applied. The main reason for this precaution is the great number of electrolytic condensers which are used in this unit. By having the filaments heated, voltage surges which might otherwise damage the electrolytic condensers can be materially lessened.

Plate II shows the power cable arrangement for connecting the two power supply units to the indicator unit.

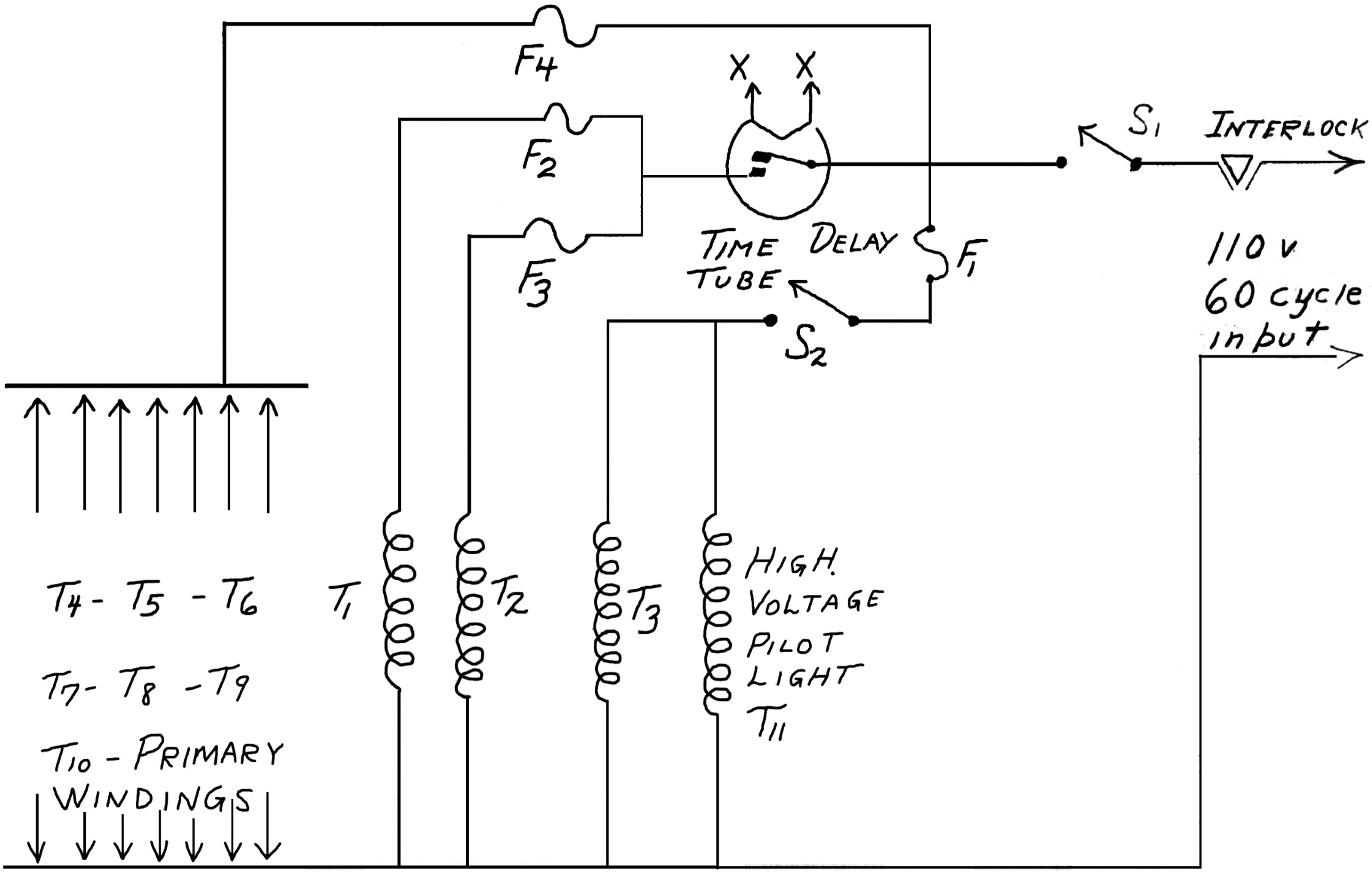
The top unit, Unit 3, contains the following components: the cathode-ray tube, focusing, intensity and positioning controls for the cathode-ray tube, the X-axis, Y-axis, and the

Z-axis amplifiers including their decade attenuators and gain controls, a transitron oscillator for time-interval marking of the trace by beam intensity modulation, the sweep circuits including both continuous and driven or "triggered" sweeps, a time-delay circuit to permit the triggered sweep to get under way before the phenomenon to be observed reaches the Y-axis final amplifier, and a pulse generator for producing both negative and positive pulses of variable recurrence rate from a low-impedance source.

EXPLANATION OF PLATE I

Circuit diagram of the switching arrangement used for controlling the power supplies and filament transformers.

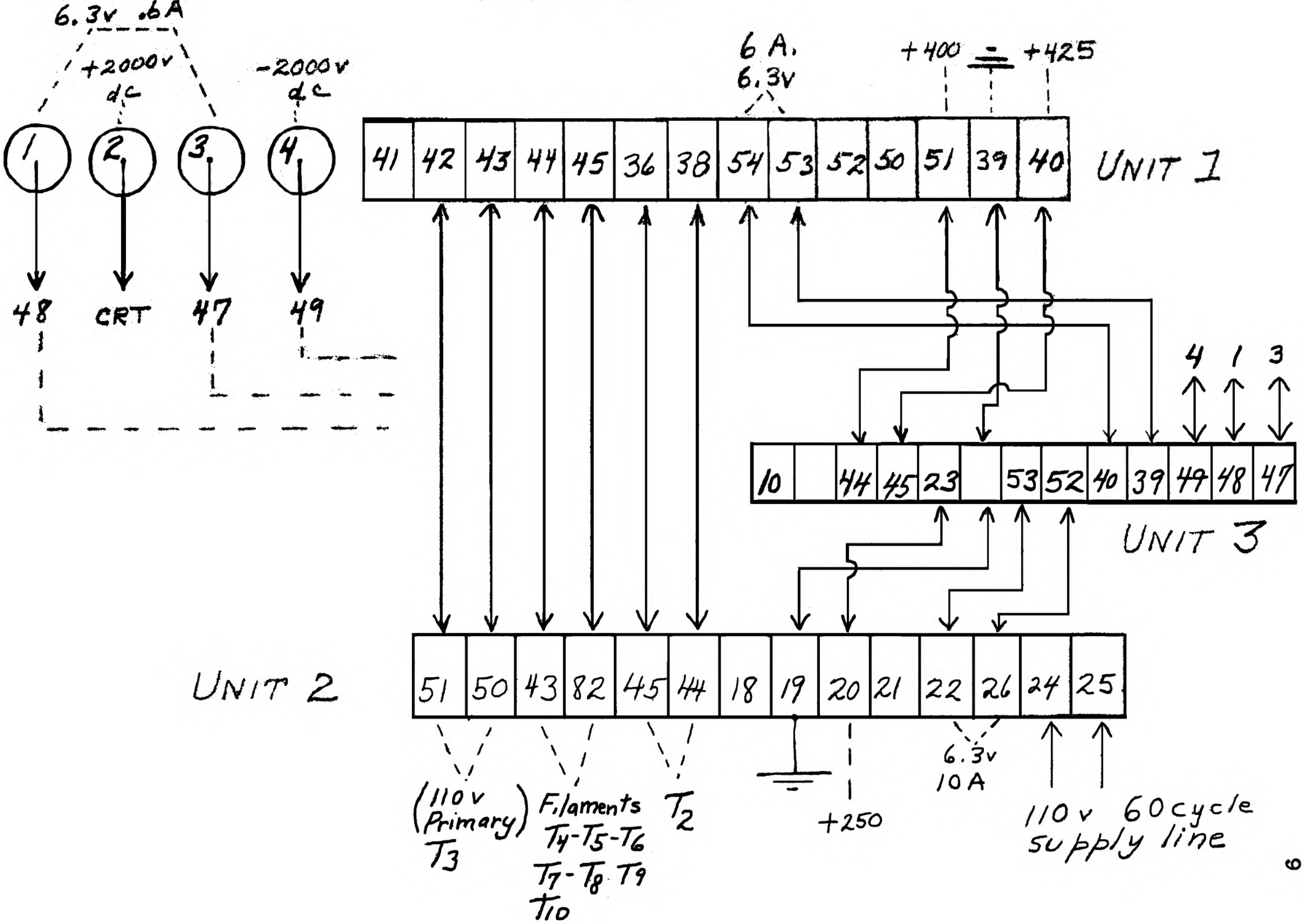
PLATE I


F4
X
X
F2
S1
INTERLOCK
F3
TIME DELAY
TUBE
F1
110 v
60 cycle
input
S2
T4 - T5 - T6
T7 - T8 - T9
T10 - PRIMARY
WINDINGS
T1
T2
T3
HIGH
VOLTAGE
PILOT
LIGHT
T11

EXPLANATION OF PLATE II

Power cable connection diagram for interconnecting the three units. This transfers the filament,250 volt, 400 volt, and 4000 volt power supplies.

PLATE II


6.3v .6A
+2000v dc
-2000v dc
1
2
3
4
48
CRT
47
49
6 A.
6.3v
+400
+425
41
42
43
44
45
36
38
54
53
52
50
51
39
40
UNIT 1
4
1
3
10
44
45
23
53
52
40
39
49
48
47
UNIT 3
UNIT 2
51
50
43
82
45
44
18
19
20
21
22
26
24
25
(110v Primary) T3
Filaments T4-T5-T6 T7-T8 T9 T10
T2
+250
6.3v
10A
110v 60cycle supply line

Each of these circuits will now be taken up in detail. Plate III shows a block diagram of the oscilloscope unit.

Cathode-Ray Tube - Focusing, Intensity, and Positioning Controls

A 5CP1 cathode-ray tube was used in the oscilloscope unit. A P1 screen was selected as being the most practical one for general use. It gives a green trace of medium persistence and is suited for work dealing with recurrent phenomena, still photography and medium frequencies. It will be necessary to change to a P7 screen when observing high-speed transient phenomena as this screen has a much greater persistence. If one wishes to photograph transient phenomena, it would be best to use a P11 screen.

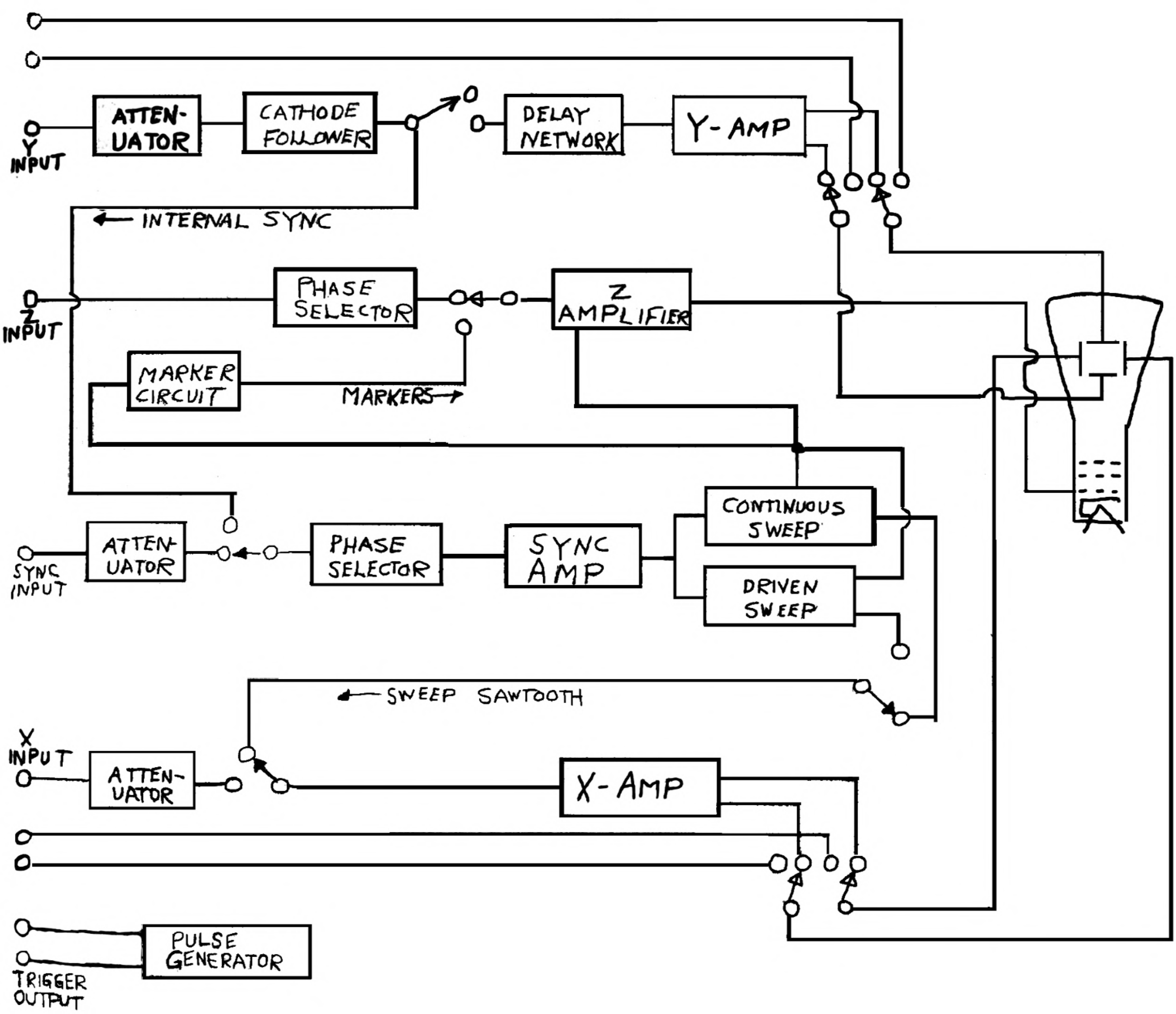
The focusing and intensity controls are potentiometers in a bleeder network connected to a negative 2000 volts d-c. This network is designed to give the necessary range of voltage variation to both the grid bias and the focusing anode No. 1. The grid is held at a minus 2000 volts d-c and the cathode is run at a variable voltage which is less negative. The accelerating anode No. 2 is held at plus 125 volts.

The positioning circuits consist of two 4-megohm dual potentiometers, one for the vertical and one for the horizontal axis, and is known as alternating current position-

EXPLANATION OF PLATE III

Block diagram of indicator unit.

PLATE III

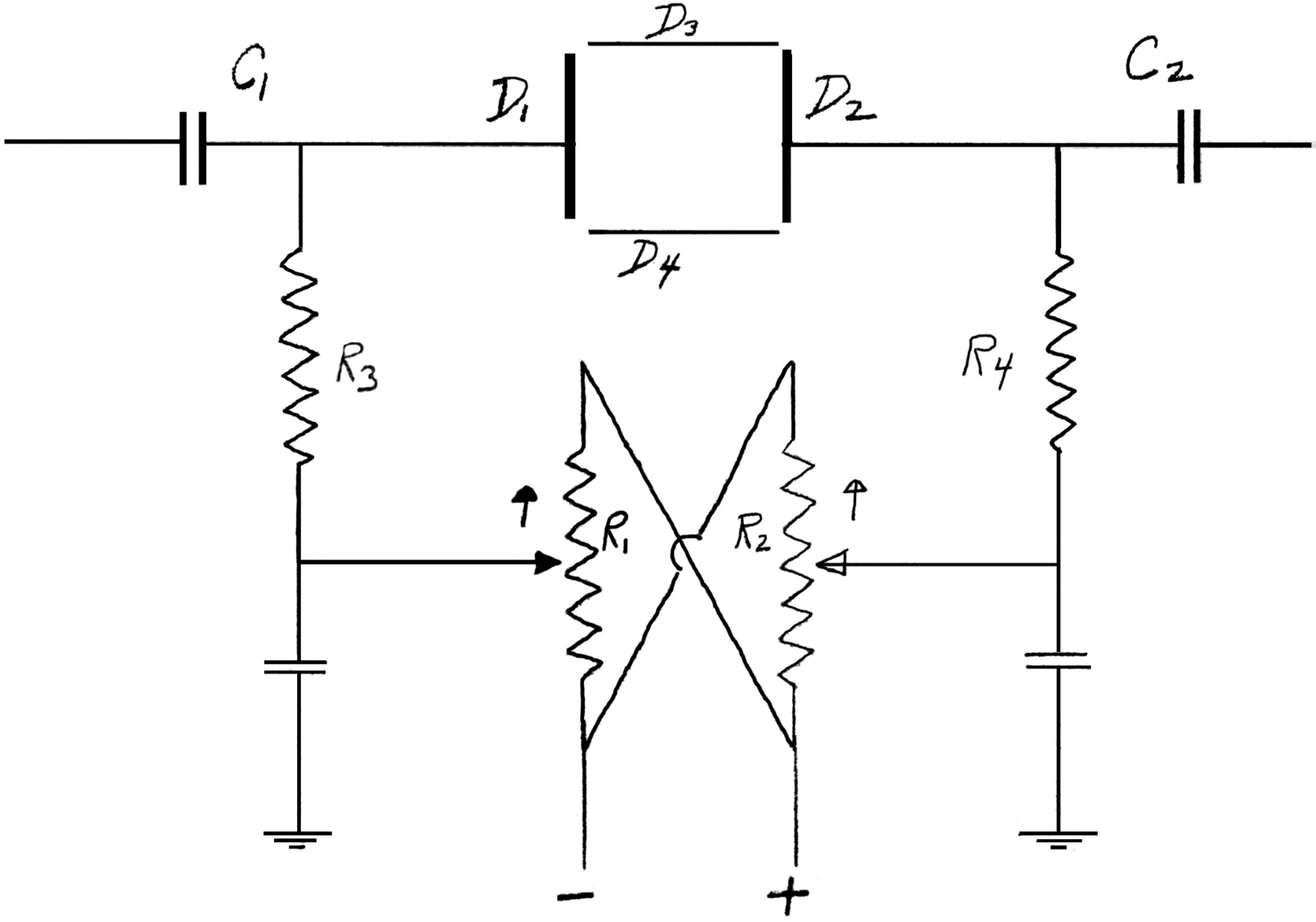


Y INPUT
ATTEN-UATOR
CATHODE FOLLOWER
DELAY NETWORK
Y-AMP
INTERNAL SYNC
Z INPUT
PHASE SELECTOR
Z AMPLIFIER
MARKER CIRCUIT
MARKERS
SYNC INPUT
ATTEN-UATOR
PHASE SELECTOR
SYNC AMP
CONTINUOUS SWEEP
DRIVEN SWEEP
SWEEP SAWTOOTH
X INPUT
ATTEN-UATOR
X-AMP
PULSE GENERATOR
TRIGGER OUTPUT

EXPLANATION OF PLATE IV

Diagram of alternating current positioning used for centering the trace both horizontally and vertically.

PLATE IV



ing. As shown in Plate IV, R_3 and R_4 consist of 4.7 megohm resistors and C_1 and C_2 are 0.1 mf condensers. Due to the high resistances employed, alternating current positioning is sluggish because of the large time constants C_1R_3 and C_2R_4. The above mentioned lag or "electrical backlash" is caused by the time for the capacitors C_1 and C_2 to establish a steady direct current potential at plates D_1 and D_2 after position centering potentiometers R_1 and R_2 have been adjusted to some new value. High values of resistance are necessary at R_3 and R_4 to maintain a high input impedance at the deflection plates and to insure good low frequency response in the deflection plate coupling circuit.

Decade Attenuators, Cathode-Follower Input Circuit, and Gain Control

Since the oscilloscope is to be used as a measuring instrument which will not distort the phenomenon to be measured, the power drawn from the circuit under test should be a minimum. Also, provision should be made for the attenuation of the signal to a value which may be handled by the input of the first vacuum tube of the oscilloscope without distortion or overload. These considerations require a high impedance, low capacitance voltage divider placed across the input terminals of the oscilloscope. The simplest method of obtaining such a voltage divider would be to use a high-resistance potentiometer in the grid circuit of the first vacuum tube. The use of such an attenuator, however, is subject to certain limitations, namely, extreme frequency discrimination at intermediate settings. As shown in Plate V, the distributed capacitances C_1 and C_2 produce a voltage division at the higher frequencies which is essentially constant and independent of the setting of the potentiometer arm. Thus, as the position of the potentiometer arm is changed, the relative voltage division across the sections of the potentiometer and capacitances will differ, producing serious frequency discrimination. Although this frequency discrimination may be reduced by using a low-resistance potentiometer, the loading upon the circuit under test would be excessive. A solution of the difficulty is to provide an input attenuator with fixed steps as shown in Plate VI. This circuit will permit individual adjustment for each attenuation ratio, maintaining uniform voltage division independent of frequency if the time constant C_3R_3 is equal to the time constant C_4R_4. The condenser C_3 is adjusted until a 10,000 cycle square wave is passed with minimum distortion. It has been found that this frequency is the most sensitive to attenuator misadjustment (1).

Obviously this step attenuator will not give a fine adjustment so that an additional method of attenuation is required. This can be achieved by connecting a high impedance input cathode-follower to the step attenuator and by connecting a low resistance potentiometer to the low impedance output

EXPLANATION OF PLATES V AND VI

Plate V

Diagram showing stray capacitances associated with a potentiometer gain control.

Plate VI

Decade - compensated attenuator.

PLATE V

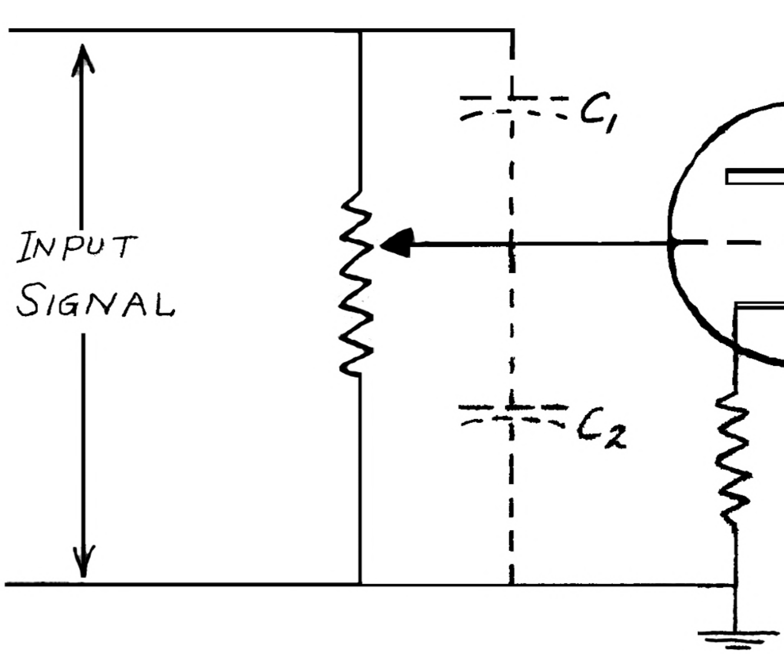
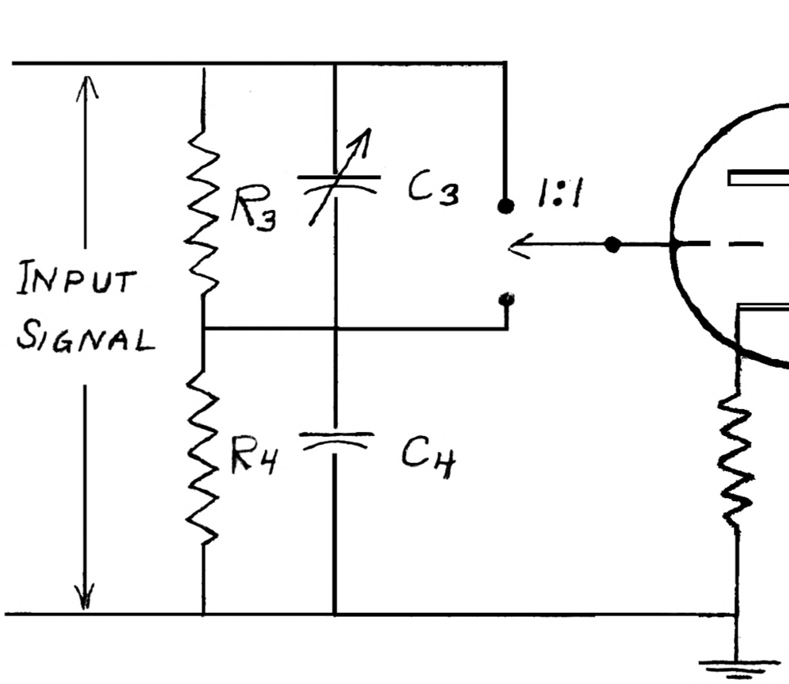


PLATE VI



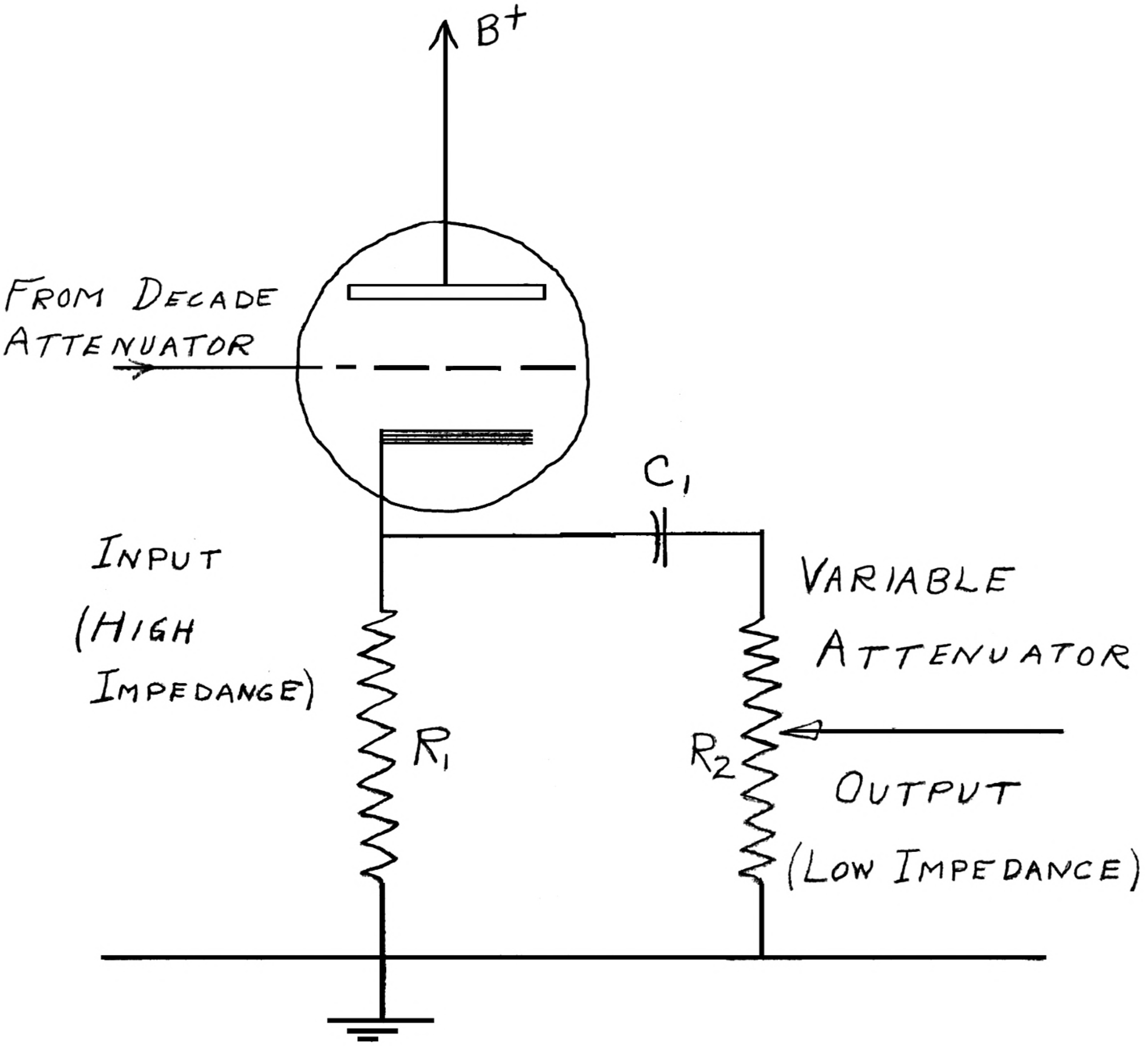
of the cathode follower.

The circuit which involves a cathode-follower stage and which will allow a wider range of input signal than conventional amplifiers without overloading (2) is shown in Plate VII. This circuit, however, will have a definite frequency limitation, but is a great improvement over other systems. With R_1 and R_2 both of low values (1000 ohms each in the Y-axis amplifier), the circuit capacitances will be ineffectual even in the megacycle region. C_1 is used as a blocking capacitor to remove the direct current from the control R_2.

EXPLANATION OF PLATE VII

Input cathode-follower stage feeding a low resistance continuous attenuator.

PLATE VII


B+
FROM DECADE ATTENUATOR
C1
INPUT
(HIGH IMPEDANGE)
R1
VARIABLE ATTENUATOR
R2
OUTPUT
(LOW IMPEDANCE)

Y-axis Amplifier

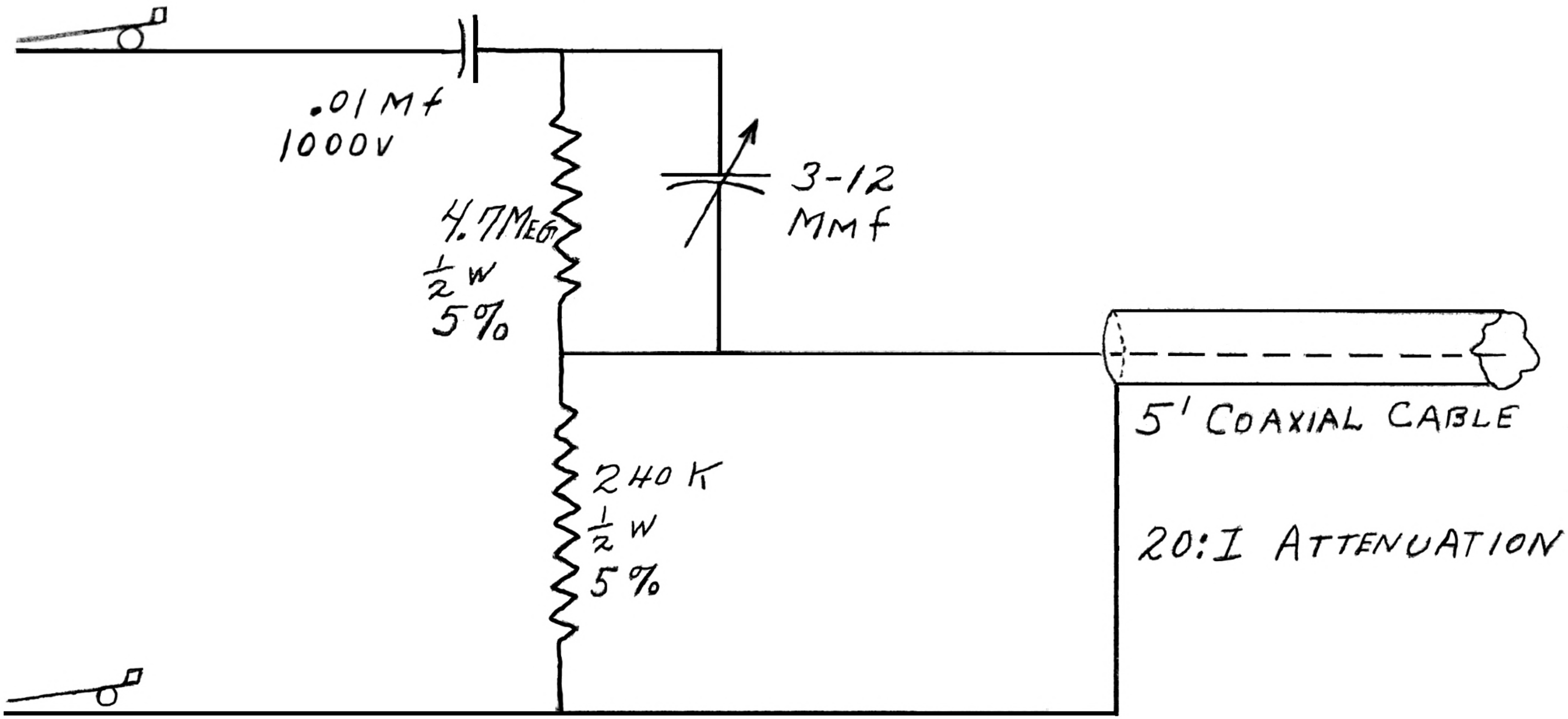
Input may be made to the Y-amplifier through a special probe which is shown in Plate VIII, or through the regular terminals on the oscillograph. Immediately following the input terminal and probe socket is an isolating capacitor and a three-position RC attenuator having ratios of 1:1, 10:1, and 100:1. This attenuator, as well as the one in the test probe, is compensated for high frequencies according to the method discussed in the previous section and introduces negligible distortion within the frequency range of the amplifier. The next circuit is the cathode-follower with the fine gain control utilizing a 1000 ohm potentiometer.

Immediately following the variable attenuator are the amplifying stages, the first employing a 6AC7 pentode, the second a 6AG7 pentode. Both plate circuits include compensating filters for low frequencies which, with slight adjustment to take care of component variations, make it possible for the amplifier as a whole to pass a 30-cycle square wave with only slight distortion. High frequency compensation is also provided, shunt peaking being used with a 1000 ohm load resistor of the 6AC7 stage and series peaking with the 1300 ohm load resistor of the 6AG7 stage. A type of compensation allowing a larger plate load for the desired frequency range is used in the latter stage in order that the maximum possible

EXPLANATION OF PLATE VIII

Test probe for feeding Y-amplifier. It has a 20:1 attenuation. Input impedance of the probe is five megohm in parallel with 10 mmf. Probe produces less loading of circuit under test than regular amplifier input.

PLATE VIII


.01 Mf
1000V
4.7Meg
½W
5%
3-12
Mmf
5' COAXIAL CABLE
240 K
½ W
5 %
20:1 ATTENUATION

output can be obtained from the deflection amplifier which it drives. Transient response is equal to that of the shunt peaked stage.

The deflection amplifier consists of two 807's in push-pull, cathode-coupled to give a balanced output. Because of low output capacitance it was found possible to use 1500 ohn plate loads and shunt peaking without reducing frequency response below that of the previous stages. The last two stages of the Y-axis amplifier and the deflection or final amplifier are shown in Plate IX.

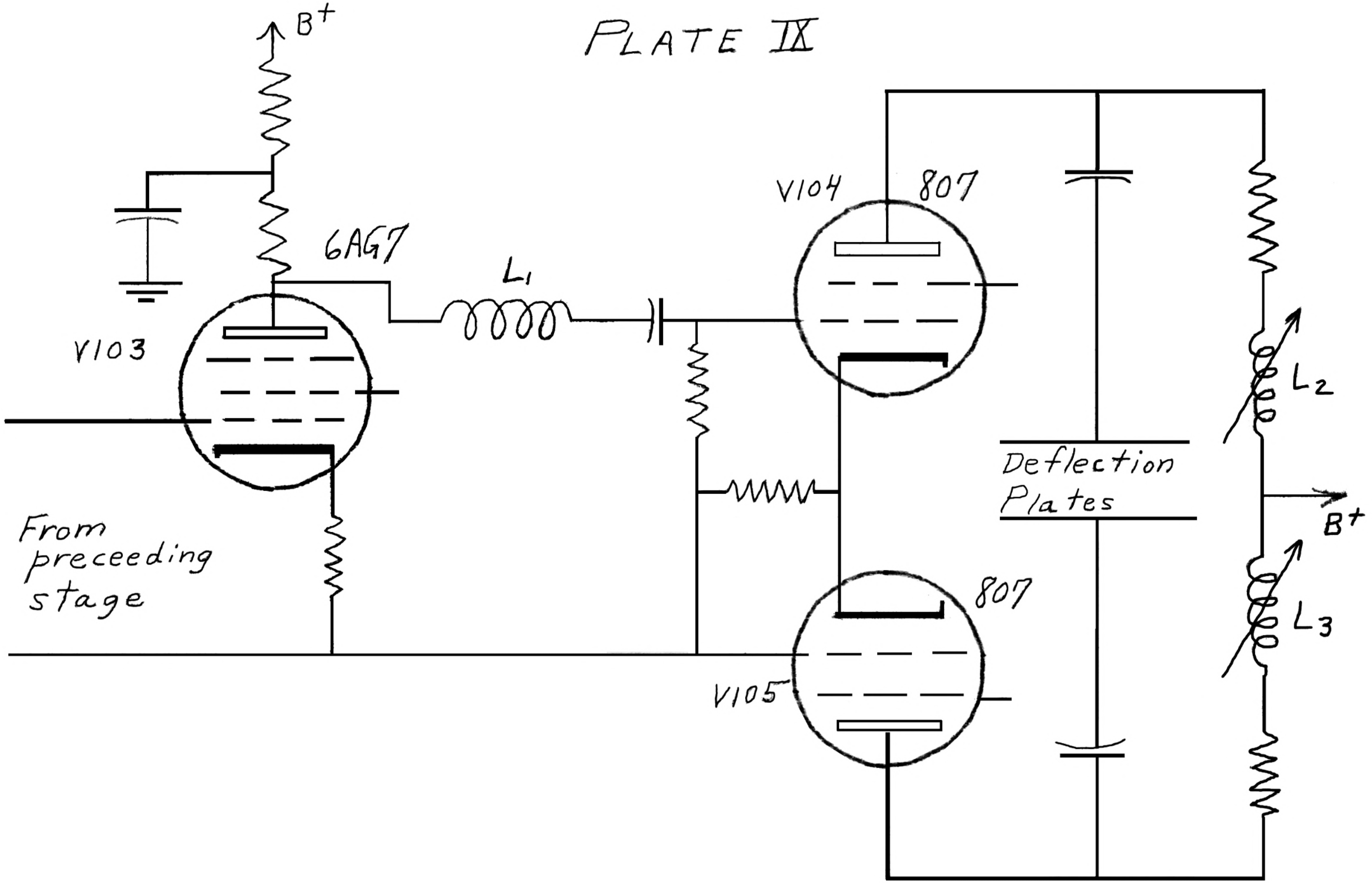
Puckle (3) has stated a number of attractive features offered by cathode-coupled push-pull amplifiers. Among them are low distortion and relatively small value of grid current when overloaded, freedom from any tendency to self-oscillation, and absence of "jitter" or hum derived from fluctuations of the power supply.

Response of the Y-axis amplifier is down less than 10 per cent at five Mc, and is 10 per cent of the mid-frequency gain at 10 Mc. Compensation is adjusted to give faithful reproduction of high frequency pulses without overshoot or oscillation. The oscilloscope input deflection factor at maximum gain is approximately 0.10 volts rms per inch of peak to peak deflection.

EXPLANATION OF PLATE IX

Last two stages of Y-axis amplifier shows cathode-coupled push-pull final deflection amplifier.

PLATE IX


B+
6AG7
V103
L1
V104
807
Deflection
Plates
L2
B+
L3
807
V105
From
preceeding
stage

X-axis Amplifier

Since high gain is not required in the X-axis or horizontal amplifier, a cathode-follower and gain control driving a balanced deflection amplifier similar to that of the Y-axis are all that is necessary. Response is down about 25 per cent at two Mc, and the deflection factor at maximum gain is 2.75 volts rms per inch.

Z-axis Amplifier

The Z-axis or beam modulation amplifier as illustrated in Plate X makes use of a phase-selector at its input stage, thus making possible blanking or intensifying of the beam by either a negative or positive signal, respectively. This amplifier, together with the time-bases, acts as a beam control circuit serving to blank the return trace and to drive the beam from cut off during stand-by to full intensity during the sweep when the driven sweep is in use.

To allow for the use of the Z-axis with video frequency signals, the response of the amplifier was made uniform to four megacycles.

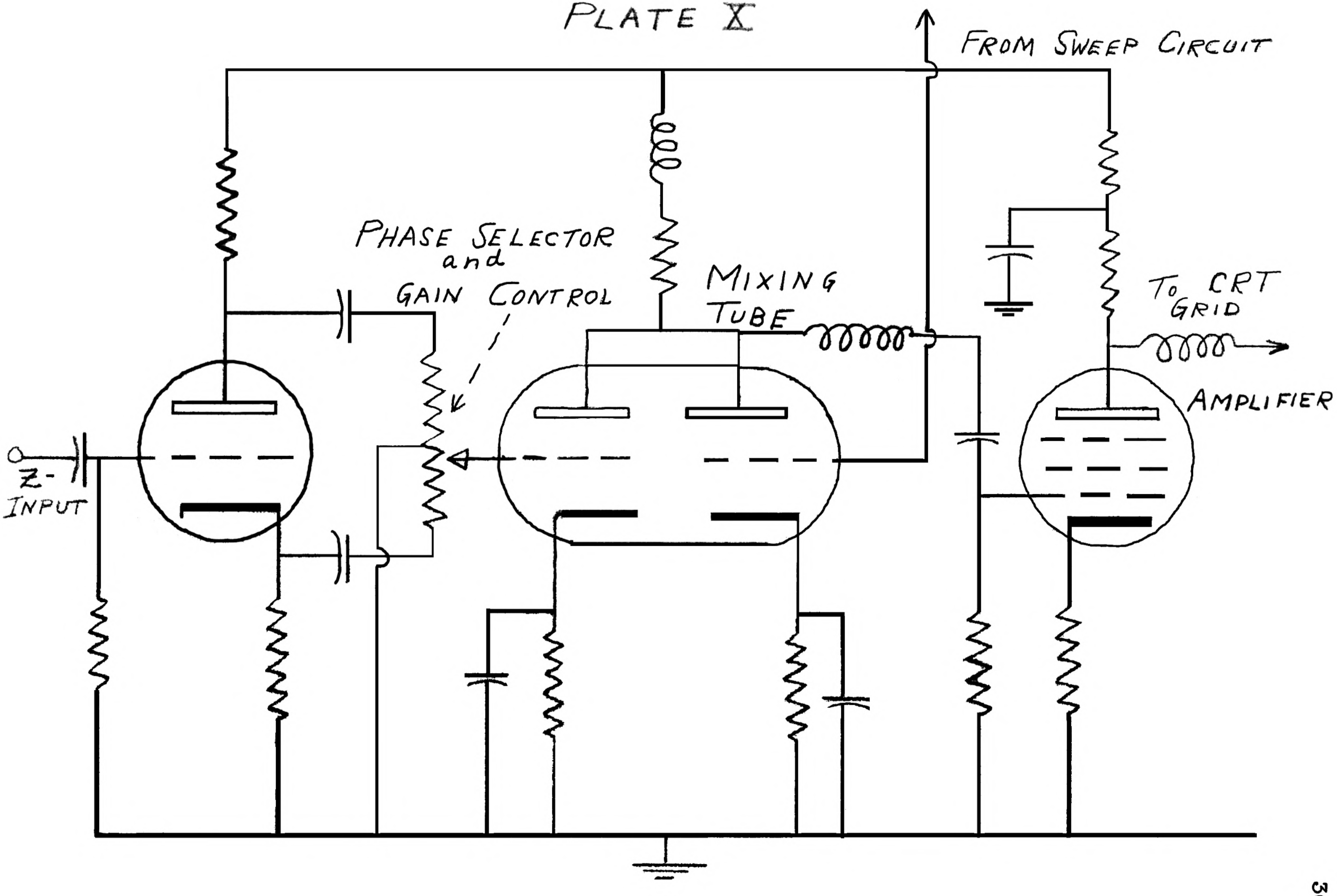
Timing Marks

For use in conjunction with the Z-axis there is provided a pulsed transitron oscillator and pulse-forming circuit which

EXPLANATION OF PLATE X

The Z-axis or beam modulation amplifier blanks the return trace by means of a pulse from the sweep circuit. This blanking pulse is superimposed upon any external modulation signal by the dual-triode mixing stage. Phase selection of the external signal is accomplished by the balanced phase-inverter and potentiometer preceding the mixer stage. Both shunt and series high-frequency compensation are used in the final stage.

PLATE X


FROM SWEEP CIRCUIT
PHASE SELECTOR
and
GAIN CONTROL
MIXING
TUBE
TO CRT
GRID
AMPLIFIER
Z-
INPUT

together, furnish sharp pulses at intervals of 1, 10, or 100 microseconds. Plate XI is a block diagram of this marker circuit. The oscillator is synchronized with the driven sweeps, and is used to indicate elapsed time along the X-axis by introducing brightening or blanking markers into the trace. Direct application of the signal to be investigated to the vertical deflection plates in no way affects the use of this timing circuit. The transitron oscillator is designed to be keyed on by the initiation of the driven sweep, but it is also useful over most of the continuous-sweep frequency range.

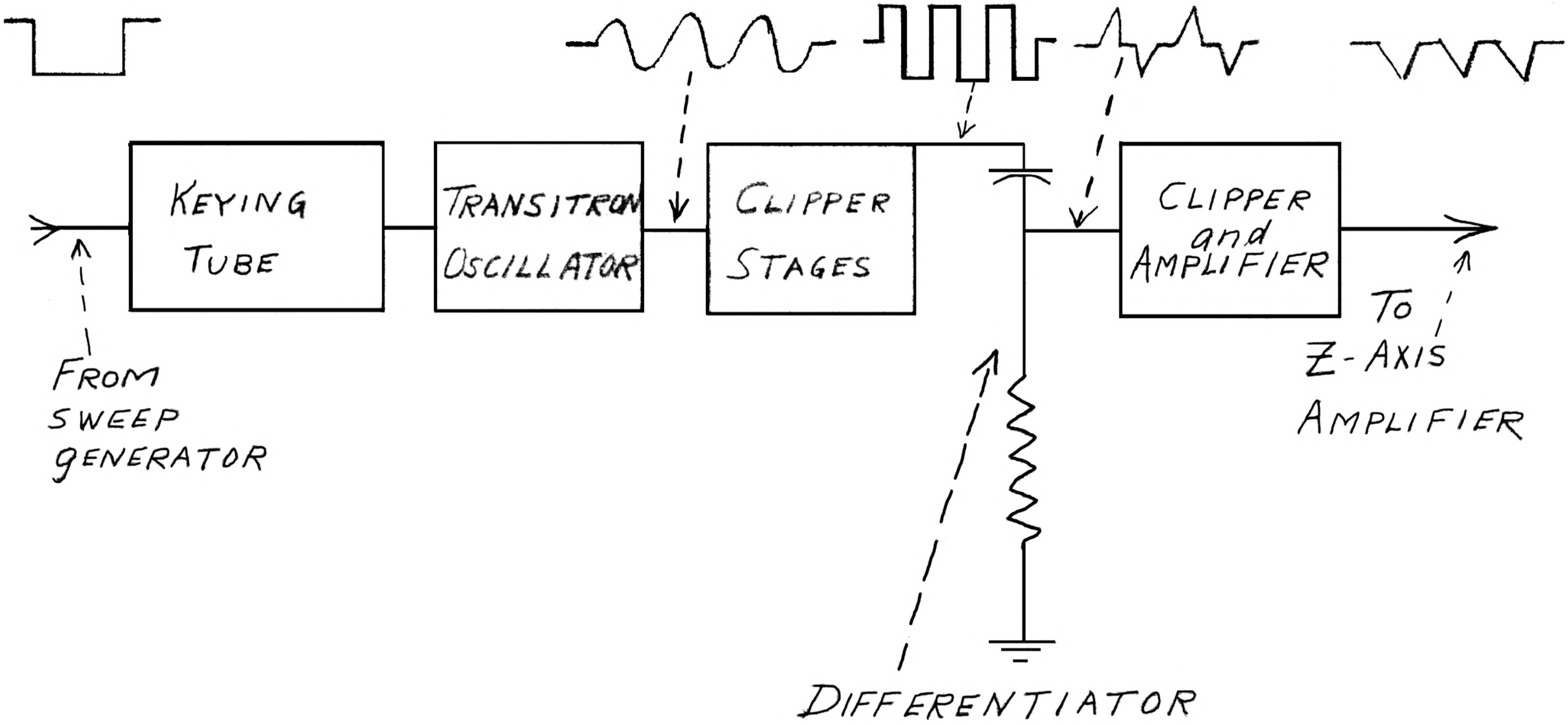
Sweep Circuits

Plate XII shows the diagram of the continuous sweep circuit. This sweep circuit is a modification of one first used by Puckle (3). In this the pentode V_2 and triode V_1 are connected as an unbalanced multivibrator. The constants are so proportioned that a short positive pulse of high amplitude is delivered to the grid of V_1 periodically. This lowers the impedance of tube V_1 and allows capacitor C_2 to be quickly charged. During the period between the sharp voltage pulses the capacitor C_2 discharges through constant current pentode V_3. The frequency of the multivibrator and hence of the sweep is determined by the size of the capacitor C_2 and the impedance of the constant current tube V_3. A switching arrangement is provided to switch in a series of capacitance values to cover

EXPLANATION OF PLATE XI

The oscillator of the time-interval marker circuit is keyed on for the duration of each driven sweep. Wave shapes show the manner by which oscillations are converted to marker pulses.

PLATE XI


KEYING
TUBE
TRANSITRON
OSCILLATOR
CLIPPER
STAGES
CLIPPER
and
AMPLIFIER
FROM
SWEEP
GENERATOR
TO
Z-AXIS
AMPLIFIER
DIFFERENTIATOR

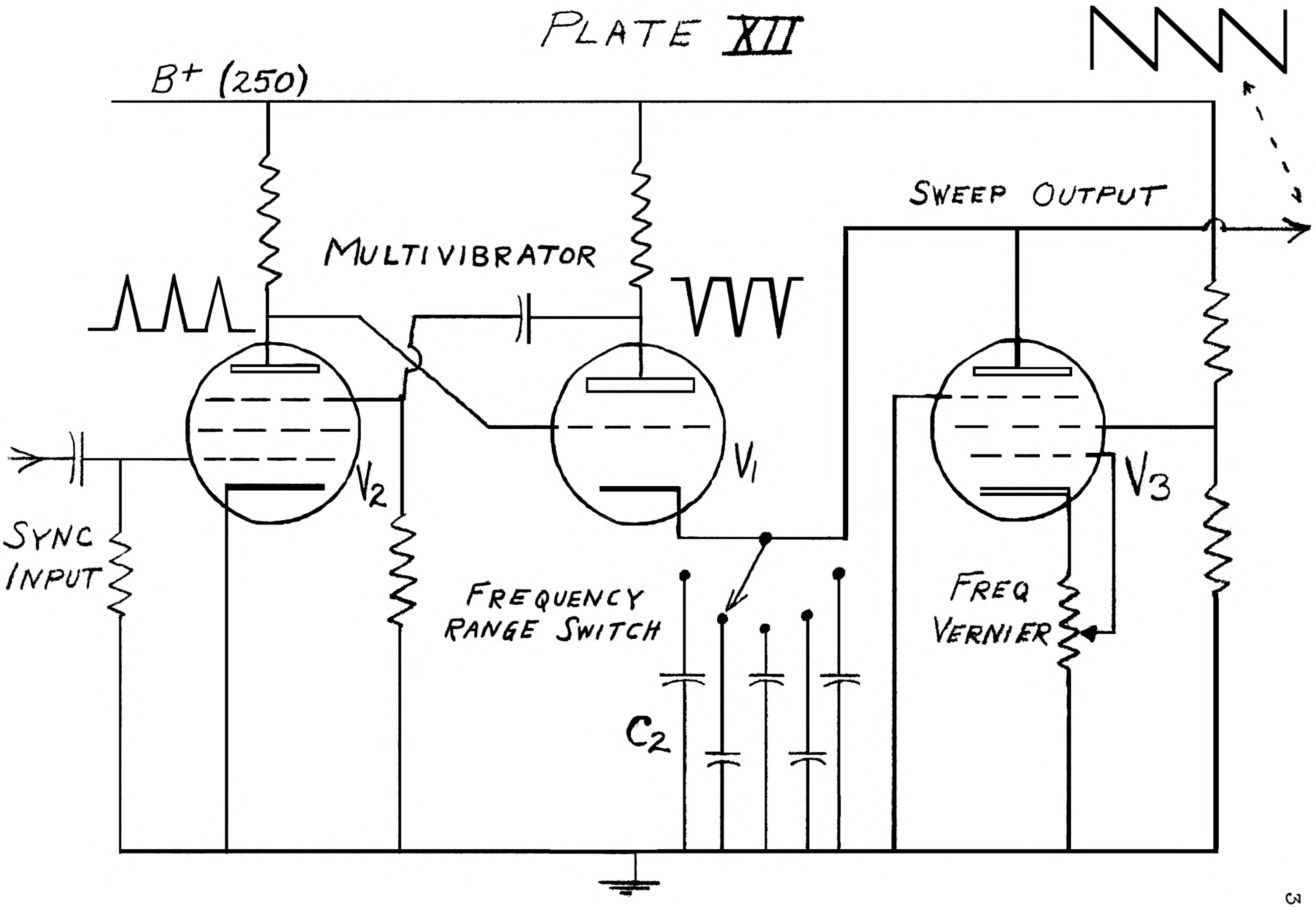
the range of sweep frequency from 15 cps to 150 kc when running free. The fine frequency adjustment is obtained by varying the grid voltage of the constant current tube V_3. The sweep circuit is synchronized by applying a signal at the grid of tube V_2. Stable operation of the sweep with more than 100 cycles of the signal on the screen can be obtained at medium frequencies. Operating frequencies as high as 300 kc or more are attained by moderate synchronizing with high frequency signals.

The driven sweep utilizes tube V_1 and V_3 of the continuous sweep which has just been explained but by a switching arrangement tube V_2 is removed from operation and the square wave from a triggered multivibrator is fed into the grid of tube V_1. Plate XIII shows the circuit diagram of the driven sweep. The triodes (pentodes were actually used) are operated with a common cathode resistor R_1 and separate plate loads. Triode V_4 is normally at cut-off while triode V_5, having no bias voltage, is conducting. If a positive signal voltage from the sync amplifier is applied to the grid of V_4, the tube will become conductive and its plate voltage will drop. This change in plate voltage is transferred to the grid of V_5 through capacitor C_3. The tube V_5 will be cut off by this voltage causing its plate voltage to rise rapidly to the power supply potential. The time constant R_2C_4 will determine how long tube V_5 will be cut off. When the capacitor C_4 is no longer discharging through R_2 at a sufficient rate to maintain V_5 at cut-off, V_5 will begin to conduct and in so doing

EXPLANATION OF PLATE XII

Simplified wiring diagram of vacuum-tube sweep circuit indicates the principle of operation. The triode of the multivibrator periodically charges one of the frequency range capacitors. The constant current pentode, which includes the frequency-vernier control, linearly discharges the frequency-range capacitor.

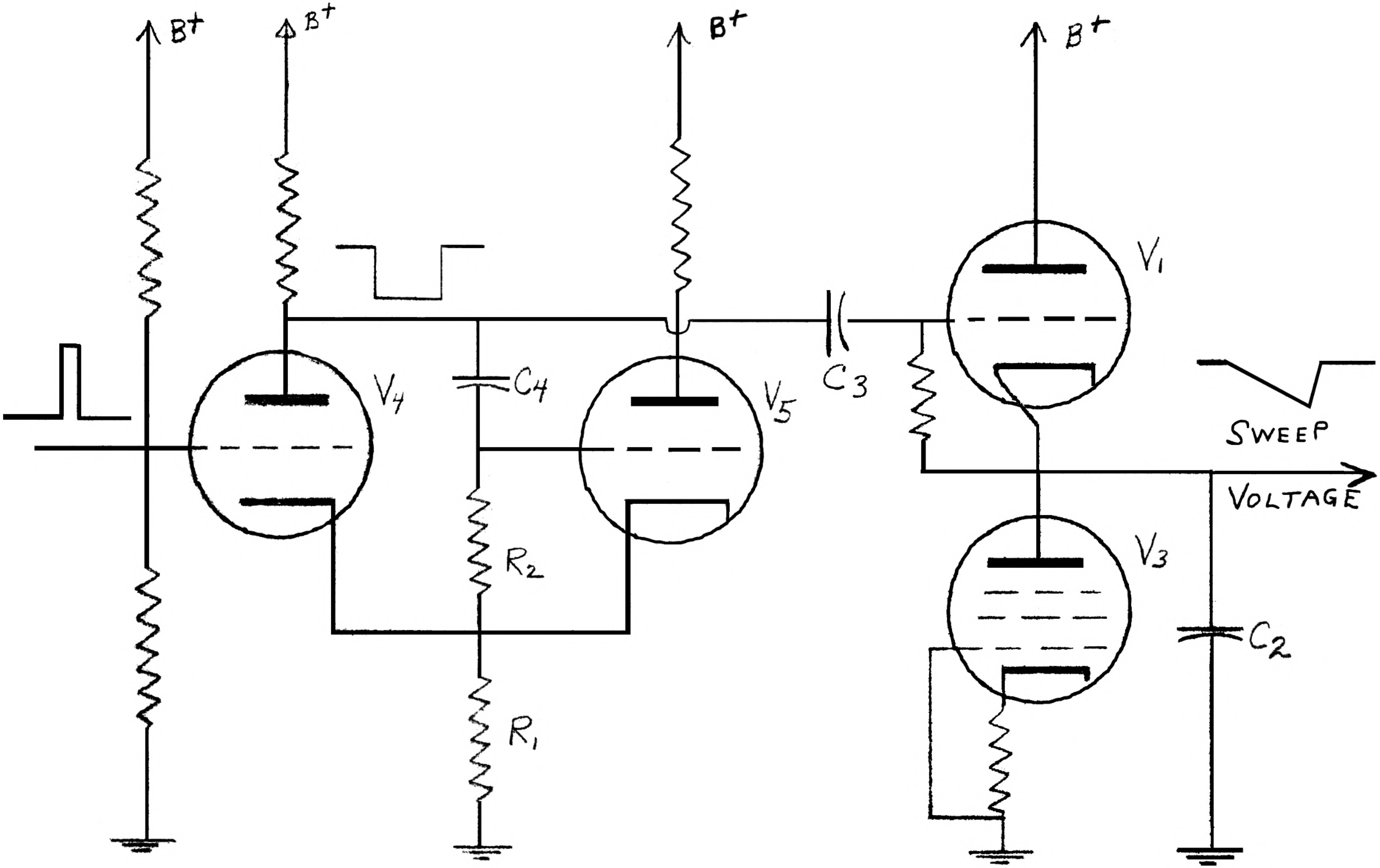
PLATE XII


B+ (250)
MULTIVIBRATOR
SWEEP OUTPUT
SYNC INPUT
V2
V1
V3
FREQUENCY RANGE SWITCH
C2
FREQ VERNIER

EXPLANATION OF PLATE XIII

Simplified diagram of driven sweep. Triggered multivibrator applies a negative pulse to discharge tube and condenser C_2 discharges linearly through constant-current pentode V_3.

PLATE XIII



will develop a potential across cathode resistor R_1 which will cause tube V_4 to cut off.

Thus, it can be seen that when initiated by a starting signal the circuit will produce a rectangular voltage pulse of length determined by the constants of R_2 and C_4. This rectangular pulse is often referred to as a gate. This voltage is used to initiate the sweep circuit as well as to "blank in" the oscillograph beam during the sweep interval.

This gate is fed to the grid of the discharge tube V_1. When V_1 and V_3 are normally conducting they act as a bleeder circuit and current, limited by V_3, flows from B plus to ground through the two tubes allowing capacitor C_2 to charge up. Upon introduction of a negative trigger to the grid of the discharge tube V_1, this tube is cut off breaking the bleeder action and allowing C_2 to discharge through V_3, the constant current pentode. In this way a single sweep voltage begins immediately after the sweep. This has an advantage over the gas triode single sweep circuit in which the condenser must first be discharged and then the linear trace is produced as the condenser recharges. This is a serious limitation in observing fast starting transients which is overcome by the driven sweep used in this unit.

Four fixed sweep durations are provided, 5, 25, 100, and 1000 microseconds. These can be triggered through the regular sync channels by an internal or external signal of at least 1.5 volts peak amplitude and of 0.1 microsecond or more duration.

Trigger Generator

The trigger generator is shown in Plate XIV. It consists of a blocking oscillator and a phase splitter tube with equal plate and cathode resistors which makes it possible to obtain both positive and negative pulses from a low impedance source. The pulse peak amplitude is between 50 and 100 volts and has a repetition rate of approximately 200 to 3000 cycles per second. This unit can be used for triggering transient phenomena in other apparatus if necessary.

Adjustments

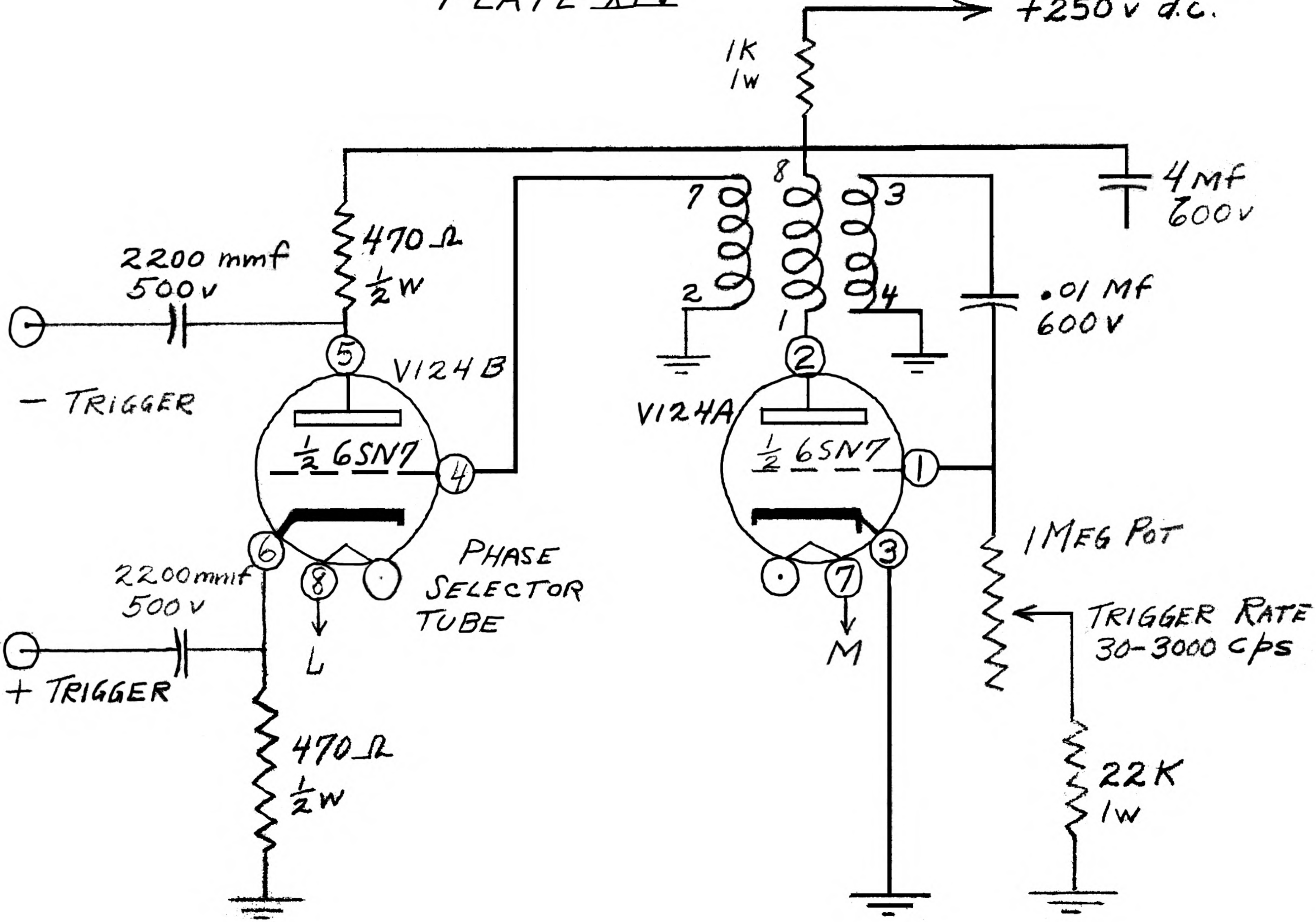
The only adjustment in the power supplies is the 50 K potentiometer which is adjusted until the regulated power supply puts out a voltage of exactly 250. This potentiometer is located on the back of the chassis of unit II.

All of the decade attenuators must be adjusted. A small trimmer condenser is provided. This condenser is adjusted until a 10,000 square wave is passed with minimum distortion. The peaking coils in the Y-axis amplifier are adjusted by applying a 100 Kc square wave to the grid of the final deflection amplifier and adjusting the two peaking coils until the square wave is passed with minimum distortion and no

EXPLANATION OF PLATE XIV

Complete circuit diagram of trigger generator. The blocking oscillator drives its grid highly negative. The grid condenser then charges up till the tube again conducts. The rise of plate currents pulls the grid highly positive. When the plate current ceases to increase, the grid potential falls, the plate current starts to decrease; thus this drives the grid further negative and the cumulative action causes the grid to cut off the tube. This action produces triggers with extremely fast rising wave fronts. The output is fed into a tube with equal plate and cathode resistors and thus it is possible to obtain both positive and negative pulses of low impedance.

PLATE XIV


+250 v d.c.
1K
1w
4 mf
600 v
8
7
3
2
1
4
.01 Mf
600 V
470 Ω
½ W
2200 mmf
500 v
5
V124B
V124A
2
− TRIGGER
½ 6SN7
4
½ 6SN7
1
6
8
3
7
1 MEG POT
PHASE
SELECTOR
TUBE
2200 mmf
500 v
L
M
TRIGGER RATE
30-3000 cps
+ TRIGGER
470 Ω
½ W
22K
1w

overshoot. Then the square wave is applied to the grid of the preceding stage and the series peaking coil is adjusted. Likewise, the next and first stage is adjusted. The same procedure is applied to the X-axis amplifier and the Z-axis amplifier.

The inductance coils which make up the tuned circuit of the transitron oscillator must be adjusted until the frequency of oscillation of the oscillator is respectively 1 megacycle, 100,000 cycles, and 10,000 cycles. The peaking coils in the clipping circuit are adjusted until the 1 usec timing marks produced are the sharpest possible.

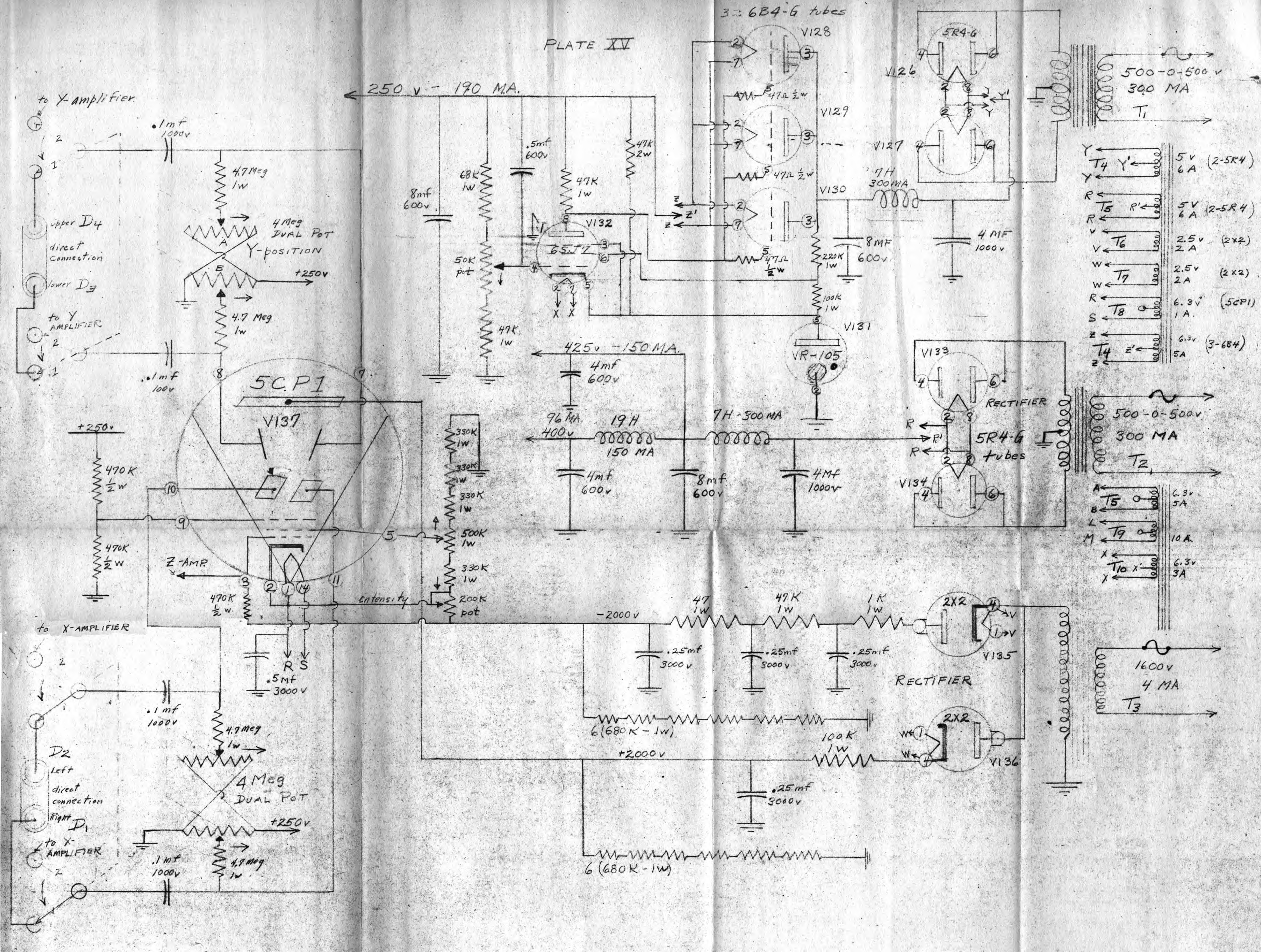
The sensitivity control which determines the amplitude of the signal needed to trigger the multivibrator which starts the driven sweep should be adjusted so that a one-volt-peak signal will trigger the 5 usec sweep internally, at full sync. If the sensitivity is made too great the circuit will tend to oscillate continuously.

The lowest frequency at which the continuous sweep will oscillate is controlled by a 50 K potentiometer. This should be adjusted so that the lowest sweep frequency is 15 cps with the X-signal selected on 15 to 125 setting and the continuous sweep vernier at minimum setting, and with no sync. The setting of the trimmer capacitor which is in parallel with 51 mmf condenser in the sweep circuit determines the highest rate at which the continuous sweep will operate on the 50 Kc to 150 Kc range. It should be adjusted to 150 Kc with the continuous sweep vernier at maximum and with no sync.

EXPLANATION OF PLATE XV

Power Supplies, Cathode-Ray Tube
Connections, and Positioning Controls

PLATE XV



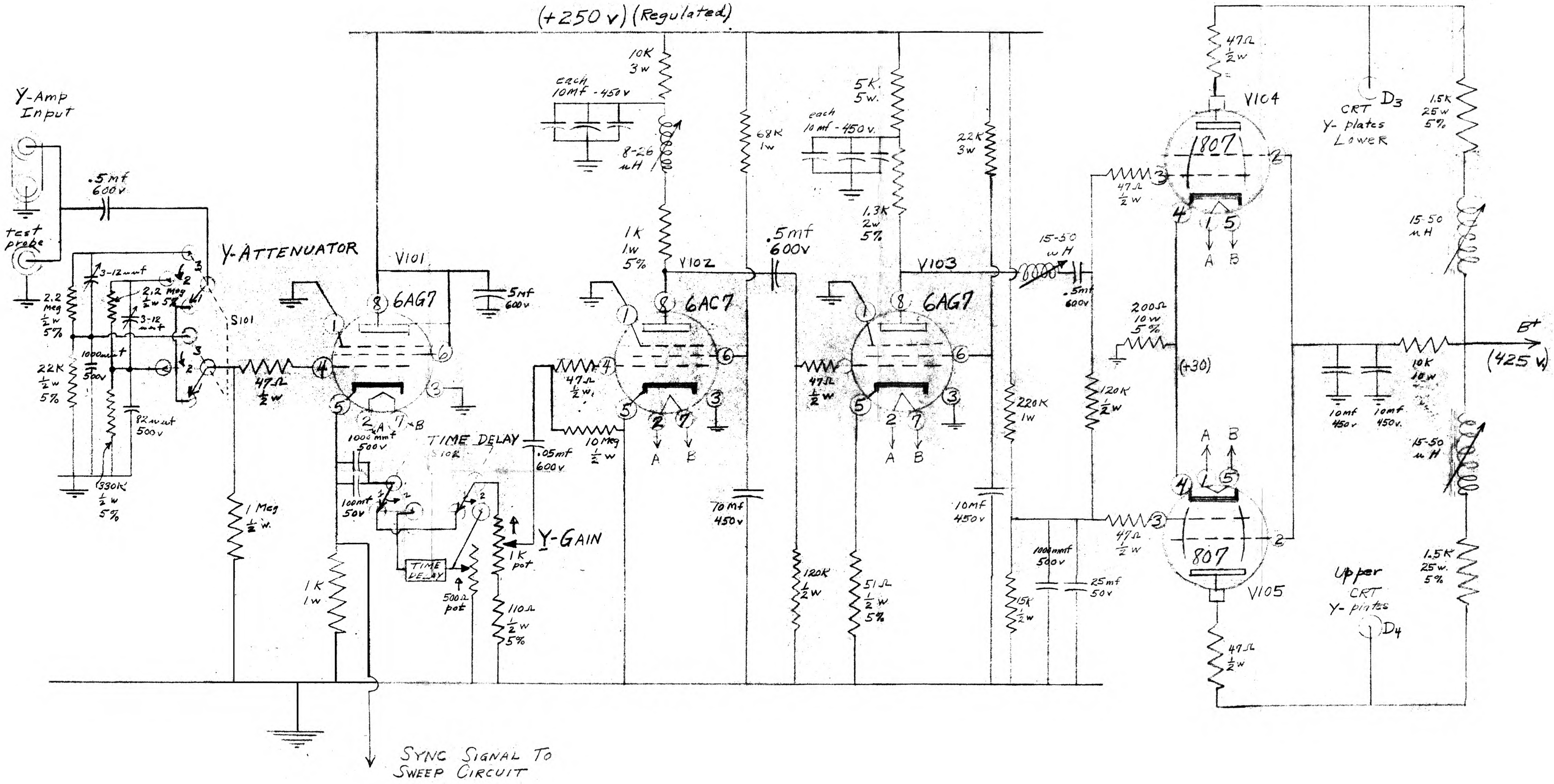
3 - 6B4-G tubes
V128
V129
V130
V127
V126
5R4-G
500-0-500 v
300 MA
T1
250 v - 190 MA.
to Y-amplifier
.1 mf
1000 v
4.7 Meg
1w
4 Meg
DUAL POT
Y-POSITION
+250v
upper D4
direct connection
lower D3
to Y AMPLIFIER
.1 mf
100v
8 mf
600v
.5 mf
600v
68K
1w
47K
1w
47K
2w
50K
pot
V132
6SJ7
47Ω 1/2 w
7H
300 MA
4 MF
1000 v
8 MF
600 v
220 K
1w
100K
1w
V131
VR-105
425 v - 150 MA.
4 mf
600 v
96 MA
400 v
19 H
150 MA
7H - 300 MA
8 mf
600 v
4 mf
1000 v
V133
RECTIFIER
5R4-G
tubes
V134
500-0-500 v
300 MA
T2
5CP1
V137
+250 v
470K
1/2 w
Z-AMP.
330K
1w
500K
1w
200K
pot
intensity
-2000 v
47
1w
47 K
1w
1 K
1w
2X2
V135
.25 mf
3000 v
RECTIFIER
1600 v
4 MA
T3
R S
.5 mf
3000 v
to X-AMPLIFIER
.1 mf
1000 v
4.7 meg
1w
4 Meg
DUAL POT
D2
Left
direct connection
Right D1
to X-AMPLIFIER
+250v
6 (680K - 1w)
100 K
1w
+2000 v
V136
5 v
6 A
(2-5R4)
2.5 v
2 A
(2x2)
6.3 v
1 A
(5CP1)
6.3 v
5A
(3-6B4)
T4
T5
T6
T7
T8
T9
T10
10 A
6.3 v
3A

EXPLANATION OF PLATE XVI

Y-axis Amplifier

At the terminals of the amplifier the input impedance is 1 megohm in parallel with 40 mmf and the maximum permissible input potential is 600 volts. The frequency response of this amplifier is uniform within 30 per cent from 20 cps to 5 megacycles. The deflection factor at maximum gain is 0.1 rms volts per inch total deflection which is the equivalent of 0.28 d-c volts per inch.

PLATE XVI


(+250 v) (Regulated)
Y-Amp Input
test probe
.5mf 600v
Y-ATTENUATOR
S101
V101
6AG7
5mf 600v
V102
6AC7
V103
6AG7
V104
807
V105
807
CRT Y-plates Lower
D3
Upper CRT Y-plates
D4
B+
(425 v)
(+30)
TIME DELAY
Y-GAIN
1K pot
500Ω pot
Sync Signal To Sweep Circuit
10K 3w
68K 1w
5K 5w
22K 3w
1.3K 2w 5%
1K 1w 5%
8-26 μH
15-50 μH
47Ω ½w
10 Meg ½w
1 Meg ½w
70mf 450v
10mf 450v
120K ½w
51Ω ½w 5%
220K 1w
15K ½w
200Ω 10w 5%
1.5K 25w 5%
110Ω ½w 5%
.05mf 600v

EXPLANATION OF PLATE XVII

X-axis Amplifier and Sweep Circuit

The sweep circuit shown is for both continuous and driven sweeps. The X-axis amplifier has an input impedance of 1 megohm in parallel with 60 mmf and has a permissible input potential of 210 volts peak a-c, and 600 volts maximum. Its frequency response is uniform with 30 per cent from 20 cps to 2 megacycles. The deflection factor at maximum gain is 2.75 volts per inch total deflection or 7.75 d-c volts per inch.

The continuous sweep has a frequency range from 15 cps to 150 kilocycles per second. The driven sweep has four possible durations of 5, 25, 100, and 1000 microseconds and can be initiated by any signal having a repetition rate up to 3 Mc, a peak amplitude of 1.5 volts and with peaks lasting more than 0.1 microsecond.

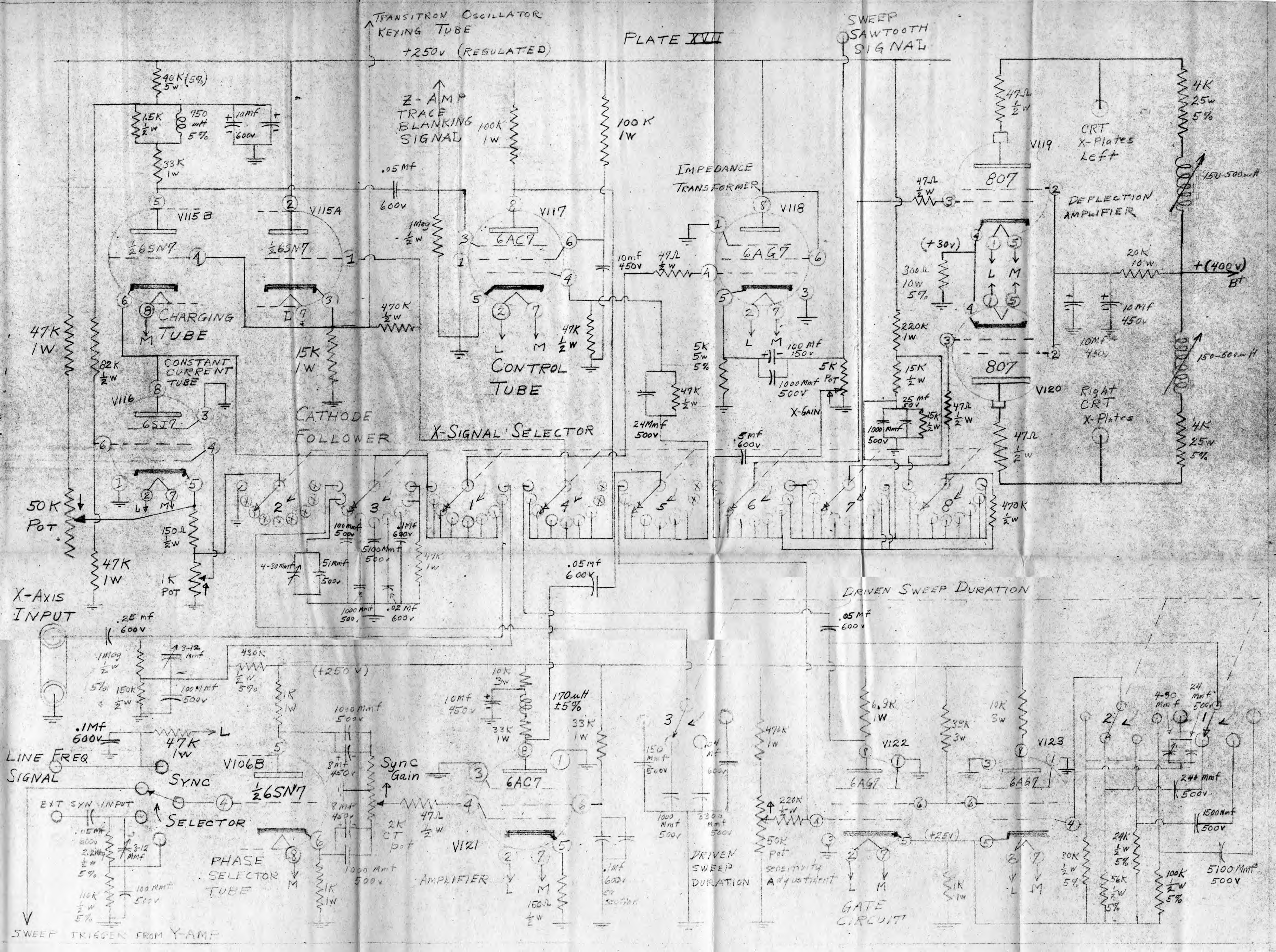


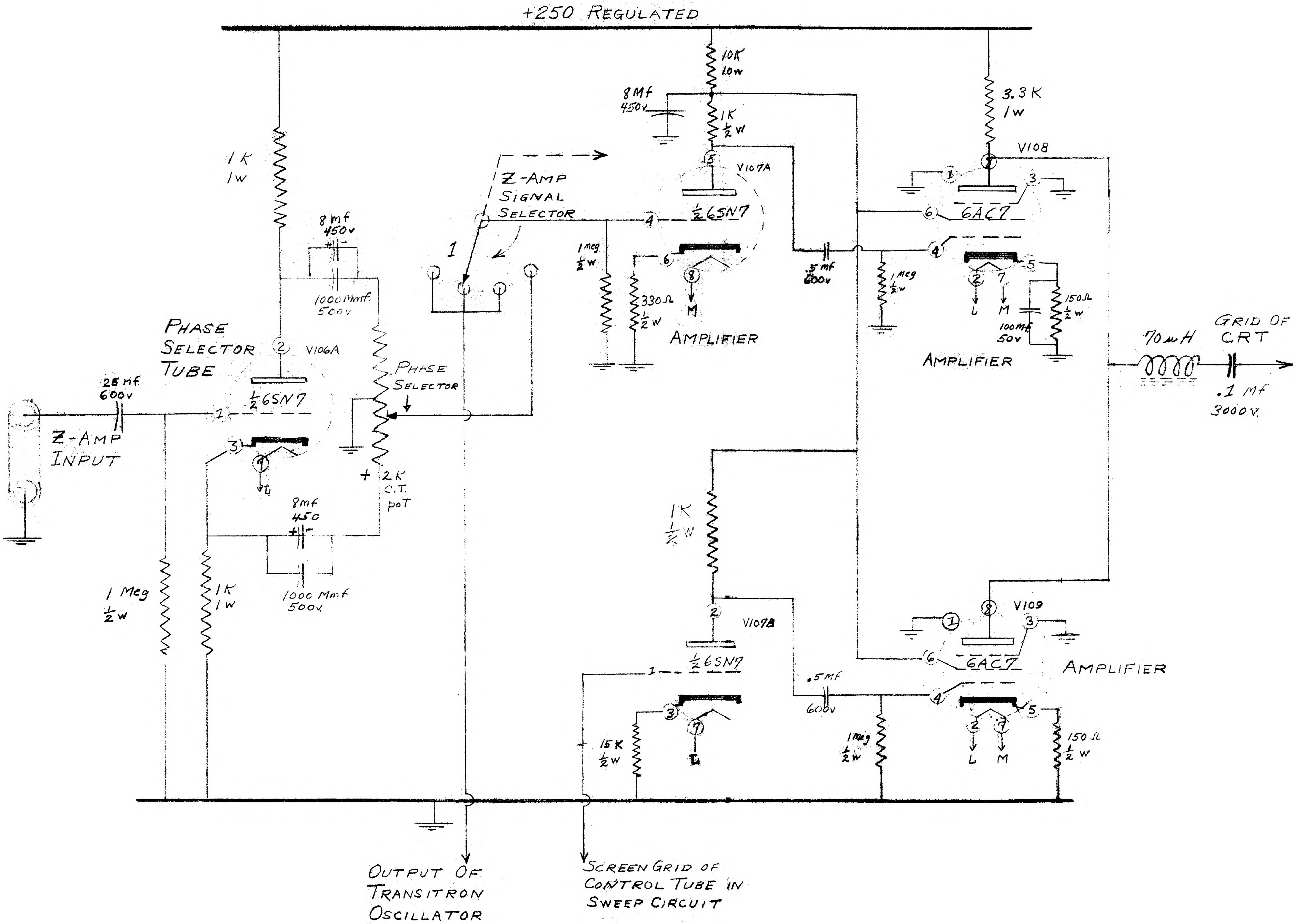
PLATE XVII
TRANSITRON OSCILLATOR KEYING TUBE
+250v (REGULATED)
SWEEP SAWTOOTH SIGNAL
Z-AMP TRACE BLANKING SIGNAL
IMPEDANCE TRANSFORMER
DEFLECTION AMPLIFIER
CRT X-Plates Left
Right CRT X-Plates
+(400v) B+
V115B
V115A
½6SN7
CHARGING TUBE
CONSTANT CURRENT TUBE
V116
6SJ7
CATHODE FOLLOWER
V117
6AC7
CONTROL TUBE
V118
6AG7
X-GAIN
V119
807
V120
X-SIGNAL SELECTOR
50K Pot
1K POT
X-AXIS INPUT
LINE FREQ SIGNAL
SYNC SELECTOR
EXT SYN INPUT
V106B
PHASE SELECTOR TUBE
Sync Gain
2K CT pot
V121
AMPLIFIER
DRIVEN SWEEP DURATION
50K Pot sensitivity Adjustment
V122
6AG7
V123
GATE CIRCUIT
SWEEP TRIGGER FROM Y-AMP

EXPLANATION OF PLATE XVIII

Z-axis Amplifier

This amplifier has an input impedance of 1 megohm and 25 mmf and a permissible input voltage of 5 volts peak a-c, 600 volts maximum. It will blank the trace on 3 volts peak input from 30 cps to 5 megacycles.

PLATE XVIII



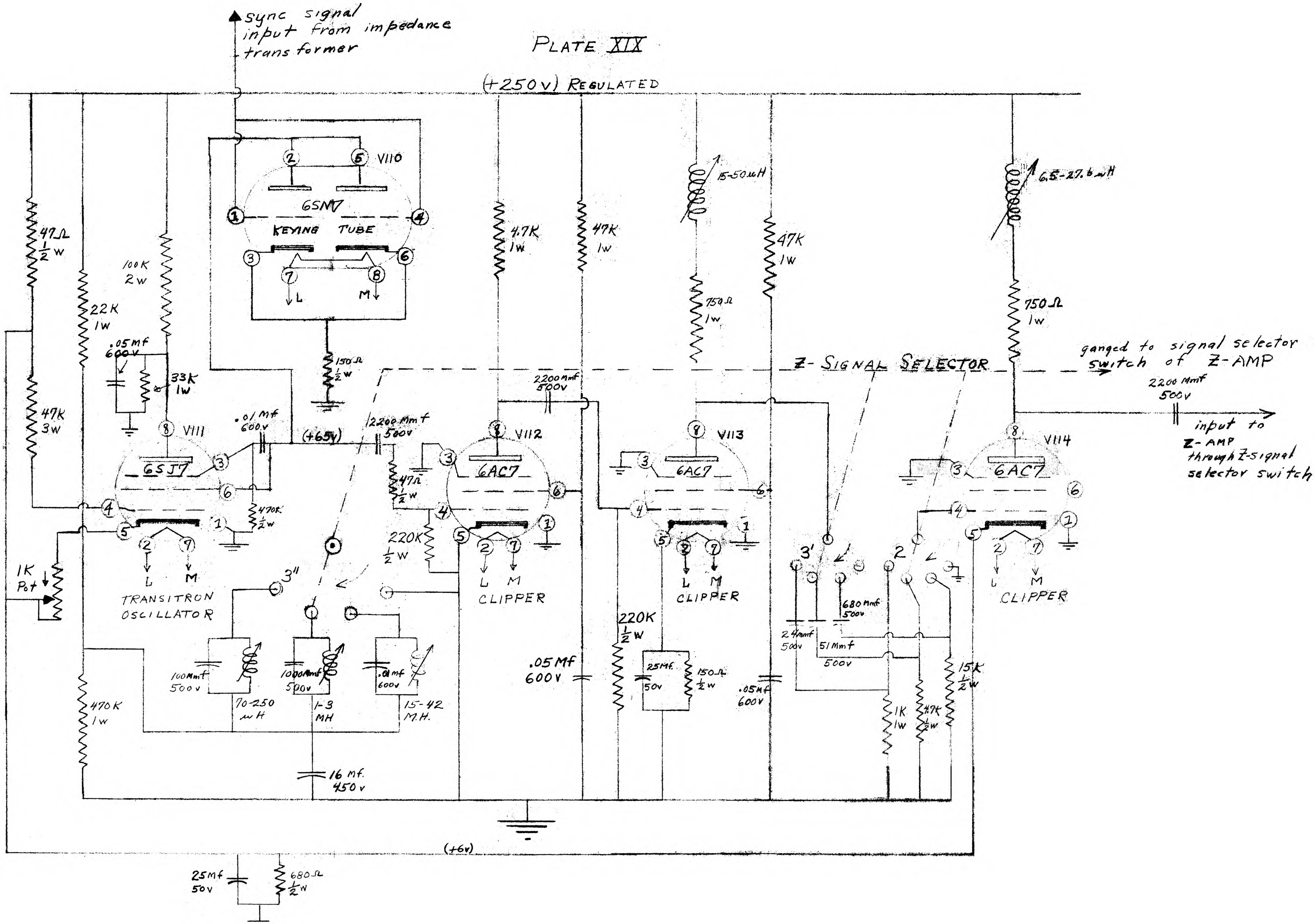
+250 REGULATED
1K
1w
8 mf
450v
1000 Mmf.
500v
10K
10w
8 Mf
450v
1K
½ w
V107A
Z-AMP
SIGNAL
SELECTOR
1
½ 6SN7
1 meg
½ w
330Ω
½ w
M
AMPLIFIER
.5 mf
600v
1 meg
½ w
3.3K
1w
V108
6AC7
150Ω
½ w
100mf
50v
L
M
AMPLIFIER
70 μH
GRID OF
CRT
.1 mf
3000V.
PHASE
SELECTOR
TUBE
V106A
25 mf
600v
½ 6SN7
Z-AMP
INPUT
PHASE
SELECTOR
2K
C.T.
poT
8mf
450
1000 Mmf
500v.
1 Meg
½ w
1K
1w
1K
½ w
V107B
½ 6SN7
15K
½ w
.5mf
600v
1 meg
½ w
V109
6AC7
AMPLIFIER
150Ω
½ w
L
M
OUTPUT OF
TRANSITRON
OSCILLATOR
SCREEN GRID OF
CONTROL TUBE IN
SWEEP CIRCUIT

EXPLANATION OF PLATE XIX

Transitron Oscillator

The output from the transitron oscillator is fed through the Z-axis amplifier. This oscillator has frequency ranges of 10 Kc, 100 Kc, and 1 Mc; thus, giving timing marks 1, 10, 100 microseconds apart.

PLATE XIX


sync signal input from impedance transformer
(+250v) REGULATED
V110
6SN7
KEYING TUBE
150Ω ½w
47Ω ½w
47k 3w
22K 1w
100K 2w
.05mf 600v
33K 1w
V111
6SJ7
TRANSITRON OSCILLATOR
1K Pot
.01mf 600v
(+65v)
2200 Mmf 500v
47Ω ½w
220K ½w
V112
6AC7
CLIPPER
4.7K 1w
47K 1w
2200 Mmf 500v
V113
6AC7
CLIPPER
15-50μH
750Ω 1w
47K 1w
220K ½w
25Mf 50v
150Ω ½w
.05Mf 600v
.05Mf 600V
Z- SIGNAL SELECTOR
ganged to signal selector switch of Z-AMP
6.5-27.6μH
750Ω 1w
2200 Mmf 500v
input to Z-AMP through Z-signal selector switch
V114
6AC7
CLIPPER
3"
3'
2
680 Mmf 500v
24 Mmf 500v
51 Mmf 500v
1K 1w
47K ½w
15K ½w
100 Mmf 500v
1000 Mmf 500v
.01mf 600v
70-250 μH
1-3 MH
15-42 M.H.
470K 1w
16 mf. 450v
(+6v)
25Mf 50v
680Ω ½w

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BIBLIOGRAPHY

(1) Atwood, H. and R. P. Owens.
Oscilloscope for pulse studies. Electronics. 17: 110-114. December, 1944.

(2) Reich, Herbert J.
Theory and applications of electron tubes. New York. McGraw Hill. 716 p. 1944.

(3) Puckle, O. S.
Time bases. Their design and development. New York. John Wiley. 204 p. 1943.