INSTRUCTION MANUAL

MODEL 5500

Universal Counter and Timer

Beckman® INSTRUMENTS, INC.

BERKELEY DIVISION

2200 Wright Avenue
Richmond, California

April 1, 1954

WARRANTY

Instruments sold by Berkeley Division, Beckman Instruments, Inc., (hereafter called "the Company") are warranted only as stated below.

Subject to the exceptions and upon the conditions specified below, the Company agrees to correct, either by repair, or, at its election, by replacement, any defect of material or workmanship which develops within one year after delivery of the instrument to the original purchaser by the Company or by an authorized representative, provided that investigation and factory inspection by the Company discloses that such defect developed under normal and proper use.

The exceptions and conditions mentioned above are the following:

(a) All instruments claimed defective must be returned to the Company, transportation charges prepaid, and will be returned to the customer with the transportation charges collect.

(b) The Company makes no warranty concerning components or accessories not manufactured by it, such as tubes, fuses, batteries, etc. However, in the event of the failure of any component or accessory not manufactured by the Company, the Company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.

(c) The Company shall be released from all obligations under its warranty in the event repairs or modifications are made by persons other than its own service personnel or authorized representatives' personnel unless such repairs by others are made with the written consent of the Company.

(d) Except as stated above, the Company makes no warranty, express or implied (either in fact or by operation of law), statutory or otherwise; and, except to the extent stated above, the Company shall have no liability under any warranty, express or implied (either in fact or by operation of law), statutory or otherwise.

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(f) Representations and warranties made by any person, including representatives of the Company, which are inconsistent or in conflict with the terms of this warranty (including but not limited to the limitation of the liability of the Company as set forth above) shall not be binding upon the Company unless reduced to writing and approved by an officer of the Company.

(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate. Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, Berkeley division of Beckman Instruments, Inc., Richmond 4, California.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

Berkeley reserves the right to make changes in design at any time without incurring any obligation to modify equipment previously purchased to conform to subsequent design changes.

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CONTENTS

ILLUSTRATIONS

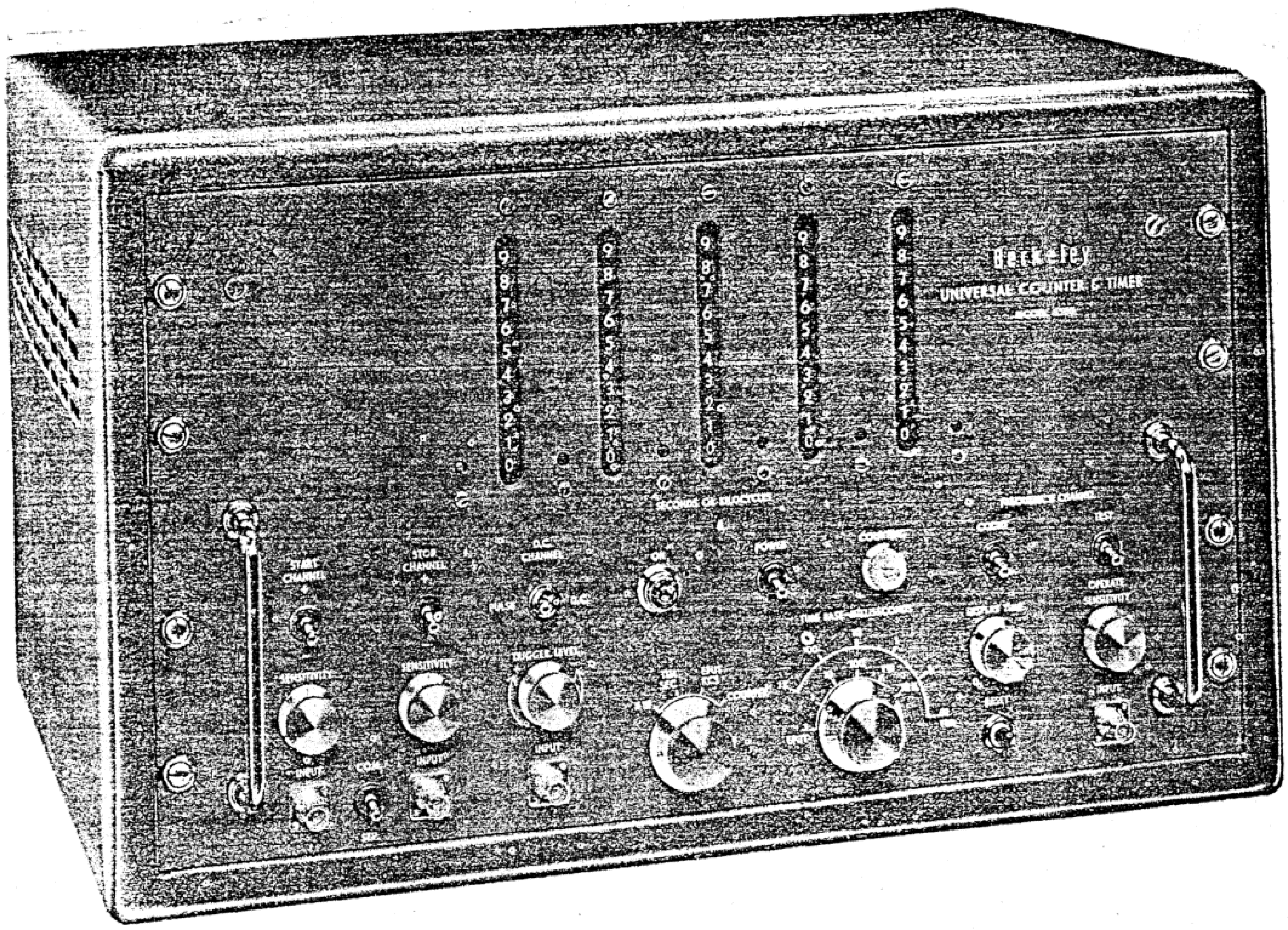


Figure 1 Model 5500 Universal Counter & Timer

Section 1
INTRODUCTION

The Model 5500 Universal Counter and Timer is an accurate high-speed electronic counting instrument designed to measure the characteristics of electrical, optical, or physical events relative to time. Discrete events in either random or regular distribution may be counted for an indefinite or precise time interval. The elapsed time between any two events or the period of frequencies can be determined with the results displayed directly by the lighted Decimal Counting Units.

Various transducers such as photocells, magnetic pickups and switches may be used to translate the event into the proper input form. Because of its versatility, the Universal Counter and Timer is ideal for rapid and precise measurements in countless applications. Among them are: relay and switch timing, viscosity determination, ballistics measurements, tachometry, determination of frequency ratio, use as a secondary frequency standard, and telemetering.

Specifications

COUNTER Operation

Range:	20 cps to 100 kc
Input Sensitivity:	0.2 V. rms
Capacity:	100,000 counts

EPUT Operation (Frequency Channel)

Range:	20 cps to 100 kc
Input Sensitivity:	0.2 v. rms
Accuracy:	± 1 count, 1 second gate ± 0.0001%, 10 second gate
Stability:	1 part in 10^6 (oven crystal)
Gate Time:	0.0001, 0.001, 0.01, 0.1, 1, 10 seconds
Self-checking:	Direct test of all dividers and operation of unit
Readout:	Direct reading in kc with decimal point indicated.

TIME INTERVAL METER Operation

Range:	40 μsec. to 100,000 seconds
Accuracy:	± 10 μsec.
Input Sensitivity:	± 1 volt peak with rise time of 1 volt/μsec.
Gate Frequency:	100 kc, 10 kc, 1 kc, 100 cps, 10 cps, 1 cps
Readout:	Direct reading in seconds with decimal point indicated

X10 (DC CHANNEL) Operation

Range:	0.0001 cps to 10 kc
Input Sensitivity:	0.2 volt peak, direct-coupled to amplifier
Gate Time:	1 cycle or 10 cycles of input signal
Accuracy:	± 10 μsec.

General

Display Time:	0.5 to 5 secnnds continuously
Power Input:	117 volts, ± 10%, 50-60 cps, 200 watts
Accessory Socket: Connections:	External reset, +100 v. at 5 ma, +290 v. at 25 ma, 6.3 v. a-c at 2a, ground
AN Connector	For use with Digital Recorder
Dimensions:	20 3/4" wide x 12" high x 15" deep
Net Weight:	85 pounds

Section 2
OPERATION

Installation

The Model 5500 requires no special installation procedure. It may be operated in any well ventilated location. The unit is designed to operate from an a-c source of 117 volts, 50-60 cps, at a power rating of 200 watts. Satisfactory operation may be expected from 105 to 130 volts.

Operation *

To put the instrument in operation, connect the power cord and turn on the POWER switch. Turn on the FAN switch (rear of fan bracket). After a fifteen minute warm-up, test the instrument for proper operation:

1. Turn DISPLAY TIME to a point near zero for a short display time and automatic operation.
2. Place TEST - OPERATE switch in TEST.
3. Set X10-TIM-EPUT-COUNTER switch to EPUT.
4. Rotate TIME BASE switch to each marking for EPUT, starting with the 0.1 MILLISECOND setting. This should give a reading of 10. As the switch is turned clockwise, other settings should read 100, 1,000, 10,000, 100,000 and 1,000,000 respectively.

Note that the DISPLAY TIME is infinite at the extreme clockwise position of the control. In this position, the instrument must be reset manually. The d-c level of the input to all jacks must not exceed 500 volts, with the exception of the DC CHANNEL input where operation is with respect to ground.

COUNTER operation: To use the Model 5500 as an electronic counter, set the controls as follows:

1. Rotate X10-TIM-COUNTER switch to COUNTER.
2. Turn DISPLAY TIME to infinity.
3. Follow steps "2, ""4, " and "5" under EPUT operation.
4. Set COUNT switch down.
5. Press RESET button to clear DCU's.
6. Initiate counting by placing COUNT switch in the up position.

*See Table 1 and Figure 2.

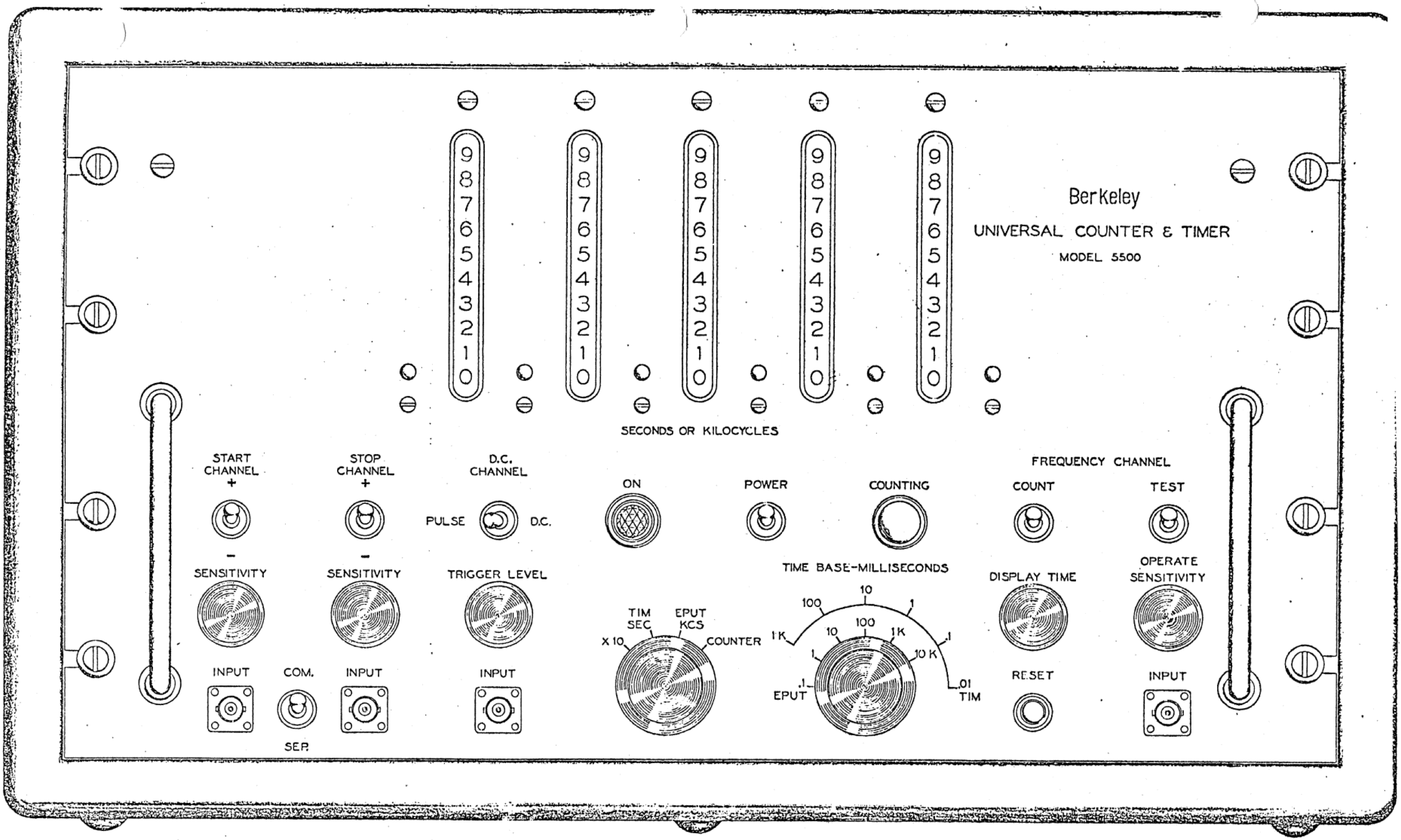


Figure 2 Outline View, Model 5500

Table 1

CONTROL & CONNECTOR FUNCTIONS

Control or Connector	Detail No.	Component	Function
		Front Panel	
START CHANNEL	S103	SPDT toggle switch	Selects polarity for START channel
SENSITIVITY	R128	100k, 2w., potentiometer	Attenuates input amplitude of START channel.
INPUT	J102	Type BNC, UG-290/U	Connector for input to START channel
COM-SEPT	S108	SPST toggle switch	Makes START-STOP channel common or separate
STOP CHANNEL (+, -)	S104	SPDT toggle switch	Selects polarity for STOP channels
SENSITIVITY	R169	100k, 2w., potentiometer	Attenuates input amplitude to STOP channel
INPUT	J103	Type BNC, UG-290/U	Connects input to STOP channel
PULSE-DC	S102	SPDT toggle switch	Selects DC or START-STOP channel operation
TRIGGER LEVEL	R186	100k, 2w., potentiometer	Varies input level required to trigger DC channel
INPUT	J104	Type BNC, UG-290/U	Connects input to DC channel
POWER	S301	DPST toggle switch	Connects line voltage to instrument when ON, as indicated by green pilot light.
X10-TIM-EPUT COUNTER	S111	4-deck rotary switch	Selects function of unit

Control or Connector	Detail No.	Component	Function
		Front Panel	
TIME BASE-MILLISECONDS	S110	3-deck rotary switch	Selects output from time base dividers
COUNTING	I117	Pilot light	Indicates instrument is counting when glowing
COUNT	S105	SPDT toggle switch	Allows instrument to count when up
DISPLAY TIME	R122 S106	10m, 2 w., potentiometer with SPST switch	Varies display time. Switching to infinity gives indefinite display time.
RESET	S107	DPDT push-button switch NC	Resets instrument whenever pushed and released
TEST-OPERATE	S101	DPDT toggle switch	Selects input connection to FREQUENCY channel
S. SITIVITY, FREQUENCY CHANNEL	R101	250 k, 2 w., potentiometer	Attenuates input signal to FREQUENCY channel
INPUT	J101	Type BNC, UG-290/U	Connects input to FREQUENCY channel
		Back Chassis	
117 VAC	J301	Recessed two-prong plug	Connects input power cord
FAN	S302	DPST toggle switch	Connects fan to power when ON
DIGITAL RECORDER	J303	AN 3102A-18-12S	Connects to Berkeley Model 1555 Digital Scanner
ACCESSORY	J302	AN 3102A-18-1S	Ten-pin connector for operating external apparatus

Control or Connector	Detail No.	Component	Function
			Pin
			A ground
			B+ 180 v.
			C -150 v.
			D External reset (see H)
			E Filament ground
			F +290 v.
			G NC
			H External reset (short D & H through a 330 k resistor)
			I 6. 3 v. a-c filament
			J +100 v.

Modification E

Extinguishing	S801	SPST toggle switch	Connects circuitry for blanking DCU lights while unit is counting

SCANNER operation: To count for an integral number of seconds or a multiple of ten seconds, set the controls as follows:

1. Rotate X10-TIM-EPUT-COUNTER switch to EPUT.
2. Follow instructions, steps "2", "3", "4" and "5" EPUT operation.
3. Rotate TIME BASE switch to 1 k (or 10 k) for a scan of a multiple of one (or ten) seconds
4. Select DISPLAY TIME for manual or automatic operation. Push RESET button for manual operation.
5. As soon as the unit starts to count, turn X10-TIM-EPUT-COUNTER switch to COUNTER before the first second has elapsed, disconnecting the time base.
6. To halt counting turn this switch to the EPUT position. When the X10-TIM-EPUT-COUNTER switch is returned to EPUT, the next one (or ten) second interval pulse will stop the counting at an integral number of seconds.

As an Events-per-Unit-Time Meter, the lighted decimal point indicates the frequency in kilocycles, e. g. 23. 645 indicates twenty-three and 645/1000 kilocycles. On the 10. 1 TIME BASE setting, no point indication is given and readings are in tens of kilocycles.

As a Time Interval Meter, the decimal points the time in seconds, e. g. 23. 645 indicates twenty-three and 645/1000 seconds. See Fig. 9.

EPUT operation: The number of events per unit time is measured by setting the controls as follows:

1. Rotate X10-TIM-EPUT-COUNTER switch to EPUT.
2. Place TEST-OPERATE switch in OPERATE.
3. Set COUNT switch up.
4. Apply input information to INPUT jack of the frequency channel.
5. Turn SENSITIVITY knob of FREQUENCY CHANNEL completely counter clockwise. Then slowly turn the knob clockwise just past the point where the DCU's commence counting.
6. Select resolution time by TIME BASE switch. Except for 0. 1 MILLISECONDS setting (extreme counter clockwise position) the small lights between the DCU's indicate the position of the decimal point for a reading in kilocycles. In the 0. 1 MILLISECOND position, the result is in tens of kilocycles, with no decimal indication. Markings around the TIME BASE switch indicate the precise counting interval.
7. For manual operation, turn DISPLAY TIME control to INFINITY and push RESET button. For automatic operation, turn the control counter clockwise from INFINITY until switch operates, then select length of time.

TIME INTERVAL METER operation: To measure the elapsed time between any two events of an optical, physical, or electrical nature, set the controls as follows (it is assumed that a pulse shaping and/or forming device has been properly incorporated within the set-up):

1. Set X10-TIM-EPUT-COUNTER switch to TIM.
2. Set TEST-OPERATE switch at TEST.
3. Place PULSE-DC switch in PULSE.
4. Apply input to INPUT jacks of respective channels.
5. Set the COM-SEP switch on COM if input information is from single source; on SEP for separate sources.
6. The polarity of each channel must correspond with the input to the respective channel. If a single source is applied, the two polarities must be identical.
7. Turn SENSITIVITY knobs of both channels completely counter clockwise. Press RESET button. Slowly turn knob of START channel clockwise until unit starts counting.
8. Rotate TIME BASE switch to the appropriate time base frequency. This setting determines the percent accuracy of the result presented. Naturally, the higher the frequency counted during the time interval, the smaller the least count. Small lights mark the decimal point for a reading in seconds. For the 0.1 MILLISECOND setting (extreme clockwise position) frequency counted during the time interval is 100 kc. Other positions in counter-clockwise order give 10 kc, 1 kc, 100 cps, 10 cps, and 1 cps frequencies.
9. Adjust DISPLAY TIME. Use RESET button for manual resetting.

DC CHANNEL operation: This channel is generally used to measure periods of very slow waveforms and d-c level changes. A low frequency sine wave and photocell output are two examples of input sources. Read a period of ten input cycles for accurate results.

To operate:

1. Rotate X10-TIM-EPUT-COUNTER switch to X10.
2. Put TEST-OPERATE switch in test.
3. Apply signal to INPUT jack. Use large coupling capacitor if d-c level of a-c signal differs from ground level. All d-c level changes applied should be referenced to or cross ground level (i. e. --- + 0. 3v. to 0v., +0. 3v. to -. 5v., 0v. to -0. 3v.).
4. Adjust DISPLAY TIME as desired.
5. With TRIGGER LEVEL control initially in extreme counter-clockwise position, slowly turn knob clockwise until unit operates. Continue turning until unit stops and set control midway between these two points.

6. Select setting for TIME BASE switch according to step "8" of TIM operation, noting that the reading is for ten cycles rather than one.

The X10 position functions only if the input information is applied to the DC CHANNEL, also, the PULSE-DC and polarity switches have no effect on this function.

If the selection of polarities is desired, the DC CHANNEL may be operated with the X10-TIM-EPUT-COUNTER switch at TIM and the PULSE-DC switch at DC. Select the polarities of the START-STOP channels in accordance with the time interval desired from the input information. Normal TIM readings result.

FREQUENCY RATIO operation: To measure frequency ratios, set the Model 5500 controls according to the instructions for TIM operation, except for the TEST-OPERATE switch which should be in OPERATE. Apply the higher of the two frequencies to the FREQUENCY CHANNEL and the lower to the START-STOP CHANNELS or DC CHANNEL. If the DC CHANNEL is used, the X10 position of the X10-TIM-EPUT-COUNTER switch may be used.

The result will appear as the ratio of the high to the low frequency with the TIME BASE switch set at 0.01 MILLISECONDS. Other settings yield a decimal fraction of the ratio. In the DC CHANNEL (X10) position a ratio ten times greater than the actual will be displayed.

Section 3
THEORY OF OPERATION

Design

Basically, the Model 5500 consists of an accurate time base, several input amplifier circuits, an electronic gate, and a series of cascaded Decimal Counting Units. The time base controls the electronic gate and determines the unit time interval. Decimal Counting Units register the number of input pulses when the instrument is used as an Events-per-Unit-Time Meter (Figure 3a). If the DCU's are used to count the known frequency of the time base, the instrument may be used as a time interval meter (Figure 3b). The Model 5500 may also be used as a high speed electronic counter (Figure 3c).

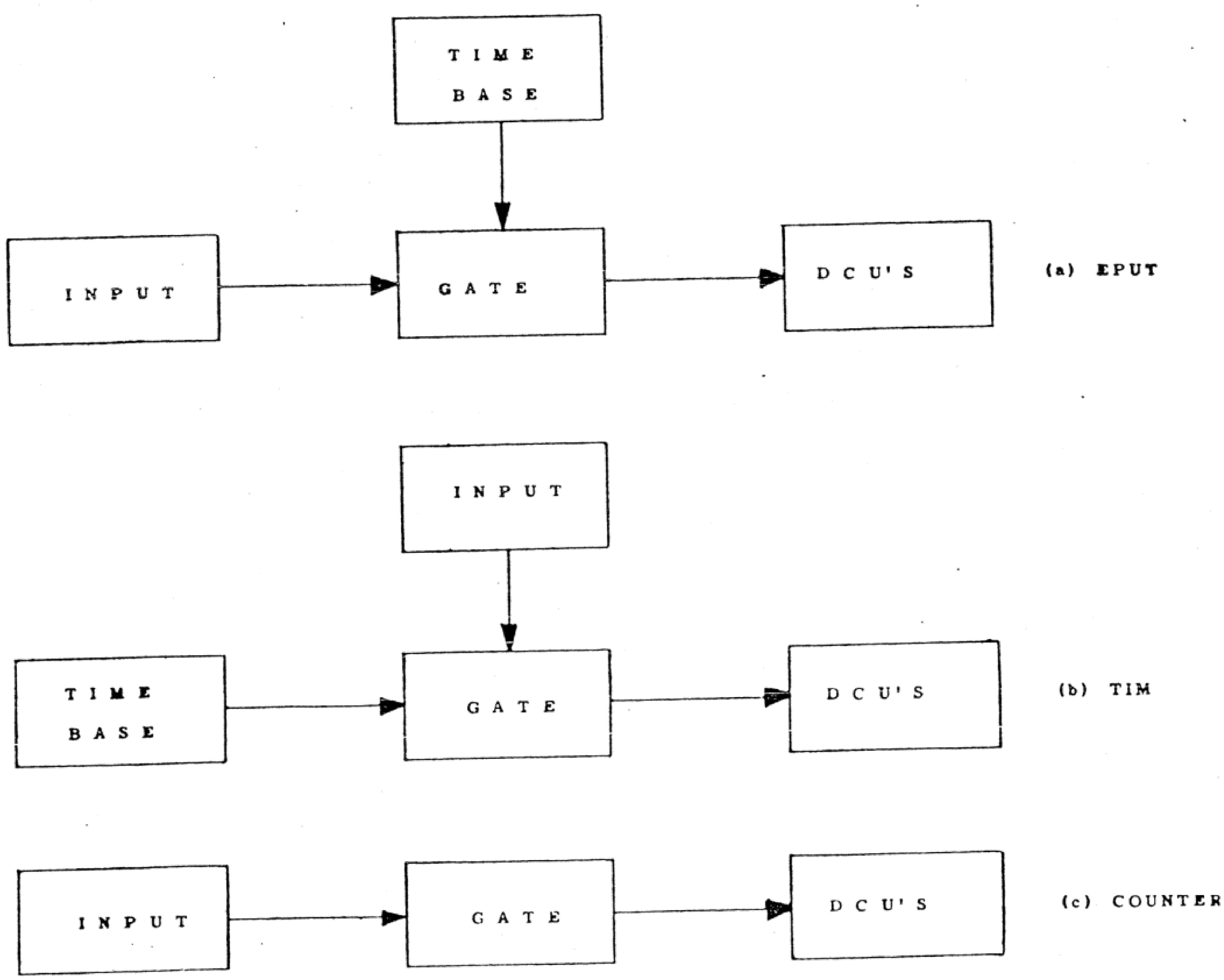


Figure 3. Basic Arrangements.

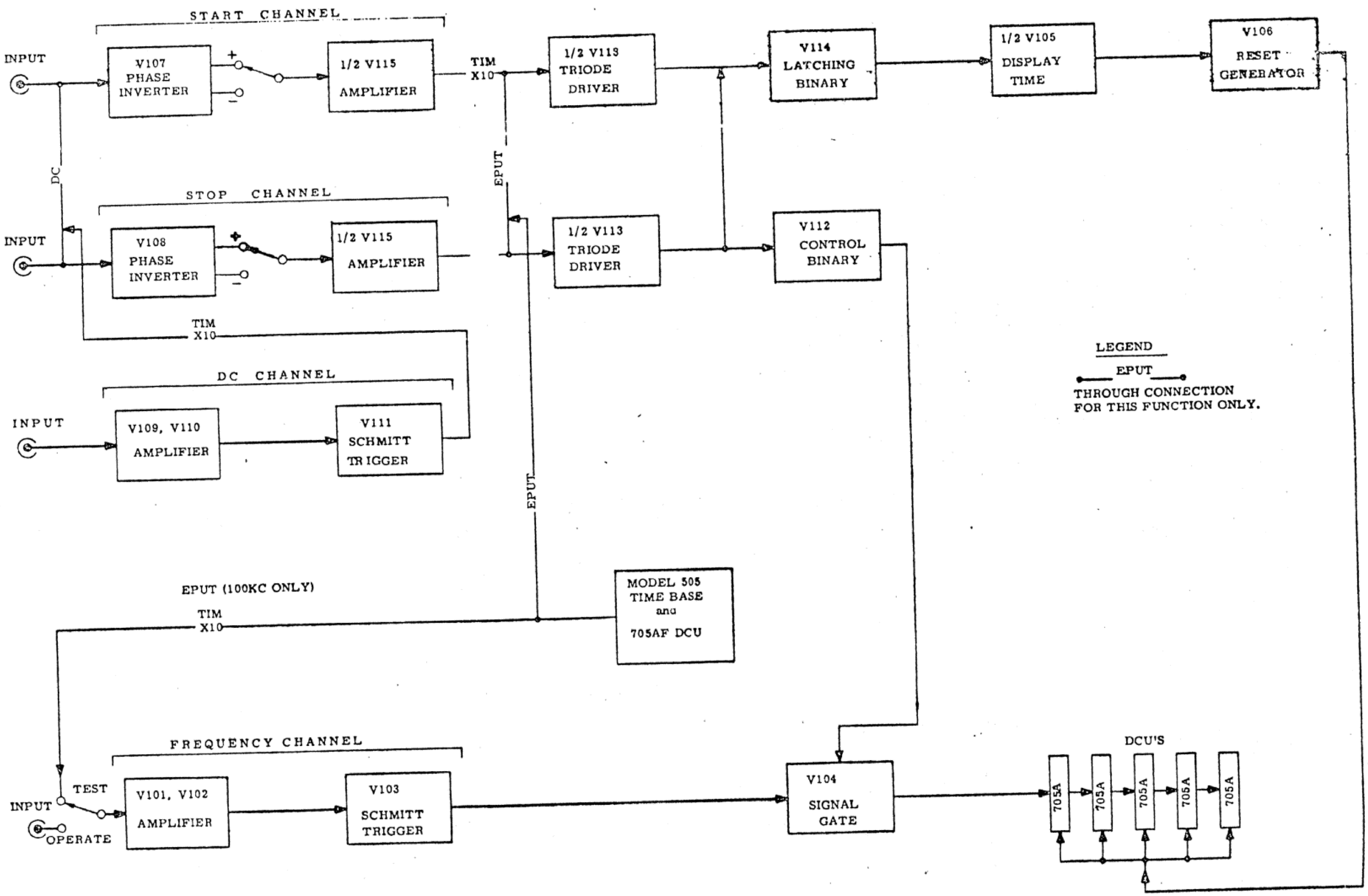


Figure 4 Functional Diagram, Model 5500

A variety of switching arrangements permits one set of circuits (time base, electronic gate, and DCU) to be used in the several ways described above. Separate input elements are switched into the group according to the requirements of a given application. For instance, the gating information from either the time base or input source is not actually applied to the electronic gate, but is amplified, shaped, and applied to the latching control binaries. In turn, the control binary actuates the gate while the latching binary initiates the display and reset action and latches the start triode driver (see Figure 4).

Frequency Channel

Feedback Amplifier. Input information applied at J101 is coupled to the grid of V101 (6AU6) through a blocking capacitor (C101) and a sensitivity adjustment (R101). The amplified signal at pin 5 of V101 is RC coupled to the grid of the second amplifier, the left hand side of V102 (5963). A portion of the output at this point is fed back to the cathode of V101, improving the gain, stability, and increasing the bandpass of the amplifier. The output is also RC coupled through C106 and R112 to the input grid of the Schmitt trigger (pin 2 of V103).

If the TEST-OPERATE switch is in TEST during TIM or self-checking, the output from the time base is connected to the input of the second amplifier tube (pin 2, V102).

Schmitt Trigger. The output signal from the feedback amplifier operates a Schmitt discriminator circuit (V103). Such a circuit characteristically exhibits two stable states. It remains in one state as long as the input level remains below a certain voltage and switches to the other state when the level of the input exceeds this value. The Schmitt trigger circuit returns to its original state when the input level is reduced to a value somewhat less than the triggering voltage. The difference between the triggering and detriggering voltages, the hysteresis or "blacklash" of the circuit, is determined by tube and component values.

In this circuit, the trigger voltage is 6 volts, detrigger 3.5 volts, and the hysteresis 2.5 volts. The output swing of 75 volts (1.5 microseconds rise time), is RC coupled to the input of the electronic gate (pin 1, V104).

Electronic Gate

Signal Gate. V104 (6AS6) amplifies and controls the signal from the Schmitt trigger. When the gate is open, the first of the cascaded DCU's is driven. Gating action is controlled by a fraction of the plate voltage from the control binary (pin 6, V112) impressed on the

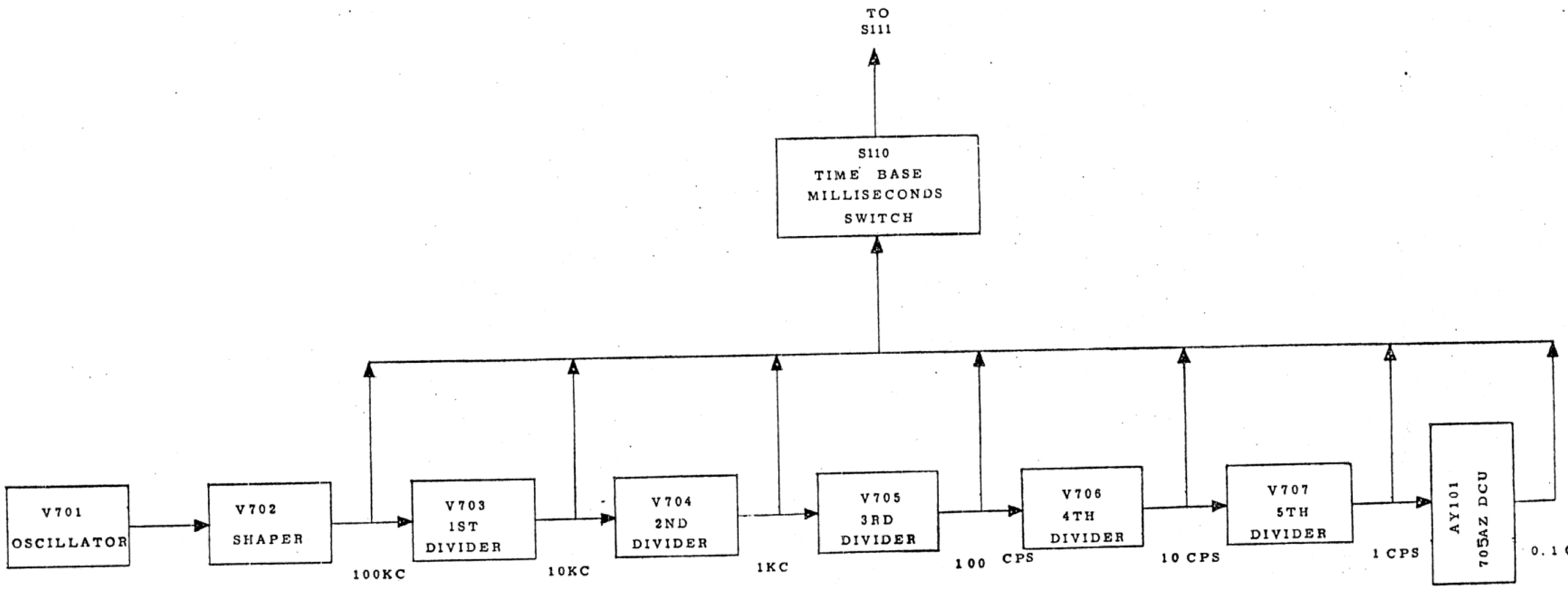


Figure 5 Functional Diagram, Model 505B Time Base

suppressor grid of V104. During EPUT operation, V104 is opened and closed by pulses from the time base via V112. Start and stop pulses via V112 control V104 during TIM operation. As an electronic counter, the gate is always open. Effects of varying screen current are reduced by connecting a low impedance screen supply to pin 6 of V104.

Decimal Counting Units

Five Model 705A DCU's form the counting system. The plate output from V104 drives the first DCU (AY101). V107 (2D21) resets the DCU's after the result has been displayed for the desired length of time. For complete details relative to DCU servicing and theory, see Appendix A.

Time Base

A stable crystal-controlled socillator (V701), a cathode-coupled shaper stage (V702), five frequency dividers (V703-707), and a DCU (AY701) form the time base circuitry. The shaper stage transforms the sinusoidal output of the oscillator into a rectangular wave, and each of the dividers scales the preceeding frequency by a factor of ten (see Figure 5).

Oscillator. V701, the time base oscillator, is a two-stage amplifier with a series resonant crystal network in the positive feedback loop. At the resonant frequency the signal is amplified and fed back through the crystal network in phase to reinforce the original signal. The conditions for oscillation are satisfied when the total phase shift around the loop is zero or 2, which is at the frequency of series resonance of the crystal. The amplifier is tuned to maximum gain and zero phase shift by C709, and the series resonant frequency of the positive feedback network is adjusted by C731. The bias developed across R703 controls the amplitude of oscillation. Bias for each stage is developed across the bypassed cathode resistors.

Shaper. The sine wave output from the oscillator is transformed into a rectangular wave by V702 (5963). This unit is a one-shot multivibrator with an RC coupling of a very long time constant compared with the sinusoidal input period. Since the input forces the tube to recover long before C710 recharges throughR716, the circuit operates much like a Schmitt trigger. The rectangular output from this stage drives the first divider stage (V703).

Frequency Dividers. Each of the five divider stages (V703-V707) is a one-shot multivibrator circuit. The first stage (V703) uses a 12BH7, the other stages, 5963's.

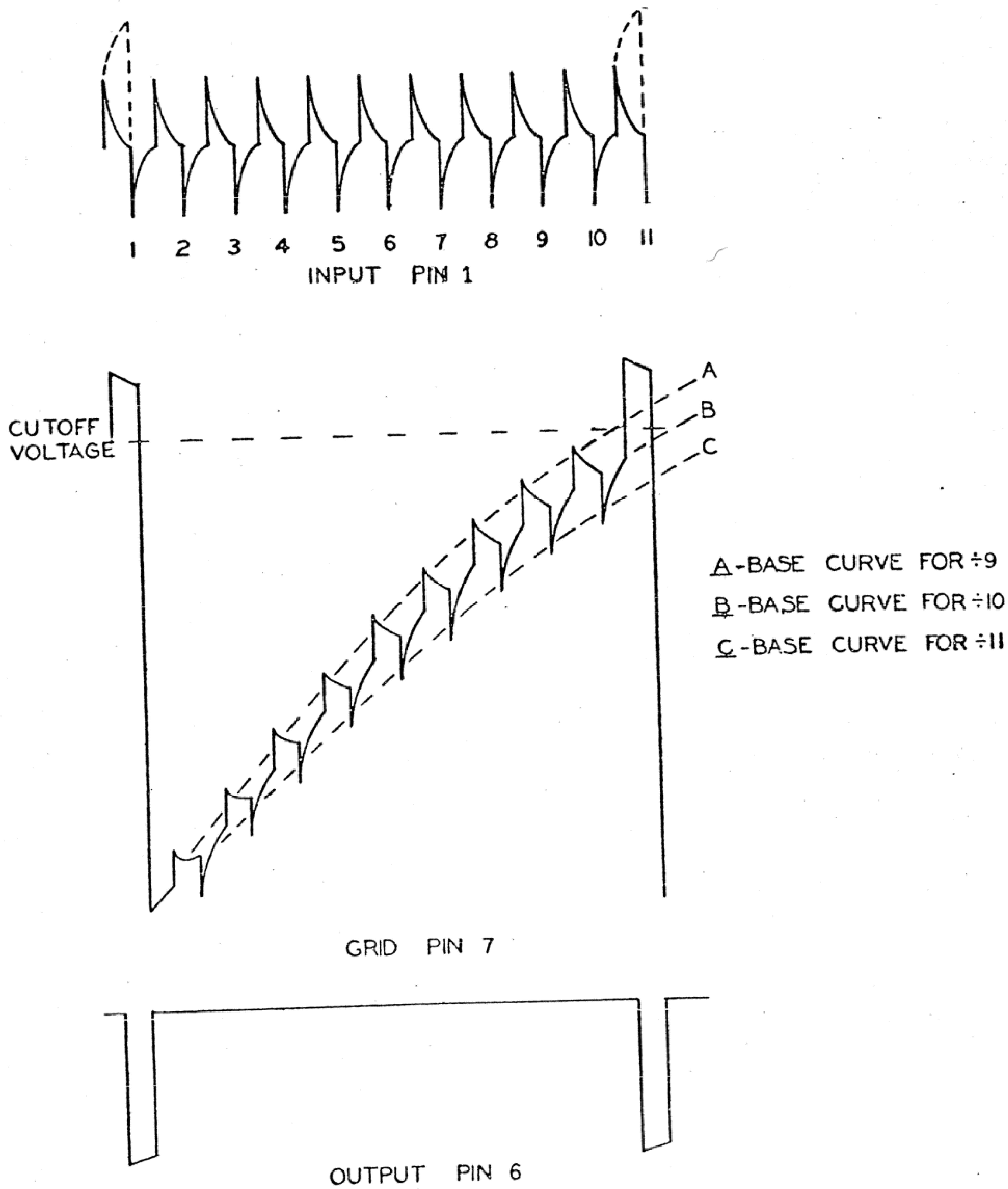


Figure 6 Divider Stage Waveforms

With no input from V702, V703 is in a stable state, the left-hand triode cut off and the right hand side conducting because its grid is tied to B+. When the rectangular output of the shaper is applied to the first divider, the positive rise of the pulse produces no change in the state of V703, but the negative rise, which is coupled to the right-hand through C714, cuts off the right-hand triode and causes a sharp rise in its plate voltage which is coupled to the left grid through the cross-over network, R714, R761, C712, and the grid-to-ground capacitance. Because of the rise in potential of the left-hand grid, the left triode conducts. V703 is now in a quasi-stable state with the left side conducting and the right side cut off. The duration of this state depends on the time necessary for C714 to discharge through the series resistances, R721 and R722.

The setting of R721 determines the slope of the recovery curve. Adjust R721 so that the positive peak of the tenth pulse rises above cut-off causing the right hand grid to conduct. By coupling the negative swing of the right plate back to the left grid, the system reverts to its normal state. The voltage waveforms at various points of the first divider are shown in Figure 6. The dotted shape at the input pin is the actual wave shape as observed on an oscilloscope, and is caused by the additive effect of the left-hand plate going positive, at the same time as the positive half of the tenth pulse.

The average recovery voltage (base curve) of the grid (pin 7) is almost linear, since only about one-third of the recovery time is used. Moving the arm of R721 towards B+ causes a division by eleven, while moving it in the opposite direction causes a division by nine. The theory of operation of the other dividers is identical except that the duration of the output changes from 5/100 of a cycle at the first divider to $\frac{95}{1000}$, $\frac{905}{10,000}$, $\frac{9095}{100,000}$, and $\frac{90905}{1,000,000}$, for the second, third, fourth, and fifth dividers, respectively.

A 705AZ DCU (AY701) is used to time ten input cycles for X10 operation and to give a ten second time base of EPUT operation. In the former case, the output from the DC channel is applied to the DCU, and in the latter case, one second pulses are applied to the DCU and the output pulses drive the triode drivers.

The decade frequencies from the various dividers or the 700AZ DCU are selected by the TIME BASE switch (S110) and applied through the function switch (S111) to the triode drivers (V113) or the second stage of the feed-back amplifier (V102), according to the application. The TIME BASE switch also lights the appropriate decimal point so that during EPUT operation, the reading is in kilocycles, except that for the 0.1 marking of TIME BASE readings are in tens of kilocycles. During TIM operation, the reading is indicated in seconds. For X10 operation readings must be divided by ten.

Controlling Circuitry

As illustrated by Figure 3, gating can be determined by either the time base or input information the time base for EPUT operation, the input for TIM operation (the gate is always open during COUNTER operation). To gain flexibility of operation, control signals are applied to the signal gate through switching, driving, and controlling elements.

Triode Drivers. By means of the function switch (S111) negative pulses generated by the time base or an input signal of unknown frequency are applied to the cathodes of the triode drivers (V113) through C120 and C121. C120 and C121 are connected in common on the switch side for EPUT operation and separately for either TIM or X10 operation. Each section of V113, a 5963 twin triode, is connected to the plates of V112. For separate or common inputs, only the triode connected to the "high" plate of V112 conducts.

Following the first two driving pulses at the triodes, the reading is displayed until a reset pulse occurs. V114 is a latching binary which prevents a third pulse from driving the start triode before the displayed reading clears. It holds the grid of the start triode below ground until the unit resets. The voltage at the grid of the start triode (Pin 2 of V113) lies midway between the voltage at the left-hand plate of V114 and that at the right-hand plate of V112. This grid is above ground only when both these plates are high. This happens only in the reset state permitting the start triode to conduct. After the first (start) pulse the start triode is cut off because the right-hand plate of V112 is low. (The left plate of V114 is still high and the start triode grid is at -25 volts.) After the second (stop) pulse the left plate of V114 is low although the right plate of V112 is high again. The start triode is still cut off with its grid at -25 volts until the unit is reset.

Control Binary. V112 (5963), a high speed binary, controls the gating action of the signal gate. The first (start) pulse triggers the binary from the reset condition (left half conducting) to the opposite state (right half conducting). A portion of the voltage rise on the left plate is applied to the grid of the signal gate through R142 and R141. When the left plate is high the gate opens, and vice versa. The second (stop) pulse also triggers the binary, returning it to the normal state and closing the gate.

I107, a neon glow lamp, is connected between the left hand plate through R137 and the junction of the divider network R135 and R136 to indicate the counting period. The firing potential of this lamp is reached when the left hand plate of V112 is high, signifying an open gate or counting period.

The cathodes of V112 are connected to R145 according to the function of the instrument. For EPUT, TIM, and X10 settings of S111, the cathodes are connected to R145. In the COUNTER position, R145 is connected to one of the cathodes as determined by the position of S105. With the COUNT switch on, the right-hand cathode is connected to R145, the left cathode floats, and the left plate and suppressor grid at zero volts and the gate is open. When the COUNT switch is off, the left hand cathode is connected and the gate closed. S105 is effective only when the function switch is in the COUNTER position.

Latching Binary. The circuitry of the latching binary (V114) is similar to that of the control binary. This circuit initiates display and reset action and latches the start triode following a measurement. The second (stop) and reset pulses trigger the circuit. From a reset state (left half cut off, right half conducting) the second (stop) pulse triggers V114. To latch the start triode, the drop in plate voltage of the left side is applied to the right grid of V113 and to the grid of a triode (1/2- V105) to initiate the display and reset operation. The positive reset pulse from V106 is then applied to the right hand grid of V114, restoring the binary to its original state.

Display Time and Reset Generator. A 5963 triode, 1/2 of V105, initiates the display and reset action. The grid (pin 2) is connected to the left plate of the latching binary (V114) through a series-limiting resistor (R120). When the latching binary is triggered by the second (stop) pulse, the left binary plate drops in voltage, causing the tube to cut-off and a rise in the triode plate voltage which is applied to the plate of V106 and C111 at a rate determined by R122 and C111. V106 (2D21) fires when the capacitor charges to +75 volts. The capacitor discharges through the tube, causing the positive output across the cathode resistor (R124) to reset the DCU's and binaries. Because the left plate of V114 and the triode grid of V105 are raised above ground when the latching binary is reset, the display time tube conducts and V106 is cut off as its plate voltage approaches ground potential. The display time, the interval between the second (stop) pulse and the firing of the reset tube, is chosen by varying R122. This resistance with the capacitance of C111 determines the time required for the voltage at the anode of V106 to rise to the firing voltage. For a particular value of R122, the plate voltage required to fire V106 varies with the grid bias. For a large bias, a high plate voltage is required, which results in a long display time. Normally the grid is set at -1.2 volts for a display time of approximately 5 seconds.

Start-Stop Channels. The start and stop channels used for time interval measurements are identical in design. Each channel consists of a phase inverter and an amplifier to provide polarity selection as well as amplification of the input pulses. A discussion of one channel applies to the corresponding points of the other.

A positive pulse on the input grid of V107, a 12AT7 phase inverter, forms a larger megative and positive pulse on the left and right hand plates respectively. S103, a single pole, double throw toggle, selects the appropriate plate so that V115 is always driven by a positive pulse.

The left half of V115 (5963) is normally biased beyond cut-off. The positive pulse which forces the tube co conduct produces a negative pulse at the plate. This pulse is applied to the start triode driver through the function switch (S111) for TIM and X10 operation. Correspondingly, a negative pulse from the stop channel is applied to the stop triode driver through S111. R201 and R205 limit the output swing of the triodes of V115 which prevents the triodes and binaries from being overdriven.

For a single source input, the input jacks are shorted by S108, the COM-SEP switch. When the DC channel is used, S102, the PULSE-DC switch, connects the output terminals of V111 to the shorted channel-jacks. An output occurs at V111 with the function switch in TIM. In the X10 position the output of AY701 is connected to the cathodes of the triode drive tubes.

DC Channel

The sensitive Direct-Coupled Channel consists of V109 (12AX7), V110 (12BH7), and V111 (12AT7). A high gain, negative feedback, comparison amplifier is formed around V109 and V110.

A small positive voltage on the input grid of V109 appears as an amplified drop and rise at the left and right plates, respectively. A fraction of the drop on the left hand plate of V109 causes the right hand grid of V110 to fall. A fraction of the rise on the right hand plate of V109 causes the left hand grid of V110 to rise (fractions are determined by R183, R184 and R187, R188). The net effect on the right half of V110 is a large decrease in grid-to-cathode voltage and a larger rise in the plate level (about 100 times). Conversely, a small negative drop in the input jack (J104) results in a large drop of the output plate level.

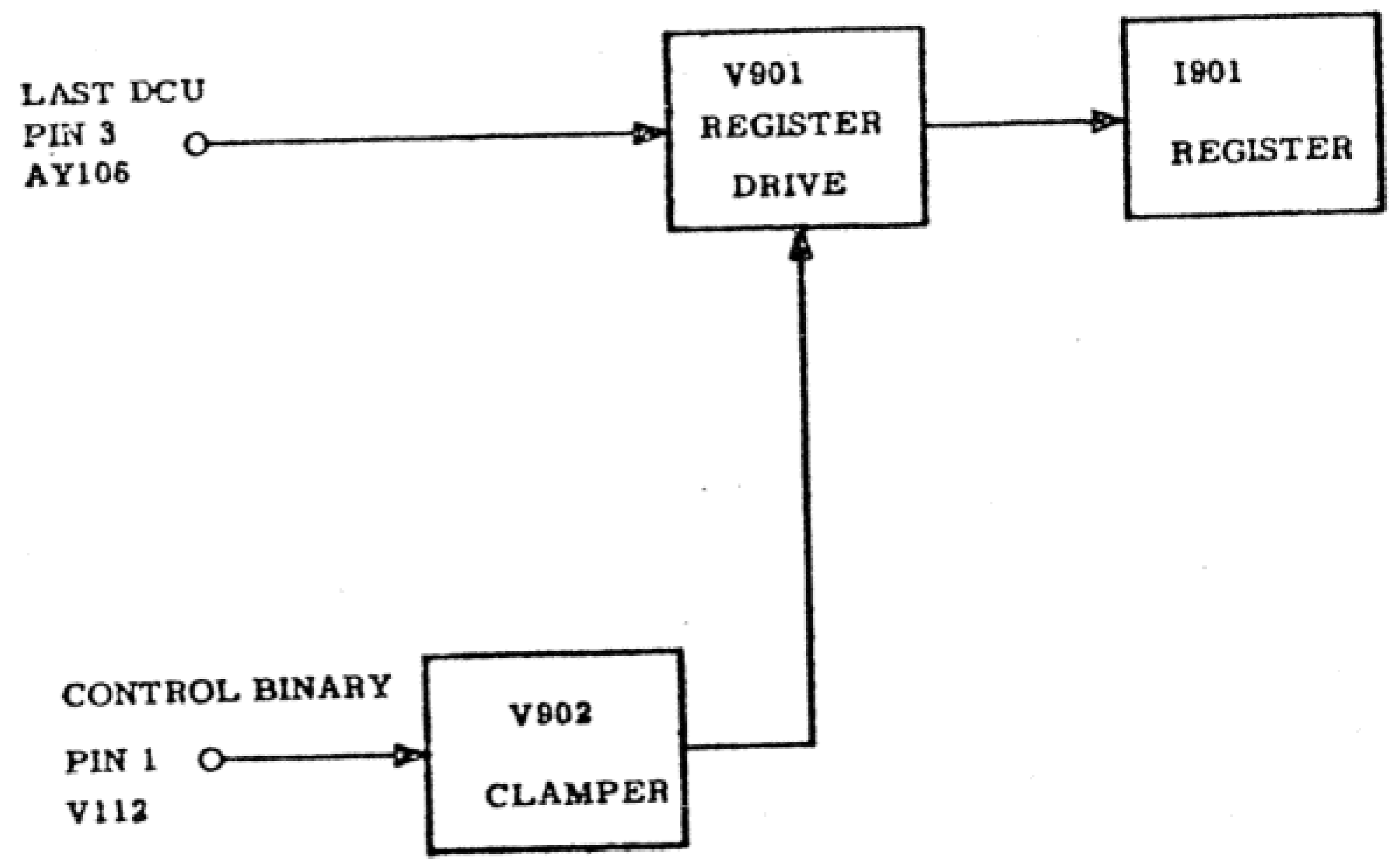
R186 adjusts the trigger level by varying the grid and right plate levels of V110. The input grid of the Schmitt trigger (V111) is directly connected to pin 1 of V110. V111 can be driven by setting R186 so that the amplified d-c change causes its input grid to rise above and drop below the triggering and detriggering levels. This circuit has a hysteresis of 7 volts with triggering and detriggering levels of -1 and -8 volts, respectively. (See Feedback Amplifier article for description of Schmitt trigger operation.)

The 120 volt output swing of the Schmitt Trigger is divided and applied to the start-stop channels or applied directly to the 700AZ DCU (AY701) through S111.

Power Supply

The power supply is designed to furnish 290 volts B+ ma at 200 ma, +180 volts regulated at 45 ma for the Model 505 Time Base, and -150 volts at 75 ma for biasing purposes. A special +100 volt supply is provided at the accessory socket for photocell applications. A special low impedance screen supply is provided for the gate tube (V104) by means of a cathode-follower circuit (1/2 - V102).

modification C



modification E

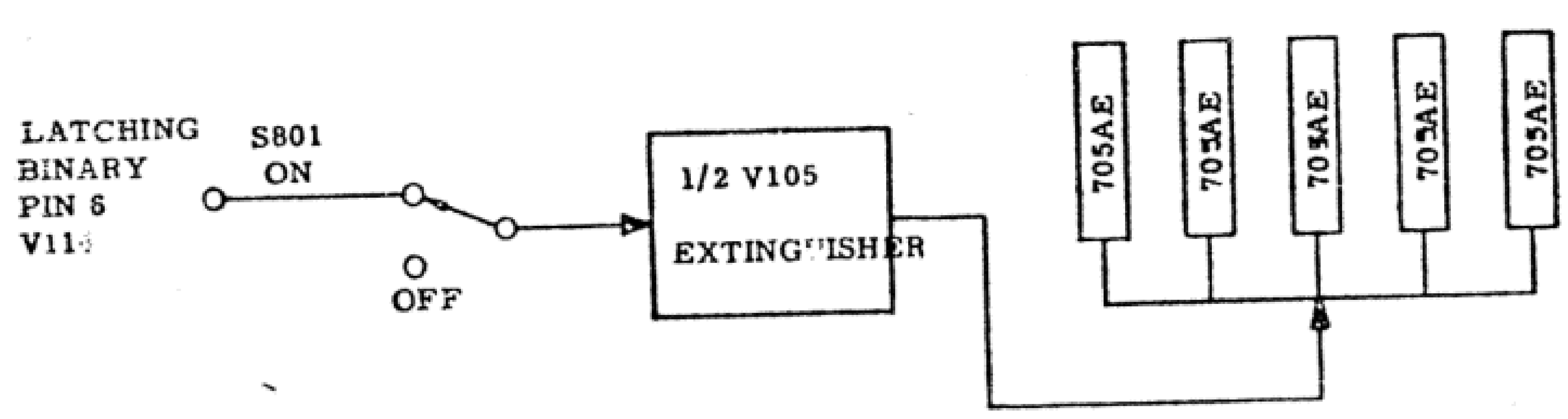


Figure 5 Functional Diagram, Modifications C & E, Model 5500

Section 4
MODIFICATIONS

Modification C

Modification C adds a six digit mechanical register which extends the capacity of the Model 5500. The total capacity is raised to one hundred billion counts (see Figure 7).

The register and register drive are shown in Figure 10c. Normally, the left half of V901, a 5963, used as a register drive tube is conducting and the right half is cut off. The negative output from the last DCU (pin 3, AY106) is applied to the left hand grid of V901. The left half is cut off causing a rise in plate voltage which is direct-coupled to the right hand grid by R904 and R906, and forcing the right half to conduct.

With current flowing through the relay armature in the cathode, the relay contacts close tripping the register (I901). When the DCU output turns positive at the count of 6, the relay contacts open, releasing the register armature. A suppressor network formed by R907 and C903 lessens the effect of transients caused by the closing of the contacts.

When the last DCU is reset to zero, its output level drops when a count above 6 occurs prior to resetting. This drop triggers the register causing an extra count unless the drive circuit is disabled. V902 (6C4) clamps the right hand grid of V901 to prevent triggering of the register. Clamp action is controlled by the control binary (V112) through R908 and R909.

Occasionally it may be necessary to replace V901 or V902. But before replacing either tube, check the 6C4 grid voltage. The grid voltage should be below-20 volts only during the counting period; at other times it should be zero to clamp V901. If the clamping voltage varies, V112 should be replaced.

Modification E

Where Modification E has been added to the Model 5500, Model 705A Decimal Counting Units have been replaced by Model 705 AE DCU's. In the Model 705AE, counting lights are extinguished during the counting period, a feature which lessens operator distraction and fatigue.

The counting lights are extinguished when pin 8 of the DCU is grounded through a suitable resistor (see Figure 10e). One half of V105 (5963) is used as an electronic switch to perform this function. During a counting cycle, the left half of V105 conducts, and the DCU lights are extinguished. The appropriate neon lights glow at the end of the counting cycle when the V105 is cut off. The plate voltage on V114, the latching binary, applied to the grid of V105 through R120, controls this circuit.

Articles in Section 5 on display and reset circuitry are also pertinent.

Where instruments carry Modification E, the Model 705AE is discussed in Appendix A.

Section 5
MAINTENANCE

Routine Adjustments

Oscillator. Whenever a crystal or oscillator tube is replaced, the following adjustments should be made:

1. Adjust PLATE TUNE (C709) for maximum bias on pin 2 of V701.
2. Connect a 100 kc secondary standard to the horizontal axis of an oscilloscope and the test point E2 to the vertical axis. (This isolates the oscillator from the oscilloscope). Adjust FREQ. VER. (C731) until the Lissajous figure is a stable, single loop.
3. Readjust C709 for small changes in frequency.

Frequency Dividers. There are two methods for adjusting the frequency dividers.

Test Method. (No auxiliary equipment required; accuracy depends on proper operation of control and gate circuitry). Operate instrument automatically in the TEST position (see Section 2). Turn the TIME BASE switch to the .1 millisecond marking for EPUT. Adjust R721 until a reading of ten is obtained. Repeat for TIME BASE settings of 1, 10, 100 and 1 k and adjust succeeding dividers so that readings of 100, 1000, 10, 000, and 100, 000 are obtained. The 10 k TIME BASE setting which uses a 700AZ DCU (AY101) for a divider has no adjustment and should read 1, 000, 000.

To make sure that the dividers are near the center of their operating range, lower the line voltage to 105 volts and test the dividers by rotating the TIME BASE switch again. Repeat for 130 volts. Readjust dividers if necessary.

Oscilloscope Method. (Requires an oscilloscope with a 10 megohm input impedance and 500 kc band width). Place the input probe on test point E3 with the oscilloscope sweep set at 100 microseconds. The screwdriver adjustment, 1ST. DIV. (R721) should be varied until the pattern shown in Figure 10c or its inversion appears on the oscilloscope. Note that there are ten visible positive excursions from point (a) to point(b). R721 should be set near the middle of the division-by-ten range.

Connect the oscilloscope to test point E4 and set the sweep for 1,000 microseconds. Adjust the 2ND. DIV. (R730) so that the pattern shown in Figure 8d appears on the oscilloscope. Note that the proper pattern shows only nine negative excursions between points (a) and (b), the tenth being hidden by the large pulse as indicated by the arrows. This same pattern will be observed at E5, E6 and E7 when the corresponding dividers are dividing properly. Since the pattern at E7 is rather difficult to see on the oscilloscope owing to the slow recurrence rate, adjust the last divider by observing the DCU reading on the front panel. As in the TEST method, check settings at both 105 and 130 volts. All dividers should be trimmed until the time base operates at any voltage between 105 and 130 volts without adjustment.

Display Time. So that any settings of the DISPLAY TIME will fall in the 0.5 to second range, set the bias on pin 1 of V106 at 1.2 volts by varying R167. Check if maximum display time is about 5 seconds. Readjust if necessary.

Servicing

Schematics, waveforms, and a maintenance chart are included in this manual as servicing aids. Proper trouble shooting requires a vacuum tube voltmeter and a quality oscilloscope.

In the event of failure, supply voltages should be checked first, if the ripple on the +180 v. bus bar exceeds a tenth of a volt peak-to-peak, the 6AU6 control tube (V303) and/or the OB2 tube (V304) should be replaced. If there is no voltage on the +290 or +180 v. busses, the 5U4G rectifier tube (V301), and/or the 6Y6 series tube should be changed. If oscillations occur on the +180 v. bus, replace the 6Y6 tube (V302) and the OB2 tube (V304). Absence of a bias supply may be caused by failure of CR101, the selenium rectifier. If a short has occurred, R301 will be burned and should be replaced. If power supply characteristics are correct, utilize the Maintenance Chart (Table 2) to locate and eliminate the source of trouble.

Read the chart from the top down, the operation of one function depends on those above it. Normally, the technician would start from the top of the chart, check the appropriate function, and work down. However, the COUNTER function involves only a few elements which may be quickly checked in the TEST position.

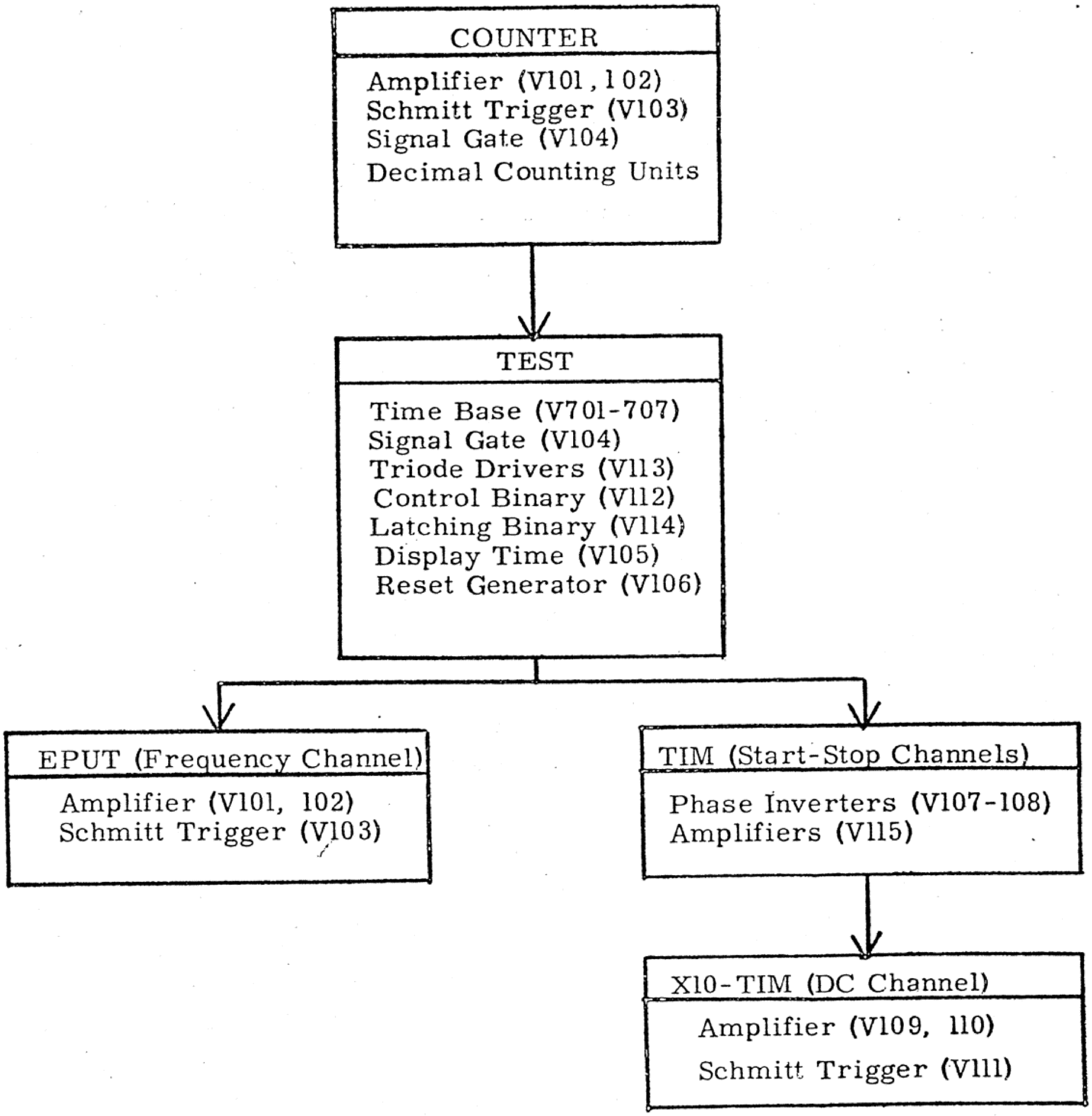


Table 2

MAINTENANCE CHART

If the unit performs properly, the elements listed under TEST and COUNTER are functioning correctly and the trouble lies elsewhere. Following the order of the chart, test the frequency, start-stop, and d-c channels. The position of the X10-TIM-EPUT-COUNTER switch at the time of failure determines the faulty channel.

If the TEST operation fails, check COUNTER operation. If the instrument operates as a counter, then the cause lies in the elements, listed in the TEST "box" of the chart. If the COUNTER test fails, the frequency channel, signal gate, and DCU's should be examined.

The following articles discuss servicing techniques. A comparison of the voltages with those given on the schematic diagrams may aid the diagnosis. Tubes are the most frequent cause of failure.

Counter Function. With the instrument operating as an electronic counter the input to the frequency jack is amplified, shaped, and applied to the first DCU through the signal gate. The voltage at the suppressor grid of the gate tube (pin 7, V104), controlled by the left plate of the control binary (pin 6, V112) should always be zero. Compare the input waveforms to the DCU with Figure 8h. If correct DCU drive exists, see Appendix A for DCU servicing. Where no drive voltage is present, trace the circuit back to the input jack. The peak-to-peak swing at pin 2 of V103 should be at least 4 volts to trigger or de-trigger the circuit. Note that the screen voltage for V104 is supplied by a cathode follower (1/2 - V102).

Test Function. When the Model 5500 fails in the TEST position, the nature of the failure should give some indication of the cause. If readings are incorrect, the time base may be at fault. No reading indicates failure in the gating, reset, or control circuitry.

Time Base Failure. Incorrect division by one or more of the dividers requires alignment of each divider (use the Test method first). If the divider ratio adjustment causes skipping (i. e. jumping from a division by 9 to 12), the potentiometer may be at fault.

Failure in a previous stage causes complete failure of the divider (replace pertinent tube) while incorrect readings frequently result from a potentiometer set midway between two divider ratios. Incorrect readings may also be caused by failure in the succeeding stage even though waveforms from this stage may be proper. Replace tubes in both the jittery stage and the one following. If the trouble persists, check the voltages and compare them with those shown on the schematic diagram (Figure 11).

If the stage is operating as a free-running multivibrator, check the ripple on the +180 volt regulated supply. V701 may be at fault if none of the dividers is functioning. Replace V701 if there is no output voltage and check components for a short, especially V709.

Sometimes time base failures are caused in the frequency channel.

Gating and Controlling Elements. The signal gate (V104) should open and close with the first and second pulses, respectively. Measure the voltage on pin 7 of V104 and set the TIME BASE switch at 1 second (1 k) or 10 second (10 k) to check this function. Starting from a reset condition with a voltage of -12 volts at pin 7, the first pulse raises the voltage to zero and the second returns it to -12 volts. The input to the gate is a 100 kc signal from V103. Compare the output at pin J with Figure 8h.

The gating operation is controlled by the left plate of the control binary (pin 6, V112). In the reset state, the left plate is at -60 volts. The first pulse "flips" the binary, resulting in a left plate voltage of +5 volts. The second pulse restores the binary to the reset state. If the binary fails, replace the tube. If the binary free-runs (oscillates), a component has failed. Determine the voltages throughout the circuit, especially the grid-to-cathode voltages, for low voltages may cause free-running. Lack of drive on the binary plates may indicate absence of pulses from the triode driver stage.

The accumulation of readings rather than the usual display and reset action indicates trouble in the latching binary (V114). The voltage at pin 2 of V113 changes from +5 to -25 volts on the second pulse latching the start gate and back to +5 on the reset pulse. This voltage may also be checked at the left hand plate of V114 where the readings should be +5 and -60 volts respectively.

Display and Reset Circuitry. The left plate of V114 also initiates reset action, controlling the grid of the display time tube (pin 2, V105). Where a reading is diaplayed indefinitely on automatic operation, check the grid voltage (pin 2, V105). If the second pulse causes the grid voltage to drop from 0 to -20 volts and the plate rises to +150 volts (pin 1, V105), the stage is operating normally, which indicates that the fault lies in the reset stage (V106). Check the bias on the grid of the 2D21 thyratron.

If the instrument is continuously reset, pins D and H of J302 may be shorted.

EPUT Circuit (Frequency Channel). In the TEST position the frequency channel (V101 - 103) may be checked with an internal signal. The circuit is literally checked only for a frequency of 100 kc. Even though the circuit operates normally in this position, failure caused by weak tubes may occur with an external signal. To localize faults in this stage, trace the signal from V103 back to the input jack (see Figure 8g). The voltage swing at pin 2 of V103 should be at least 4 volts peak-to-peak.

TIM Circuitry (Start-Stop Channels). Where trouble occurs in this stage, only three tubes require consideration. If the unit starts but doesn't stop, replace the stop phase inverter (V108). If the unit won't start, replace the start phase inverter (V107) or the triode amplifier (V115).

To determine whether sufficient amplification occurs through the inverters, note the pulse height on either grid of the triodes (pins 2 and 7 of V115). It must overcome a bias of -12 volts. R201 and R205 limit the peak-to-peak output swing to 30 volts to prevent the over-driving of V113.

Failure of a channel to discriminate polarity may be caused by excessive input amplitudes or input waveforms with disproportionately large overshoots and undershoots.

DC Channel Circuitry. Set the instrument up for d-c operation with no input and the function switch at TIM. Normally, two complete back-and-forth movements of the TRIGGER LEVEL control should initate a start and stop cycle. Failure in this stage may be caused by V109, V110, V111. Working backwards from V111, the tubes and their voltages should be checked to determine the source of trouble.

This channel will not properly accept signals which never cross ground level. Any input is amplified by a factor of a hundred before reaching the input grid of the Schmitt trigger. Therefore a blocking capacitor must be placed in the circuit for satisfactory operation.

Manual Reset. To obtain a manual reset, charge C111 to +200 v. and discharge it across V106 which resets the DCU's and binaries when it fires. Used in conjunction with the Digital REcorder System, S107A over-rides the inhibit reset to permit resetting. The contacts of S107 are so bent that the release of the pushbutton causes S107B to reset the instrument before S107A breaks (disconnected from ground), dischargingC111 across V106 before the inhibit reset action is operative.

List of Non-Standard Components

Detail No.	Stock No.	Item	Mfr. & No.	Description
		Meter Section		
I101 to I106	21-2959	Decimal light	GE 1768	Midget Lamp
I107	21-1679	Counting light	GE NE-51	Glow lamp
J101 to J104	17-0849	Connector	IPC 2700	Type BNC
S101	12-1909	Switch	Cutler-Hammer 8373K7	DPDT Toggle
S102 to S105	12-1641	Switch	Cutler-Hammer 8284K14	SPDT Toggle
S106	1-0457	Switch	Centralab N178-1 Model M	SPST connected to R122, 10 m pot.
S107	12-0879	Switch	Switchcraft 1006L	DPDT pushbutton
S108	12-1643	Switch	Cutler-Hammer 8280K15	SPST Toggle
S110	12-2810	Switch	Oak Type F	3 deck, 7 pos., rotary
S111	12-2811	Switch	Oak Type F	4 deck, 4 pos., rotary
		Power Supply		
T301	6-2807	Trans former	Electro-Eng. 7984	900 vct at 260 ma 117 vct at 60 ma 5 v. at 2.5 a 6.3 v. at 20 a 6.3 v. at 3 a
B301	9-2743 25-1822A	Fan Motor Fan Blade	Scruggs T-103-849 Barber-Coleman YAB 328	 4" diameter

Detail No.	Stock No.	Item	Mfr. & No.	Description
L301	3-2615	Choke	Triad HS-319	10 hy at 300 ma 83 ohms
CR301	8-1699	Rectifier	Radio Receptor Corp.	5 M1
CR302				
J301	17-2286	Connector	GE 2711	Motor base type, two pronged
J302	17-1665	Connector	AN3102A-18-1S	10 pin AN type
J303	17-2713	Connector	AN3102A-18-12S	6 pin AN type
I301	21-1677	Pilot Lamp	GE 47	6. 3 v.

Model 505 Time Base

Detail No.	Stock No.	Item	Mfr. & No.	Description
Y701	13-2354	Crystal	James Knights JK5	100 kc, 6. 3 v. a-c, heater oven, ± 1°C.
L701	3-1509	Choke	Miller 650	5 mh
L702	3-2422	RF Choke	Miller 692	30 mh, 120 ohms
S802	12-1643	Switch	Cutler-Hammer 8280K15	SPST Toggle
I901	21-0452	Register	Veeder Root	100 v. a-c, 8w.
K901	16-1865	Relay	Leach type 321	Coil 912

Tube Complement

Tube	No. Required per Unit
	Meter Circuit
6AU6	1 (V101)
5963	7 (V102, V103, V105, V112, V113 V114, V115)
6AS6	1 (V104)
2D21	1 (V106
12AT7	3 (V107, V108, V111)
12AX7	1 (V109)
12BH7	1 (V110)
	Time Base
12BH7	1 (V703)
5963	6 (V701, V702, V704, V705, V706, V707)
	Power Supply
5U4G	1 (V301)
6Y6	1 (V302)
6AU6	1 (V303)
OB2	1 (V304)

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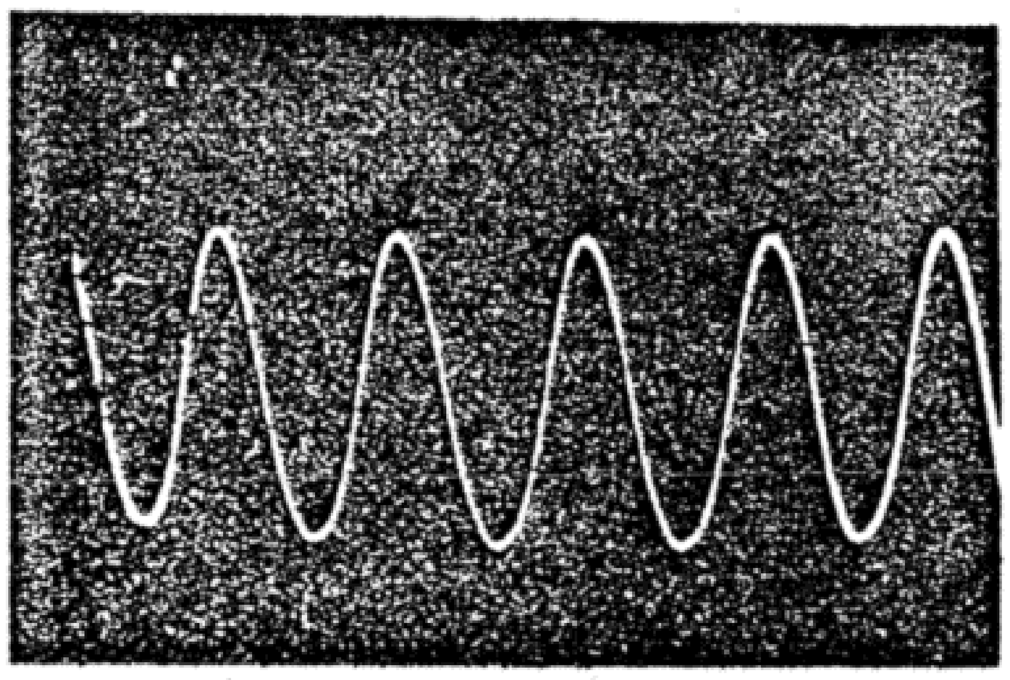
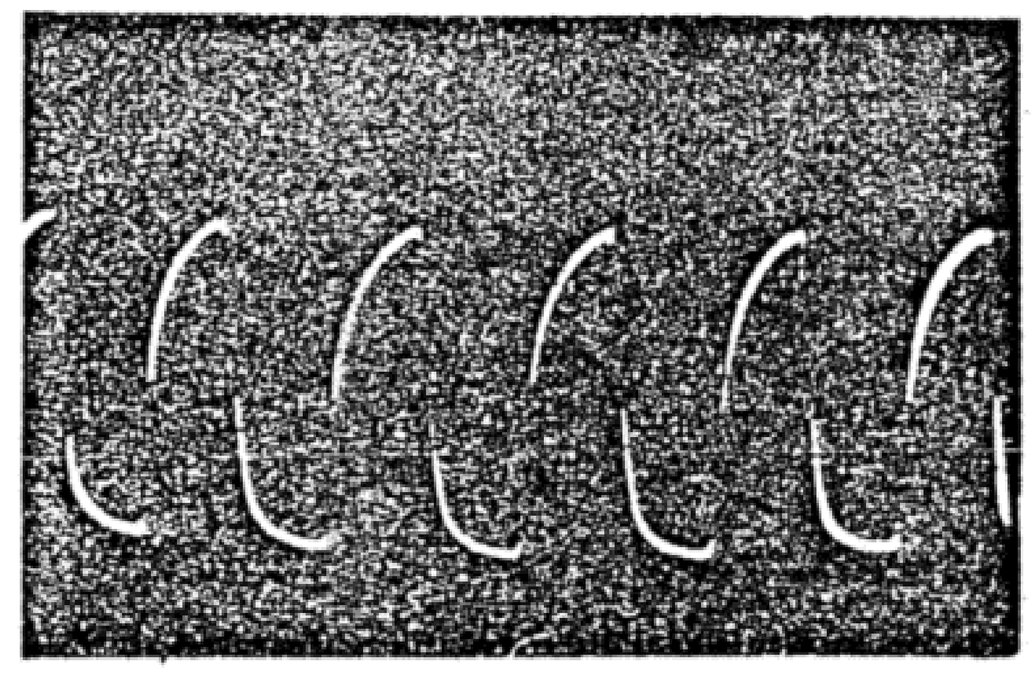
NOTES:

NOTE

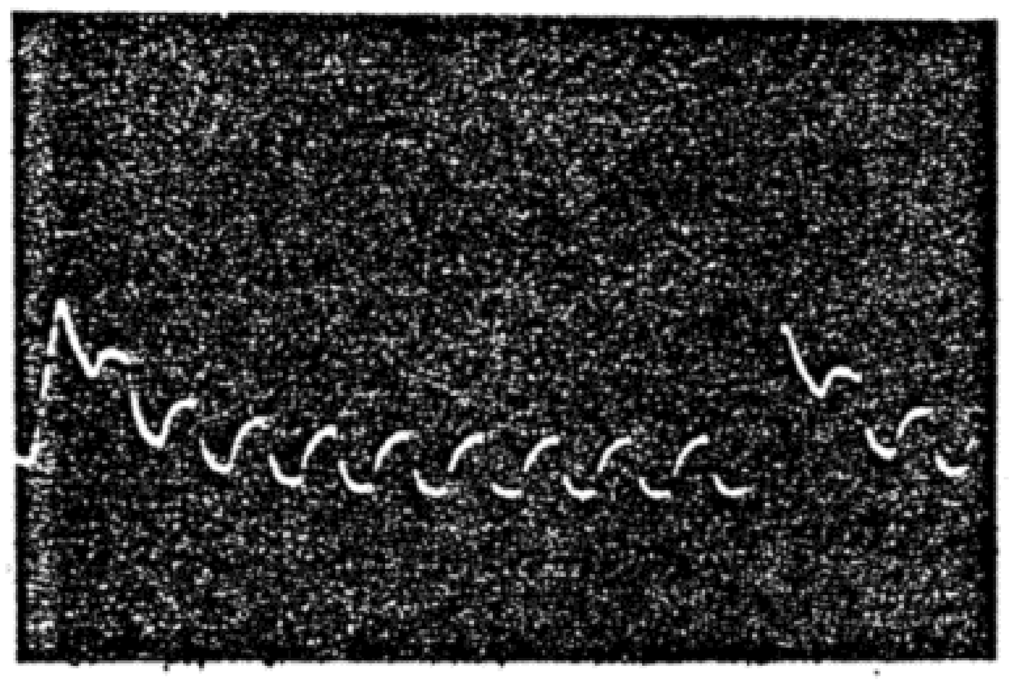
The following photographs wére taken from a Model 511D Tektronix oscilloscope with a 4 x 5 Speedgraphic camera.



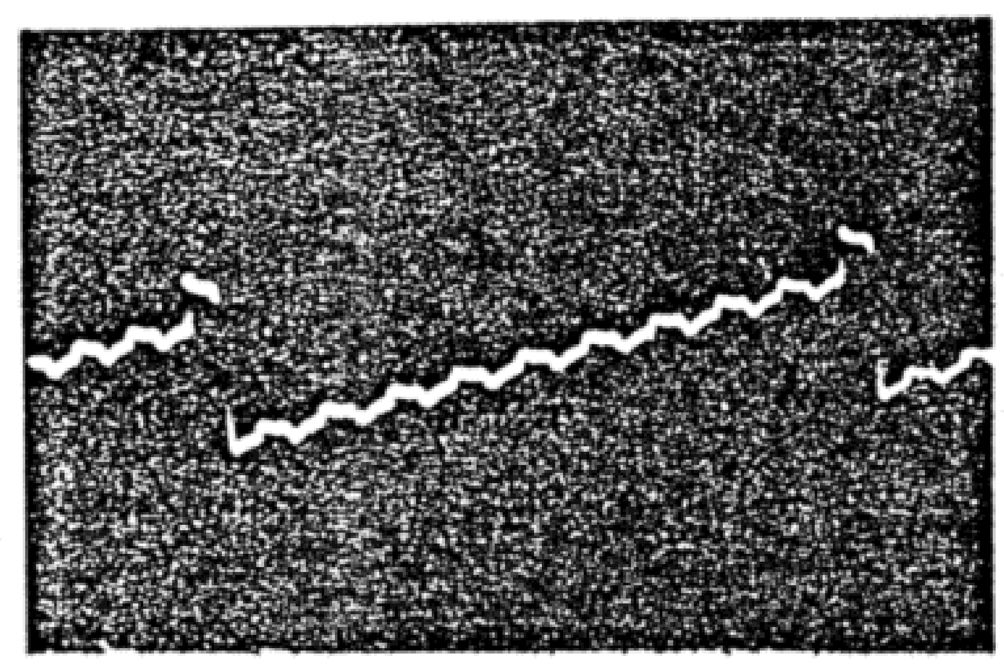
a. Oscillator output (pin 6, V701) 100 kc sine wave, 35 volts peak-to-peak.



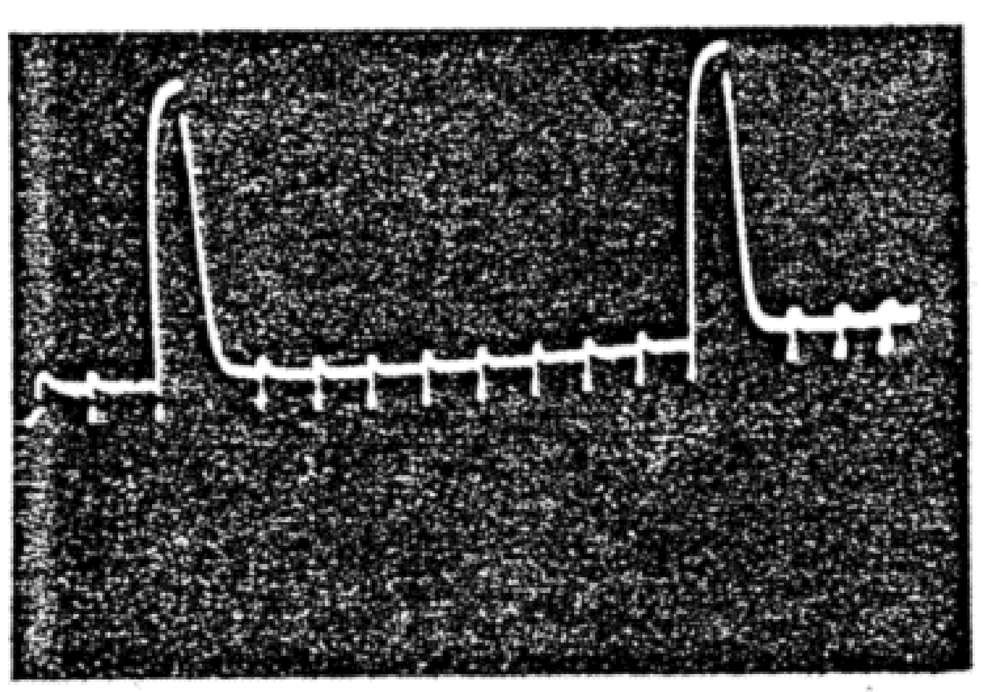
b. Shaper output (pin 6, V702) 100 kc square wave, 75 volts peak-to-peak.



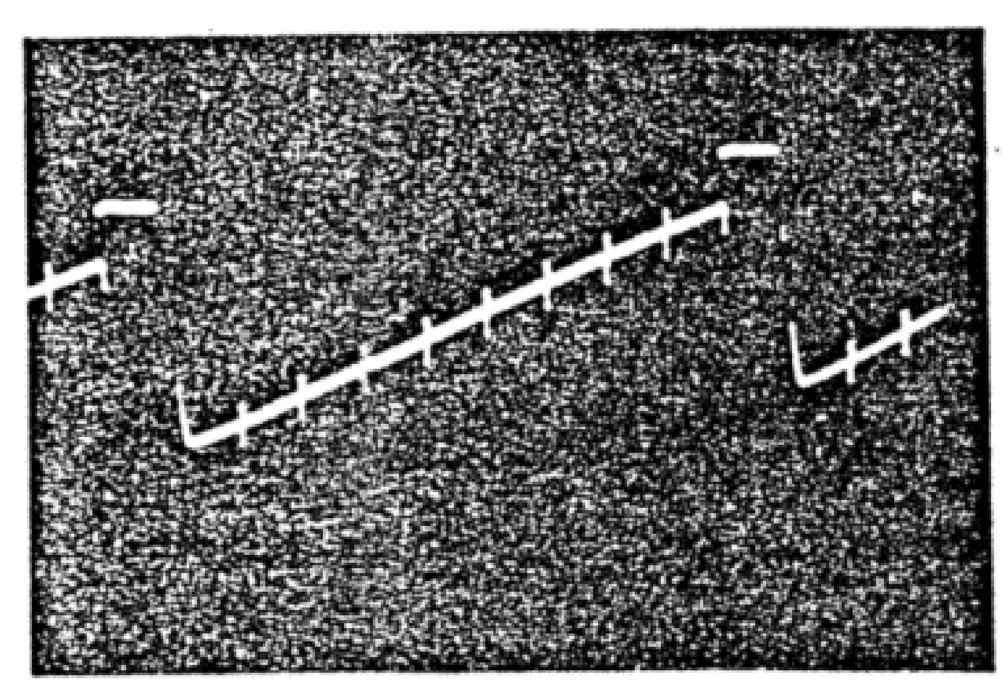
c. Test Point E3, 30 volts peak-to-peak, 100 μsecs. between maximum peaks.



d. Grid waveform (pin 7, V703) 50 volts peak-to-peak, 100 μsec. between highest and lowest levels.

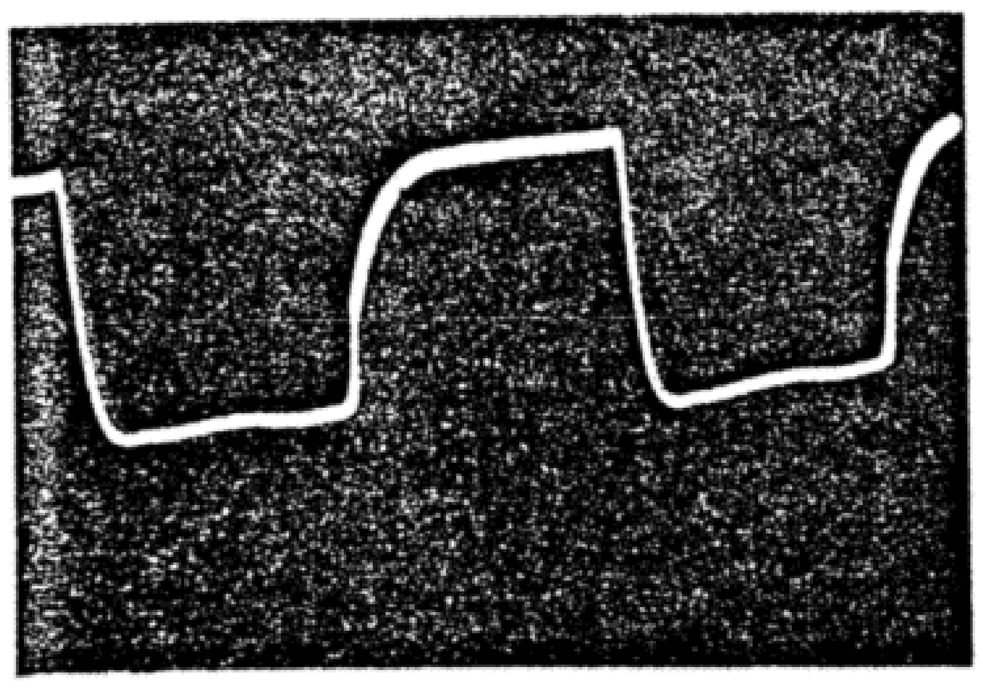


e. Test Point E4, 75 volts peak-to-peak, 1000 μsecs. between maximum peaks.

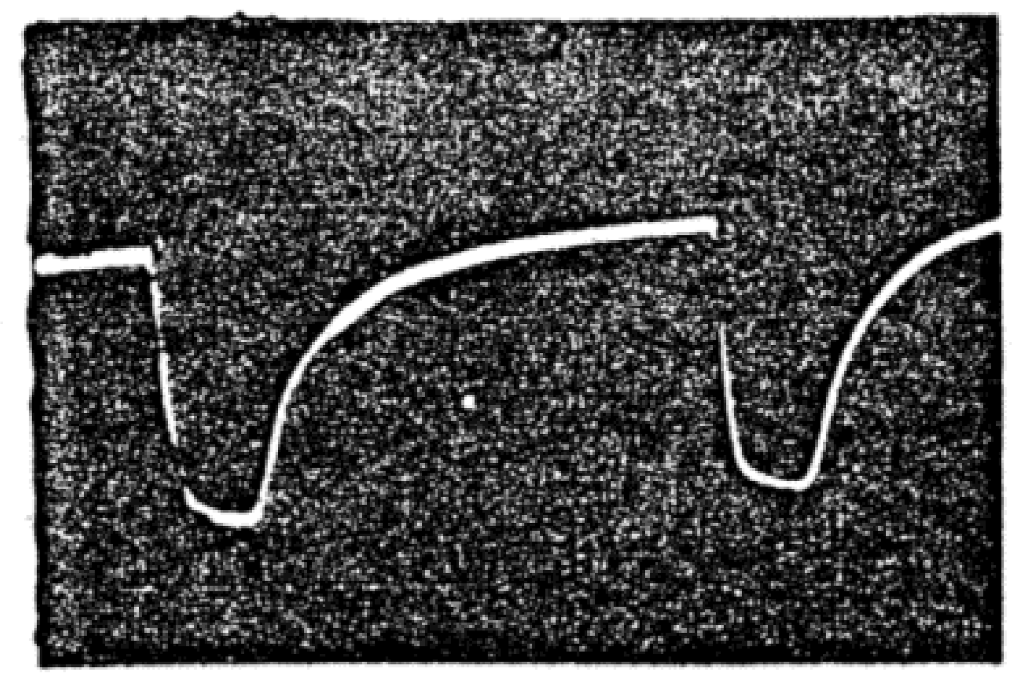


f. Grid waveform (pin 7, V704) 70 volts peak-to-peak, 1000 μsecs. between maximum peaks.

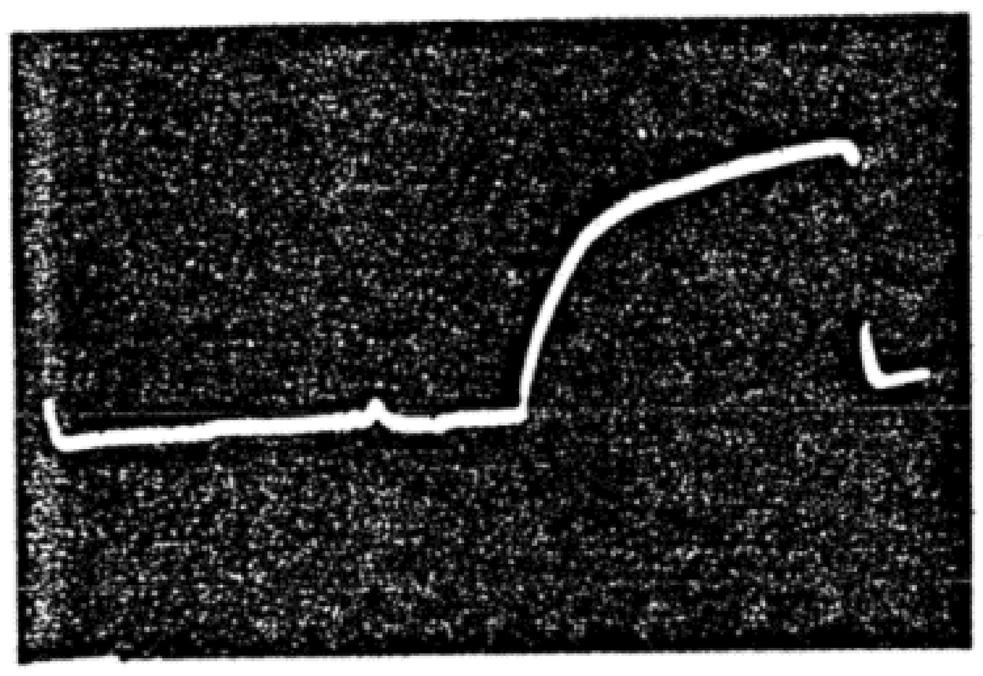
Figure 8 Typical Waveshapes



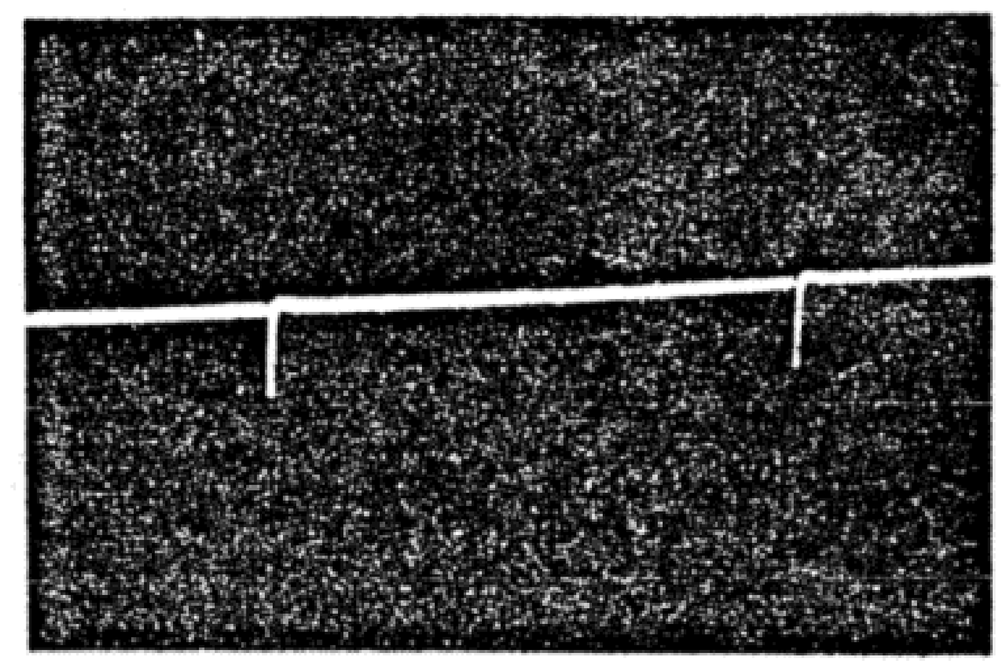
g. Schmitt trigger output (pin 6, V103) 50 kc square wave, 90 volts peak-to-peak.



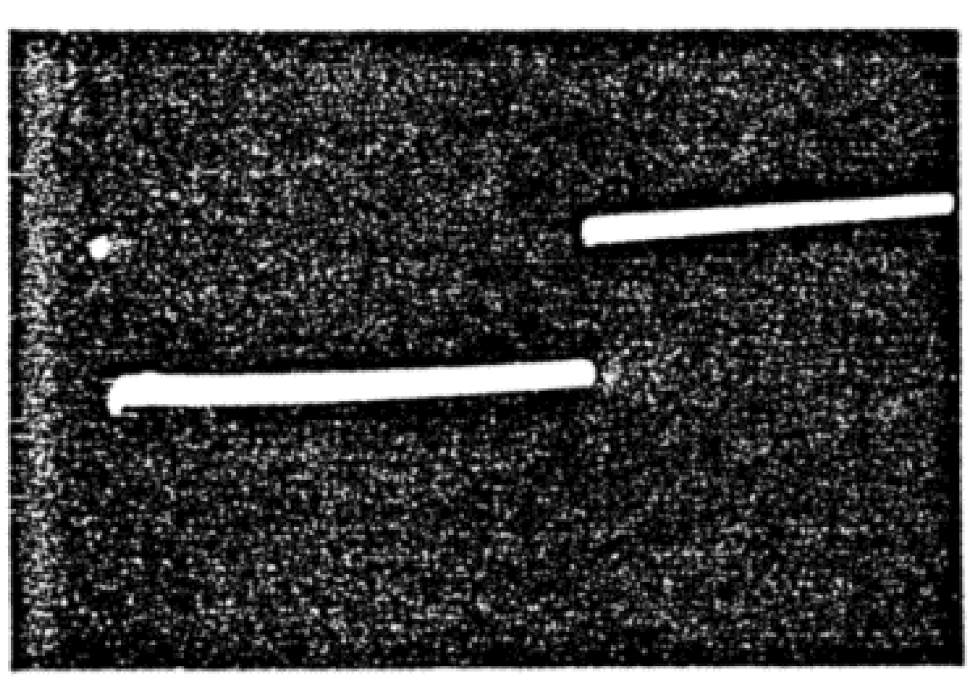
h. Signal gate output (pin 5, V104) 50 kc, 100 volts peak-to-peak.



i. 705A DCU output (pin 3, AY101-105). Output varies between 55 and 135 volts.



j. Input to triode driver (pin 3, V113) 40 volts peak, 2 kc input to d-c channel.



k. Drive to binary plate (pin 1, V113), 65 volts peak, 2 kc input to DC channel.

l. Reset pulse (pin 2, V106), 100 μsec. sweep, 80 volts peak.

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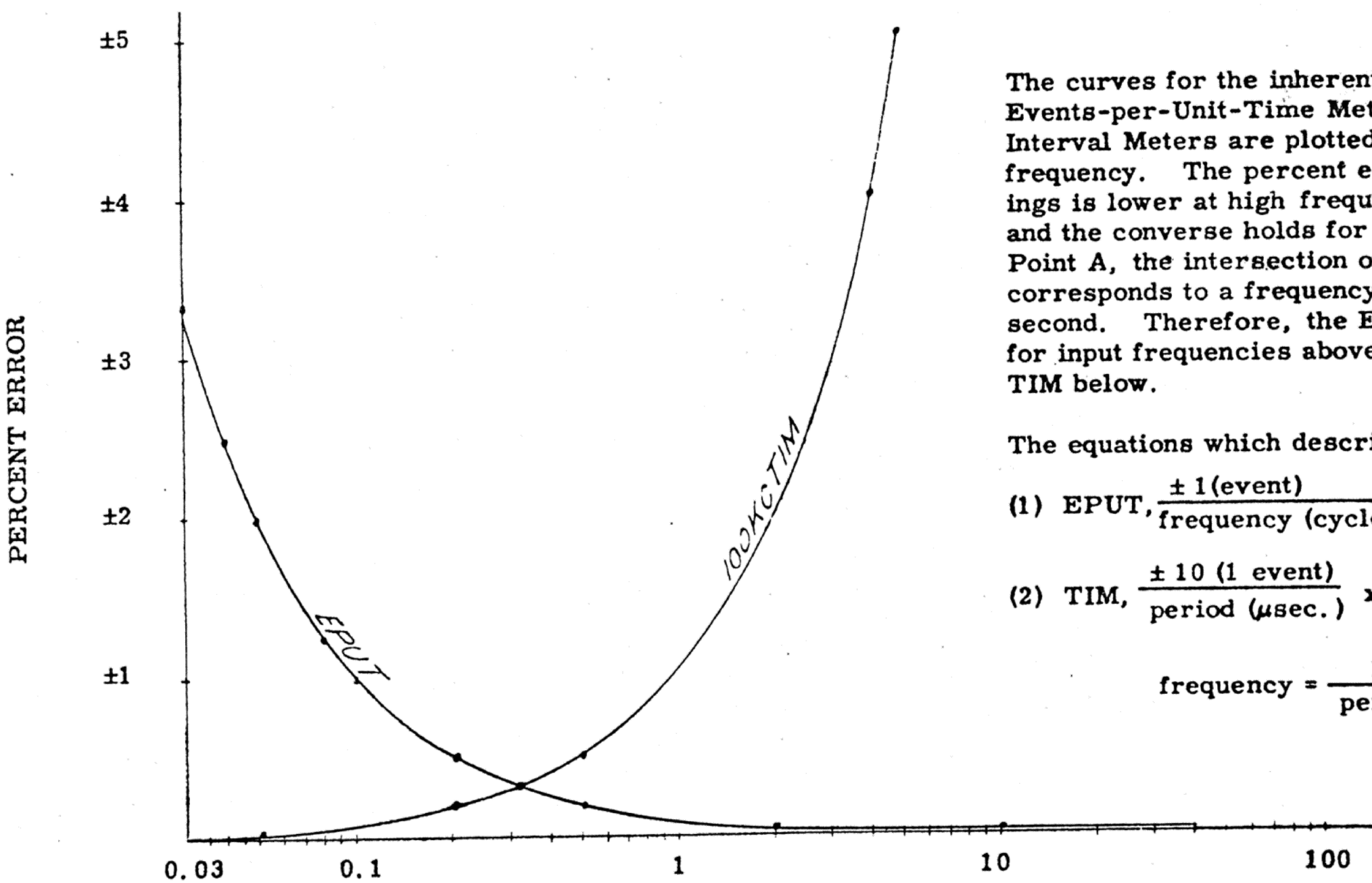

The curves for the inherent percent errors in Events-per-Unit-Time Meters and Time Interval Meters are plotted against the input frequency. The percent error in EPUT readings is lower at high frequencies and vice versa and the converse holds for TIM readings. Point A, the intersection of the two curves, corresponds to a frequency of 316 cycles per second. Therefore, the EPUT should be used for input frequencies above 316 cycles and the TIM below.

The equations which describe error are:

(1) EPUT, $\frac{\pm 1 \text{(event)}}{\text{frequency (cycles)}} \times 100 = \%$ error

(2) TIM, $\frac{\pm 10 \text{ (1 event)}}{\text{period } (\mu\text{sec.})} \times 100 = \%$ error

$$\text{frequency} = \frac{1}{\text{period}}$$

Figure 9

NOTES:

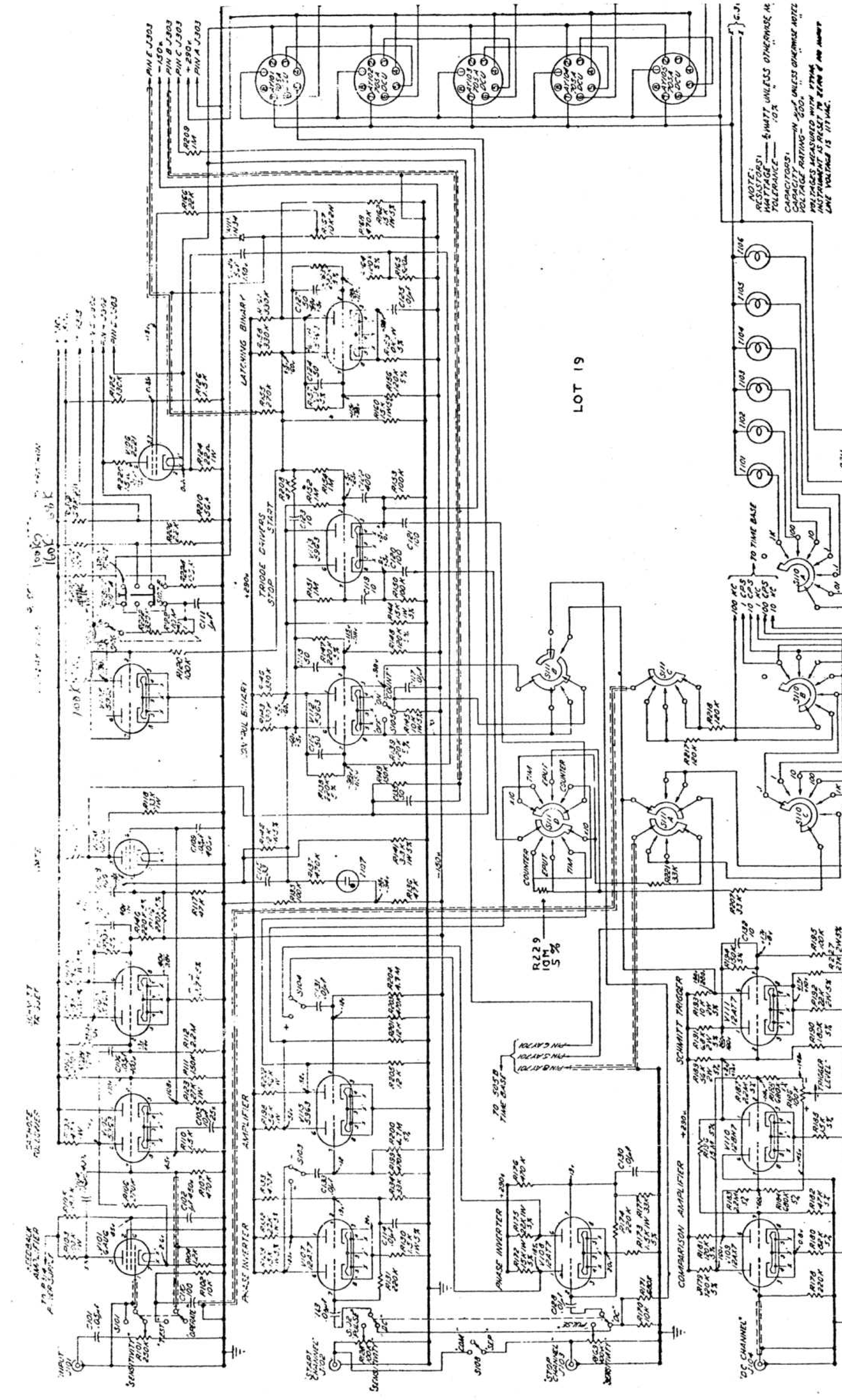

Figure 10 Schematic Diagram, Model 5500

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Scan courtesy of Patrick Jankowiak KD5OEI, Dallas, Texas

NOTES:

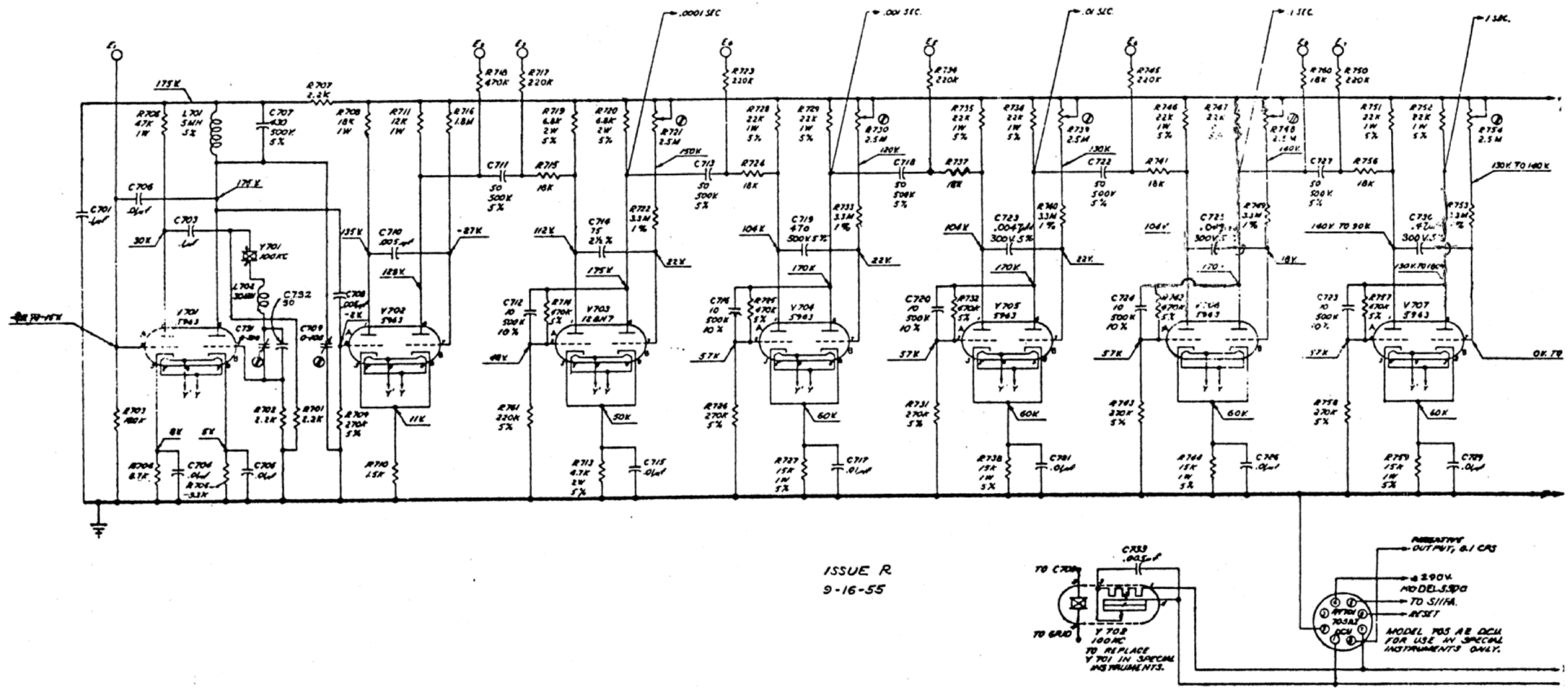

Figure 11 Model 5500, Time Base Schematic

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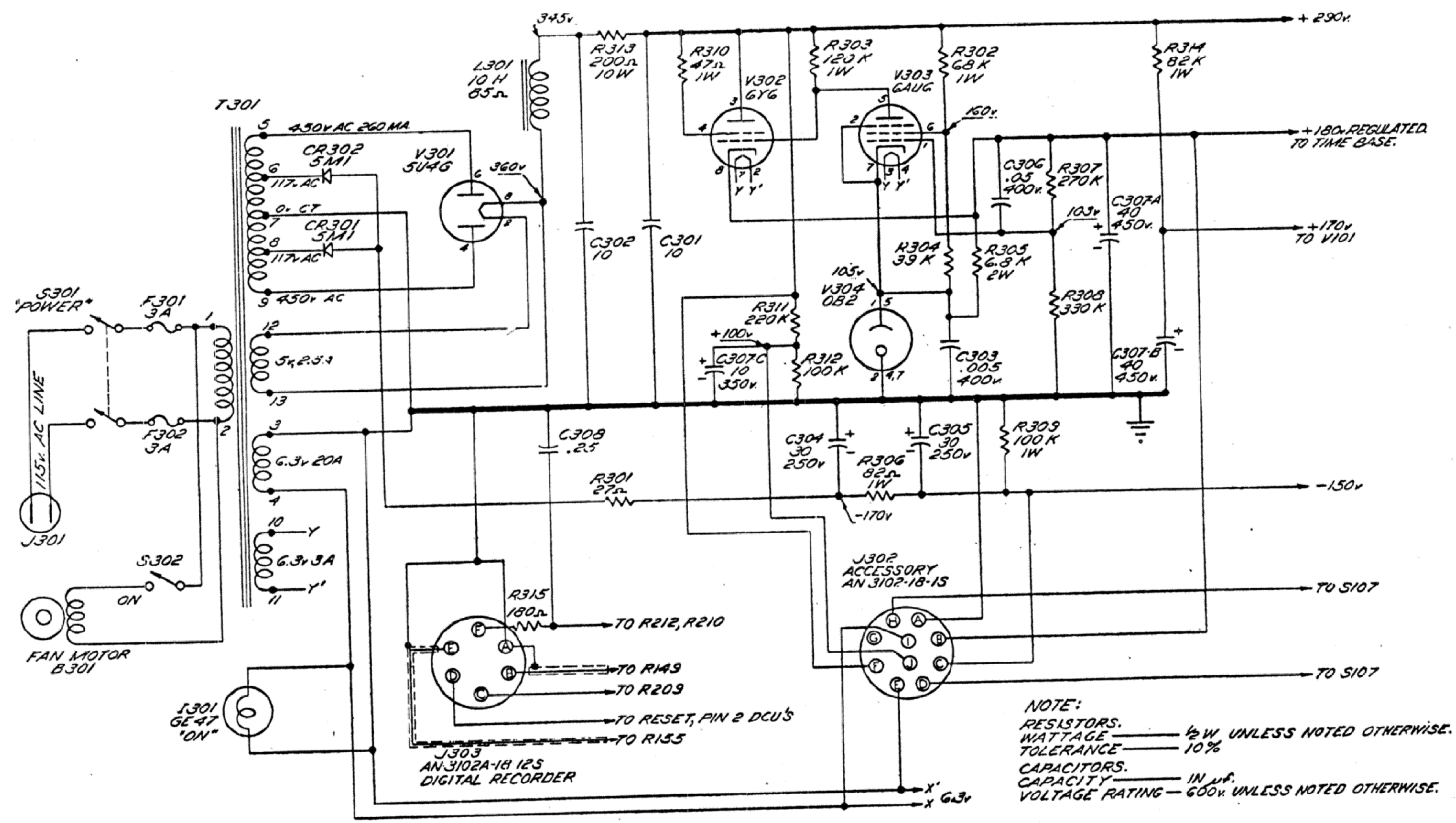


Figure 12 Schematic Diagram, Model 5500 Power Supply

INSTRUCTION MANUAL

MODEL 705A

Decimal Counting Unit

Beckman® INSTRUMENTS, INC.

BERKELEY DIVISION

2200 Wright Avenue
Richmond, California

May 1954

WARRANTY

Instruments sold by Berkeley Division, Beckman Instruments, Inc., (hereafter called "the Company") are warranted only as stated below.

Subject to the exceptions and upon the conditions specified below, the Company agrees to correct, either by repair, or, at its election, by replacement, any defect of material or workmanship which develops within one year after delivery of the instrument to the original purchaser by the Company or by an authorized representative, provided that investigation and factory inspection by the Company discloses that such defect developed under normal and proper use.

The exceptions and conditions mentioned above are the following:

(a) Some components and accessories by their nature are not intended to, and will not, function one year. If any such component or accessory manufactured by the Company and part of the item sold fails to give reasonable service for a reasonable period of time, the Company will, at its election, replace or repair such component or accessory. What constitutes reasonable service and what constitutes a reasonable period of time shall be determined solely by the Company after the Company is in posession of all the facts concerning operating conditions and other pertinent factors and after such component or accessory has been returned to the Company, transportation prepaid.

(b) All instruments claimed defective must be returned to the Company, transportation charges prepaid, and will be returned to the customer with the transportation charges collect, unless the item is found to be defective in which case the Company will pay all transportation charges.

(c) The Company makes no warranty concerning components or accessories not manufactured by it, such as tubes, fuses, batteries, etc. However, in the event of the failure of any component or accessory not manufactured by the Company, the Company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.

(d) Except as stated above, the Company makes no warranty, express or implied (either in fact or by operation of law), statutory or otherwise; and, except to the extent stated above, the Company shall have no liability under any warranty, express or implied (either in fact or by operation of law), statutory or otherwise.

(e) The Company expressly disclaims any liability to its customers, dealers, and to users of its products, and to any other person or persons for consequential damages of any kind and from any cause whatsoever arising out of or in any way connected with the manufacture, sale, repair, replacement of, or arising out of or in any way connected with the use of any of its products.

(f) Representations and warranties made by any person, including representatives of the Company, which are inconsistent or in conflict with the terms of this warranty (including but not limited to the limitation of the liability of the Company as set forth above) shall not be binding upon the Company unless reduced to writing and approved by an officer of the Company.

(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate. Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, Berkeley division of Beckman Instruments, Inc., Richmond 4, California.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

Berkeley reserves the right to make changes in design at any time without incurring any obligation to modify equipment previously purchased to conform to subsequent design changes.

BERKELEY DIVISION

BECKMAN INSTRUMENTS, INC.

CONTENTS

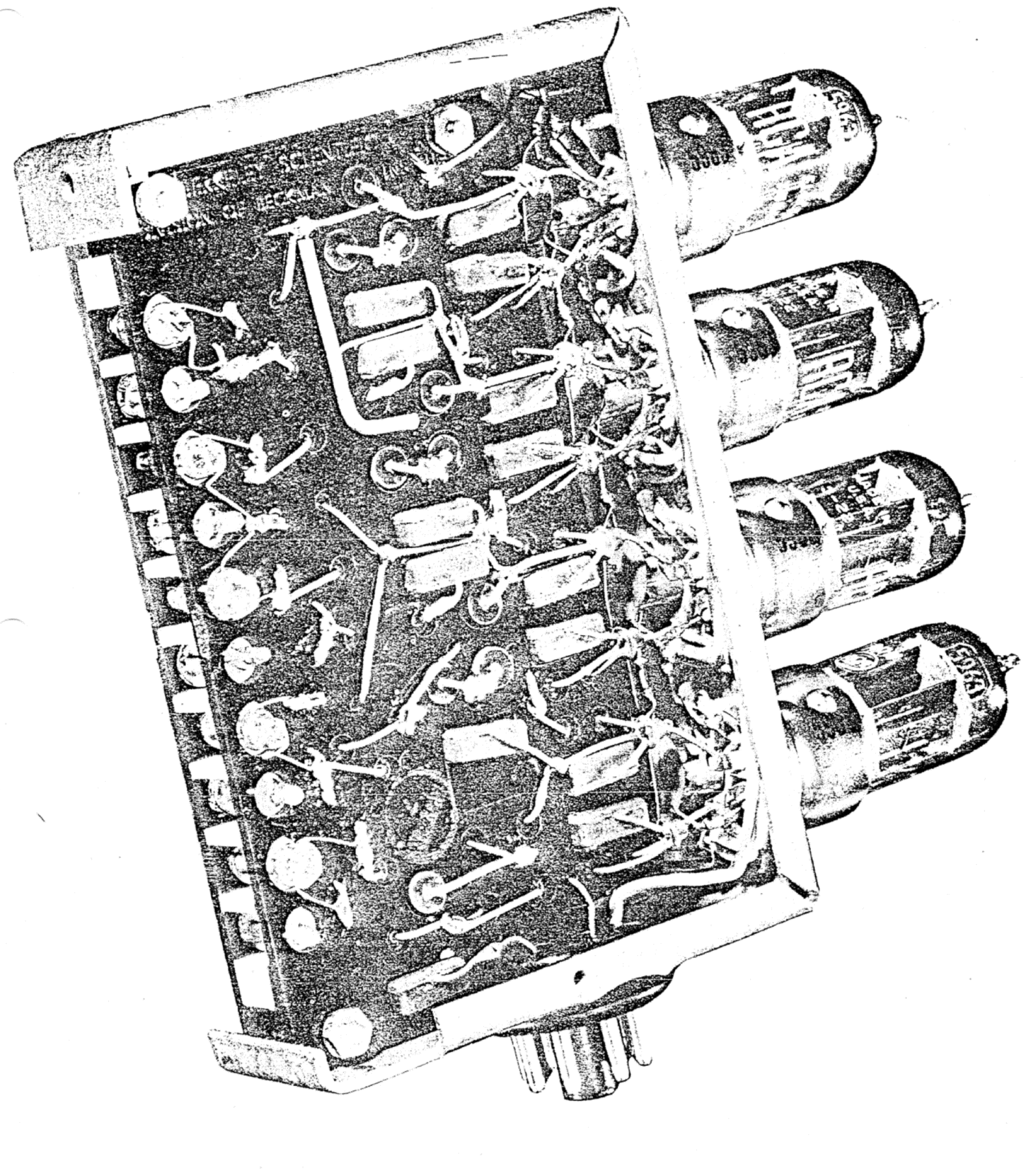


Figure 1 Model 705A Decimal Counting Unit

Section 1
INTRODUCTION

The Model 705A Decimal Counting Unit (DCU) is a direct reading, plug-in electronic counter. The number of counts received is indicated by the illumination of one of ten neon lamps placed behind a numbered acetate panel. Each unit counts from zero to nine, the tenth pulse resetting the counter to zero and simultaneously generating an output signal. Any number of units can be connected in cascade (the output of one unit driving the next) to form a counter whose total capacity depends only on the number of DCU's. Thus, five units will count to 99, 999 and reset to 00,000 on the 100, 000th pulse.

Specifications

Count Indication	Direct Reading Decimal presentation
Power Requirements	Heater: 6. 3 v. at 1. 2 amps Plates: 300 v. at 15 ma.
Input Requirements recommended	Negative pulse 100 volts peak amplitude
Rise Time	Less than 1 μsecond
Duration	At least 2 μseconds
Output Characteristics	Designed to drive a Model 700A, 705A, or 707A
Resolution of Paired Pulses	5 μseconds
Reset to Zero	Instantaneous through opening of grid return
Maximum Counting Rate	100, 000 cps
Construction	Plug-in unit octal socket
Dimensions	1-3/8" x 5-1/2" x 5-1/2"
Weight	1 lb.
Tubes	Four type 5963

Section 2

OPERATION

Installation

Normally, Decimal Counting Units are installed in Berkeley instruments. No special instructions are necessary. For unusual installations, we invite your inquiry.

Operation

Power requirements:

Plates: 225 to 400 volts (nominal 300 volts at 15 ma.)
Filaments: 6.3 volts at 1.2 amperes.

Input requirements:

If the Model 705A is powered by an unregulated supply, the drive amplitude should vary with the supply voltage. A negative transient is required to drive the unit, either a square wave or a rectangular pulse at least 2 microseconds wide. The pulse amplitude depends on the rise time. For a rise time of 0.5 microseconds (measured between ten and ninety percent values), the pulse amplitude should be between 75 and 135 volts; for a 2 microsecond rise time, an amplitude of 120 to 165 volts should be used. Rise times of 1 microsecond or less, pulse amplitudes of 100 volts, and a 300 volt supply offer optimum performance. The input load presented by either unit during triggering is equivalent to 100 $\mu\mu$f in series with 15,000 ohms.

Output requirements:

The output is a rectangular waveform presented at the output terminal as a change in d-c voltage (see Figure 4). Between "0" and "6", the output is 55 volts; "6" and "7", 125 volts; and "8" and "9", 135 volts. The step between "7" and "8" is caused by an interpolation network.

The load imposed on either unit must not be more than 300 K to ground or 6 K in series 100 $\mu\mu$f.

Section 3
THEORY OF OPERATION

Basic Design

The basic circuit of the Model 705A is a modification of the Eccles-Jordan trigger circuit with two stable states, referred to as a binary. It is a two-stage amplifier with the output of the second stage connected to the input of the first, as shown in Figure 2.

With no input, the loop gain is less than one, and the circuit is in one of its two stable states, i. e., either V2 conducting and V1 cut off, or vice-versa. The circuit is triggered from one state to the other by making the loop gain greater than one. The binary is coupled to a single trigger source through C1 and R1 in such a way that the effect of the trigger is different on the two stages, depending on which stage is conducting. For example assume that V2 is conducting and V1 is cut off. If a negative pulse is applied to the input, there is a drop in the plate voltage of V1. This drop in voltage is transmitted through the cross-over network (R5, R8, C3 and the grid-to-ground capacitance of V2) and applied to the grid of V2. The plate voltage of V2 then starts to rise, carrying with it the grid of V1. When the input pulse is of sufficient amplitude, the loop gain becomes greater than one, and the binary is triggered to its other stable state, V1 conducting the V2 cut off. The next input pulse reverses the process and causes the binary to return to its original state. Thus, the binary completes a cycle for every two input triggers, and is a scale of two. By a cascade arrangement of binaries, a counter having a scale of any power of two can be obtained.

Circuit Analysis

Four binaries are connected in cascade forming a scale of 16, which is permuted to a scale of 10 by two resistor-capacitor "feedback" networks (see Figure 3).

The circuit operates as a conventional binary counter up to the count of four. On the count of four the third stage is triggered, sending a pulse through the first feedback network, thereby triggering the second stage. Since it requires two inputs to trigger the second stage, this is the equivalent of adding two input pulses and the unit now corresponds to a binary count of six. On the count of six (which is the equivalent of eight in a binary counter) the fourth stage is triggered, sending a pulse through the second "feedback" network and triggering the third stage. This is the same result as if four additional input pulses had been applied and the unit has a binary

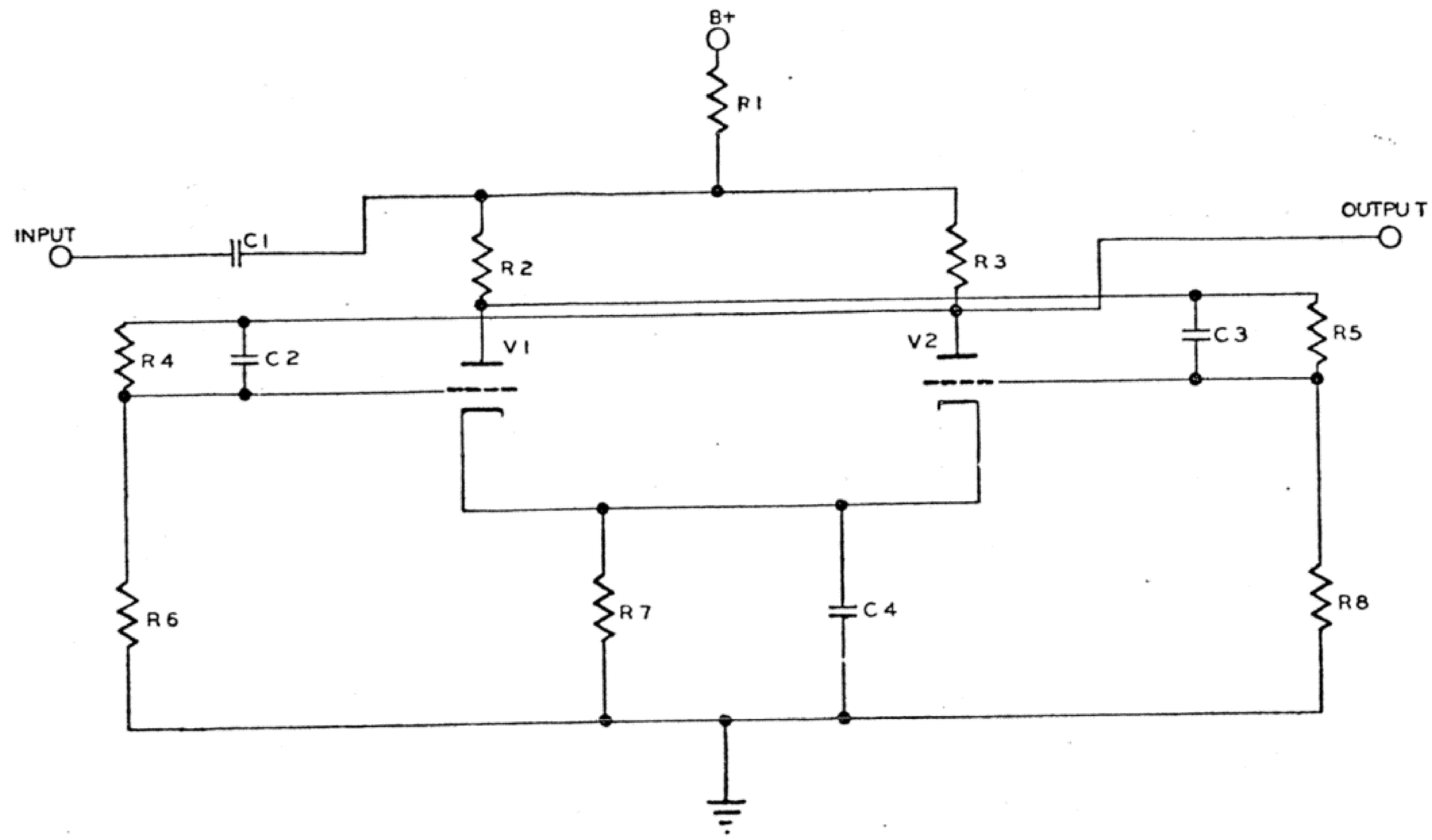


Figure 2 Basic Circuit

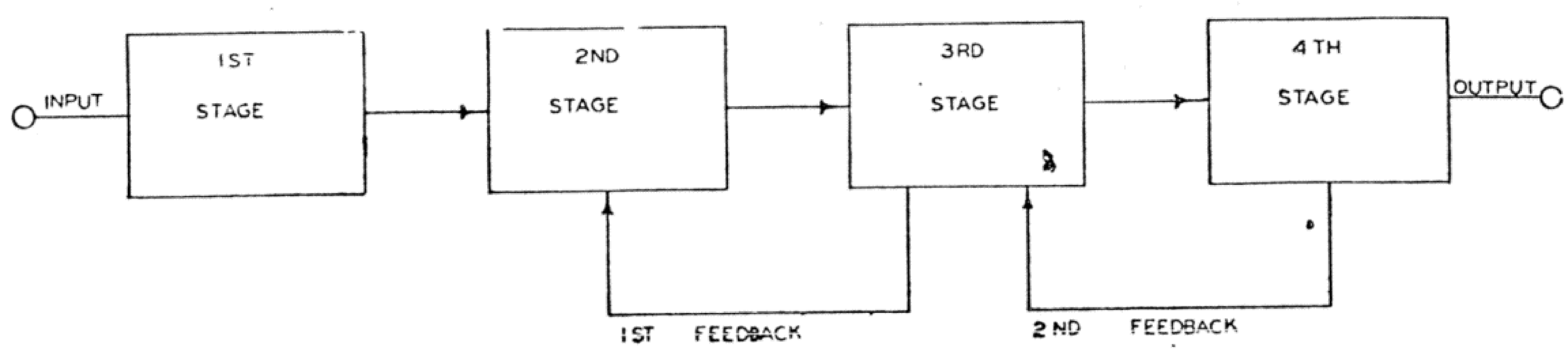


Figure 3 Functional Diagram

count of twelve stored in it. The unit again operates as a binary scaler for the remaining four pulses required to reset it to zero. Therefore, by adding the equivalent of six input pulses, the scale-of-16 has been permuted into a scale-of-10.

Section 4
MAINTENANCE

When a Decimal Counting Unit is suspected of counting incorrectly, it should be interchanged with another unit in the instrument or replaced with a spare unit to determine whether the trouble is in the suspected unit or in the associated circuitry. This test should be made very carefully. Since the counting unit is usually the indicating device of a larger instrument, faulty operation is often ascribed to it when the symptoms of external faults are displayed.

Troubleshooting

Two methods are recommended for finding the trouble in a faulty counting unit. First, by observing the lighting sequence while driving the unit at a slow repetition rate, and second, by studying the waveform of each stage while driving the unit at a repetition rate fast enough to be conveniently viewed on an oscilloscope. It is impossible to say which method should be used in every case, since marginal failures may occur at high counting speeds and not at lower counting rates, and vice versa. The first method is the only way that a neon lamp failure can be located, and it can be used to locate component and tube failures. For this reason, it is recommended that this method be used first. Table 1 lists common troubles. Faulty tubes cause most failures.

Diagrams and Tables

Typical waveforms are shown in Figure 4. By comparing these with the waveforms from a defective unit, the faulty stage can be quickly detected. Table 2 lists the voltages and resistances between tube socket connections and ground so that, in conjunction with the schematics and parts location diagrams, all information necessary to maintain the equipment in proper working order is available. It should be remembered that the values given are nominal, and considerable variations may be encountered owing to various line voltage conditions and component tolerances.

Circuit drawings and parts location diagrams will be found at the rear of the manual. The voltages shown were obtained with a vacuum tube voltmeter, a supply voltage of 300 volts, and measured between ground and the point indicated. The unit must be reset to zero to obtain the values shown.

Table 1
COMMON TROUBLES*

Symptom	Cause
Unit Fails to Count	(a) Insufficient supply voltage. (b) Input signal of insufficient amplitude. (c) Input signal of wrong polarity (d) First stage inoperative.
Unit Counts Spuriously	(a) Stray output signal. (b) Pulses received through power supply. (c) External voltages picked up by output lead.
Unit Counts Erratically	(a) Input signal too large or small, incorrect rise time. (b) Supply voltage fluctuating too much.
Unit Fails to Reset	(a) Stray counts from reset switch or associated circuitry. (b) Defective component
Unit Counts in Wrong Sequence (the pattern of lighting is repeated after a definite number of input pulses. One or more lights may be "On" simultaneously during a cycle provided that the number of states per cycle remains constant).	
1. Unit skips every other number.	(a) First stage defective. (b) Input circuit supplies double pulses.
2. Two stable states per cycle.	(a) Second stage defective (count can be 01 or 45). (b) Loss of drive to second stage (01).
3. Four stable states per cycle.	(a) Third stage defective (count can be 0123 or 6789). (b) Loss of drive to third stage (0123).

4. Six stable states per cycle.

   (a) Output excessively loaded (count can be 012345-012345).

   (b) Last stage inoperative (count can be 01234501 etc. or $67^{89}_{23}89$. The count $\genfrac{}{}{0pt}{}{8}{2}$ indicates both "8" and "2" lamps are on.

   (c) Loss of drive to fourth stage (count can be 012345).

5. Eight stable states per cycle or any failure where two successive numbers are skipped.

   (a) Second or third stage failure.

6. Ten stable states per cycle, but the lighting sequence is incorrect.

   (a) Where the "0" neon lamp lights instead of the "4", the trouble is with either the "0" or "4" lamp, and in the majority of cases it is "4". This can happen on any count; zero and four were used as examples. It is also possible that more than one lamp may light in place of, or with the one that fails.

7. Twelve stable states per cycle.

   (a) When lighting sequence is
   01
   012345456789-0, etc. (The count
   0
   4 indicates both "0" and "4" lamps are on).
   First feedback failure.
   Second or third stage losing emission.

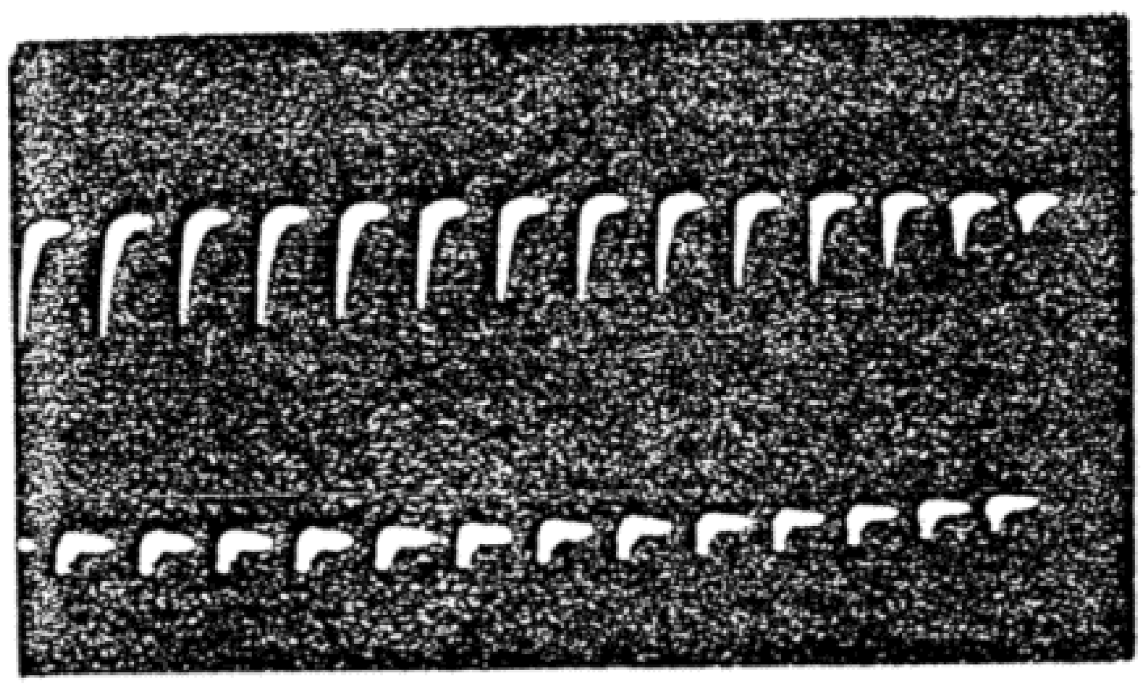
   (b) When the lighting sequence is
   23
   012345678989-0, etc.
   Second feedback failure.
   Third or fourth stage losing emission.

* Reset Unit before troubleshooting.

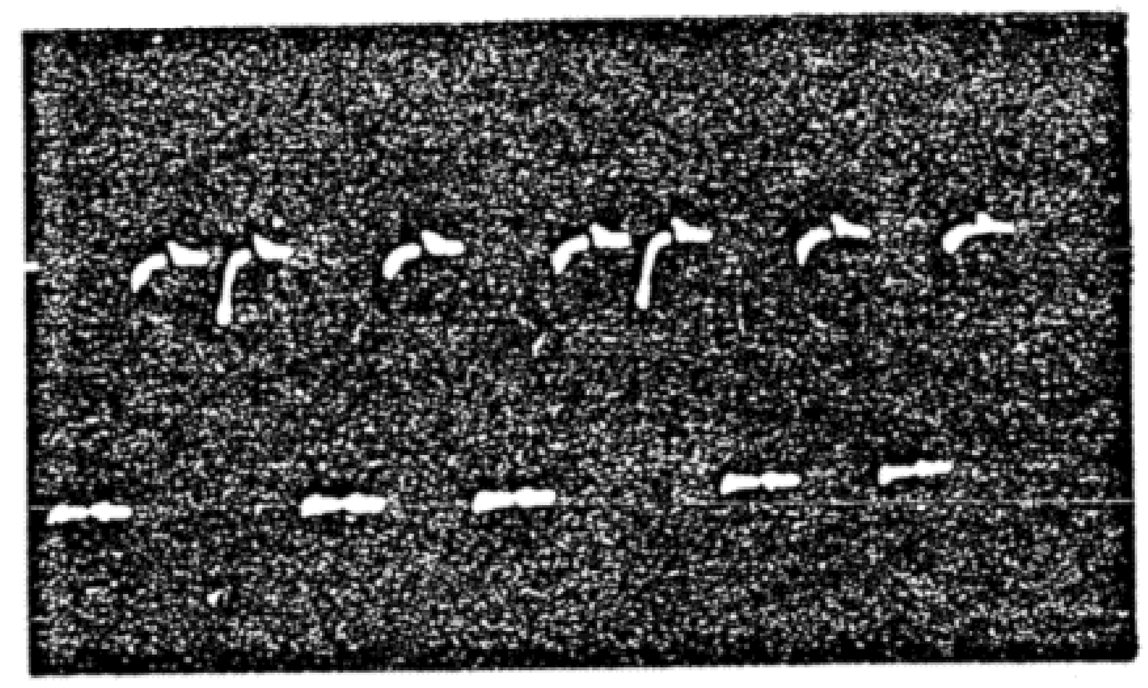
Table 2
MODEL 705A - VOLTAGES & RESISTANCES

Tube	Pin No.	D. C. Voltage to Ground	Resistance to * Ground (in ohms)
V101	1	170	105K
	2	17	85K
	3, 8	37	12K
	4, 5, 9	Filaments	
	6	60	105K
	7	37	85K
V102	1	135	93K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	93K
	7	30	83K
V103	1	135	100K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	100K
	7	30	83K
V104	1	135	93K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	93K
	7	30	83K

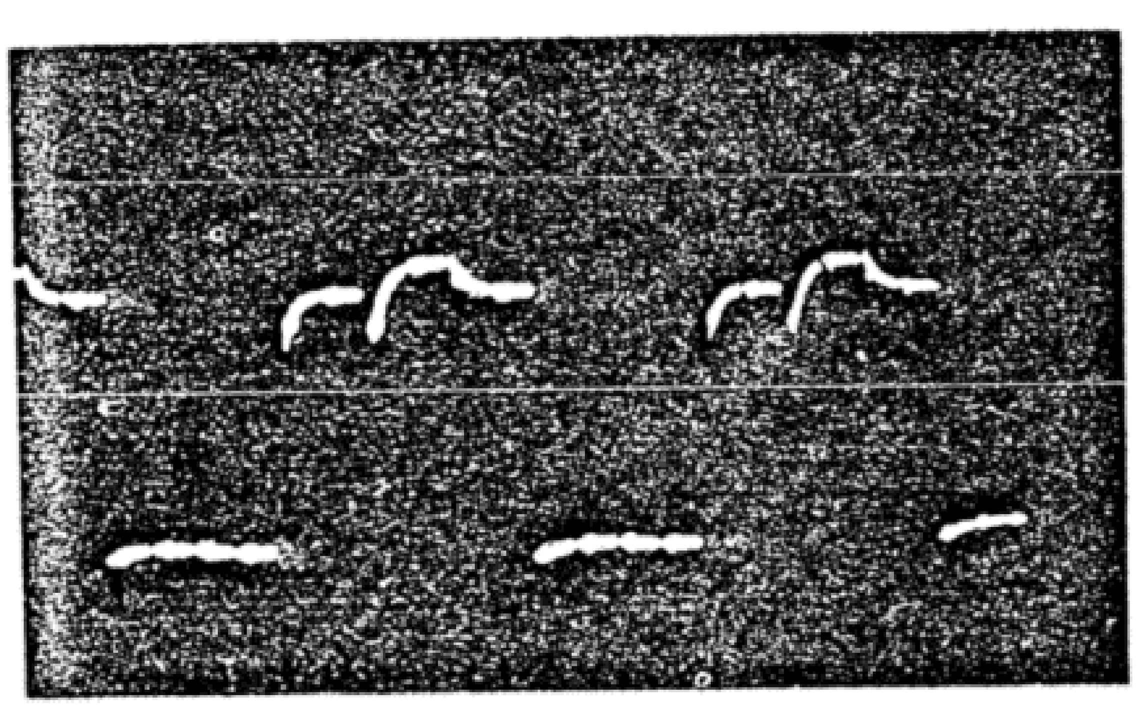
* When making the above resistance measurements on a DCU with an octal plug, connect pin 2 to pin 6. On a DCU with an 11 pin plug, connect pin 3 to pin 8.



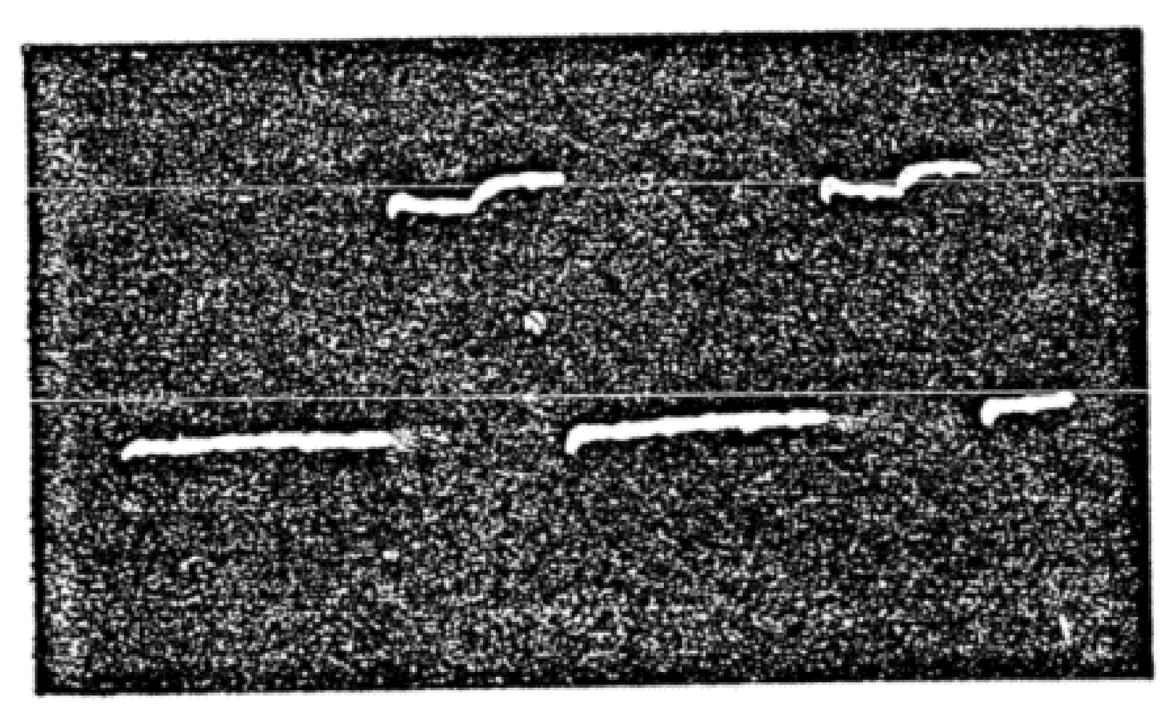
A. First Stage, Pin 6, V101, UVL + 168, LVL + 58, frequency 20Kc.



B. Second Stage, Pin 6, V102, UVL + 140, LVL + 55, frequency 20 Kc.

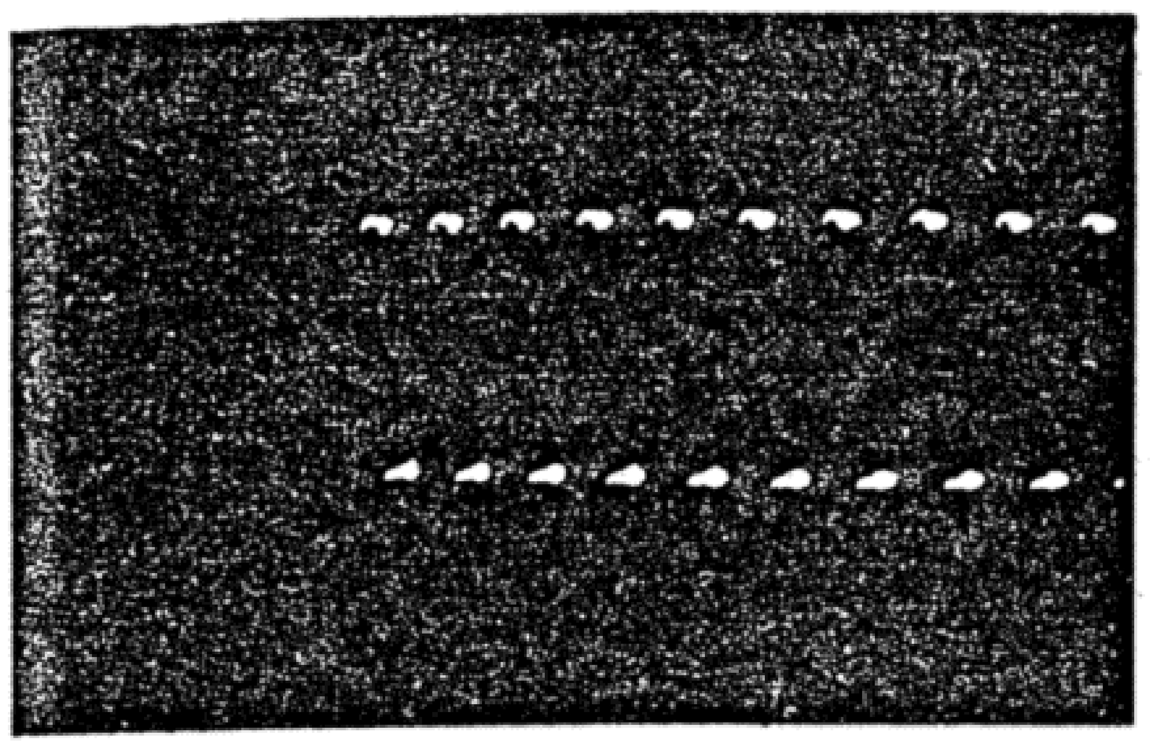


C. Third Stage, Pin 6, V103, UVL + 140, LVL + 55, frequency 20 Kc.

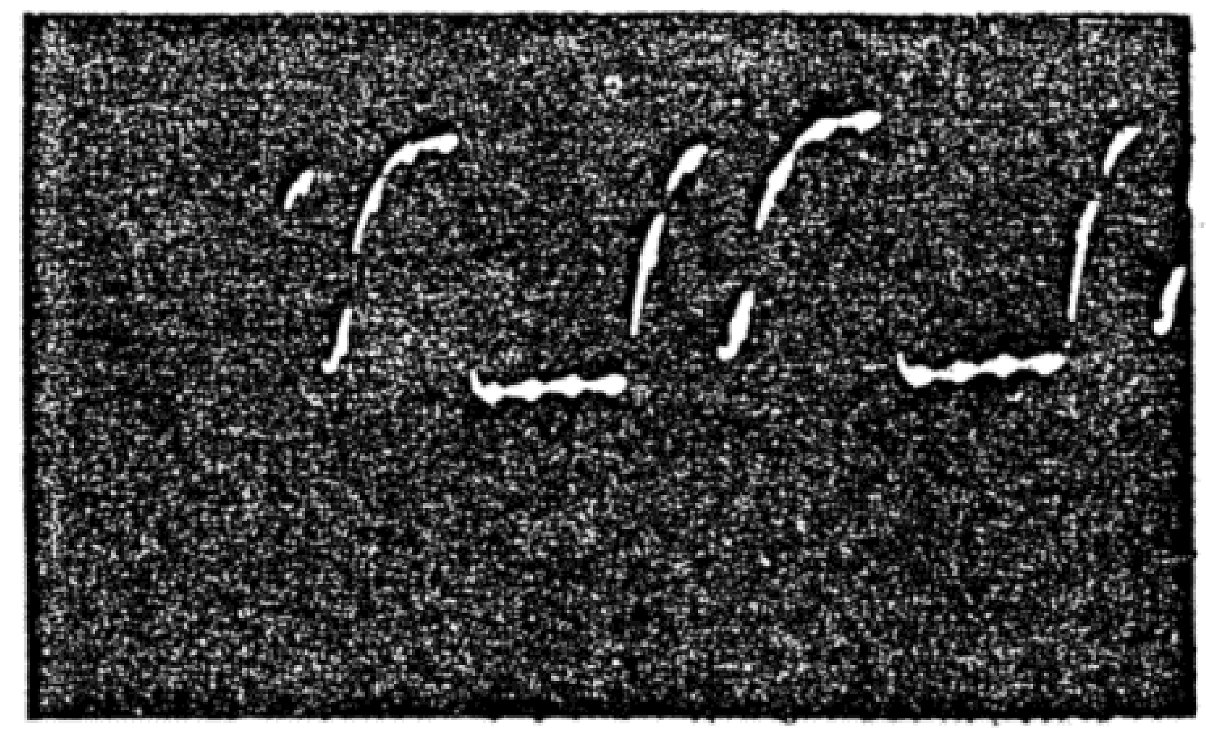


D. Fourth Stage, Pin 6, V104, UVL + 140, LVL + 55, frequency 20Kc.

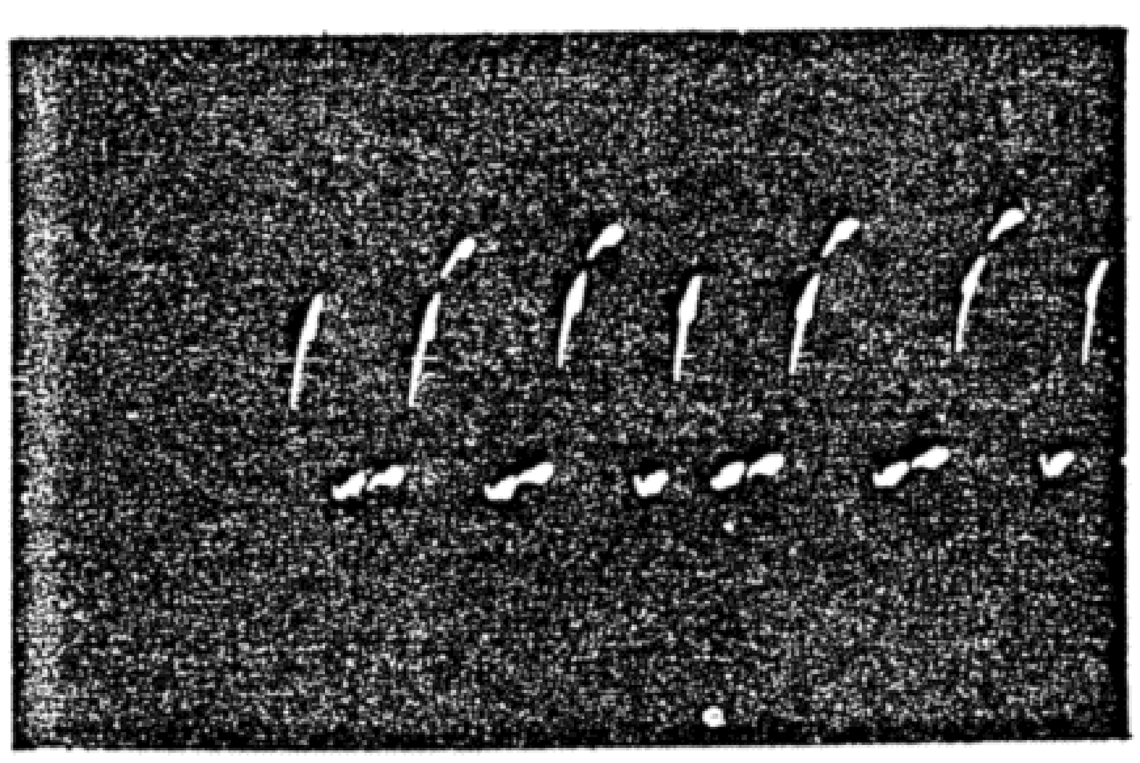
Figure 4 Typical Waveforms



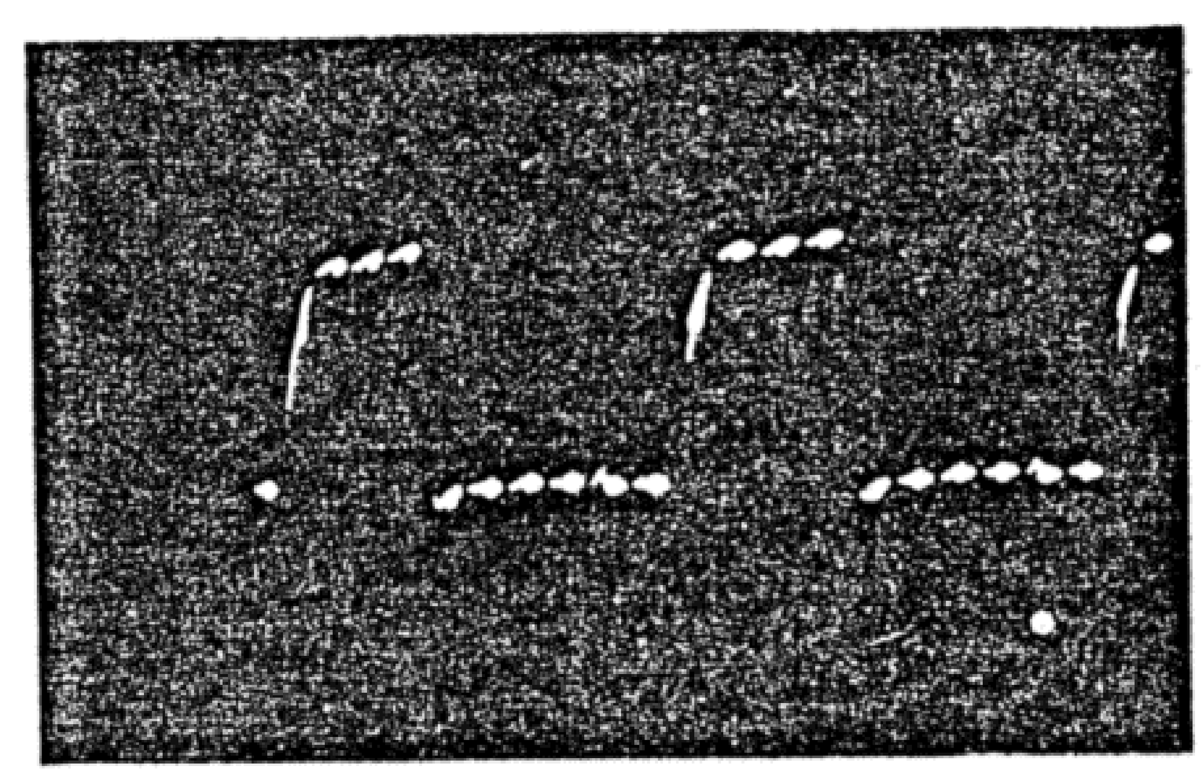
E. First Stage, Pin 6, V101, UVL + 168, LVL + 58, frequency 100Kc.



F. Second Stage, Pin 6, V102, UVL 140, LVL + 55, frequency 100Kc.

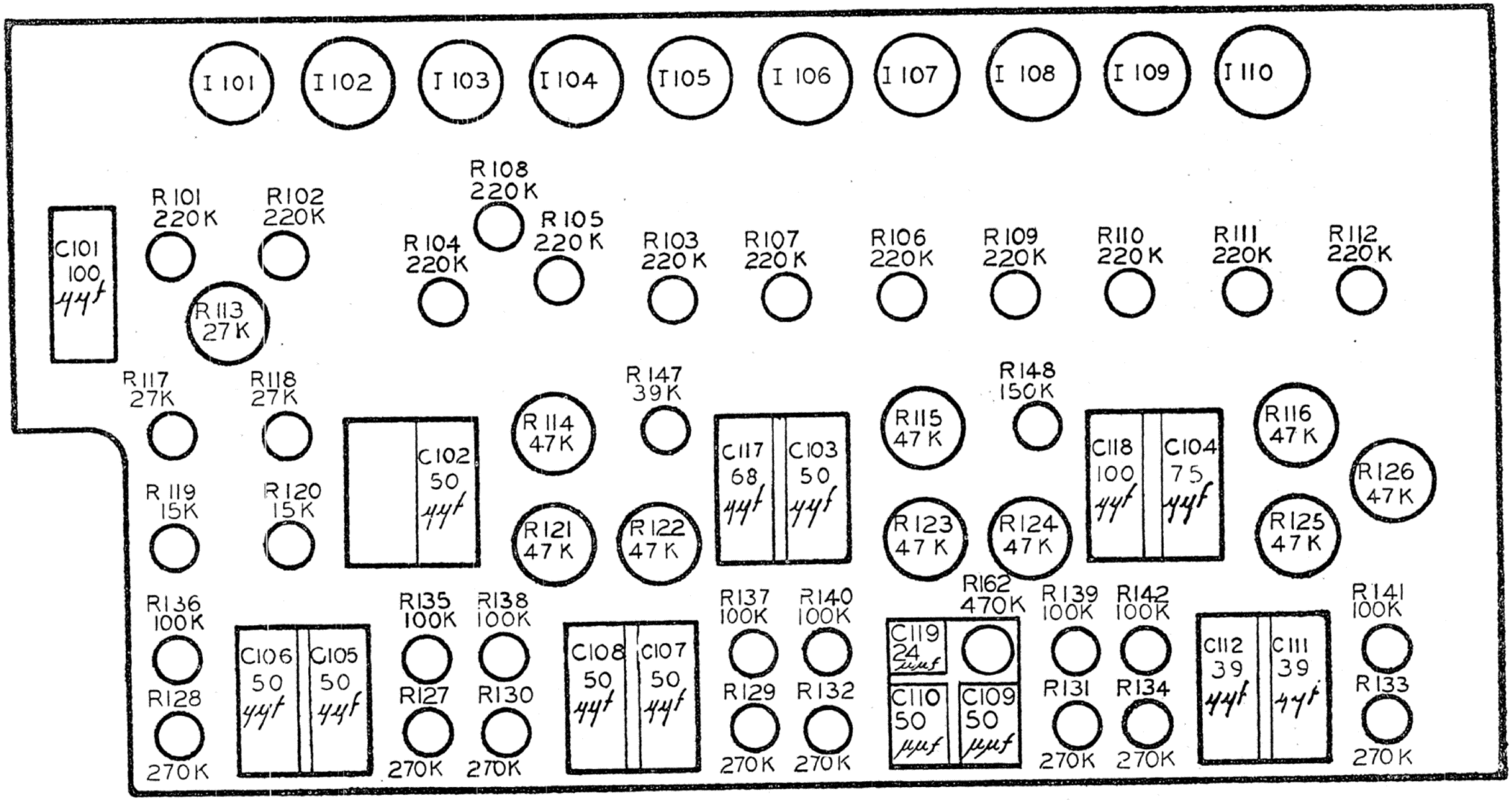


G. Third Stage, Pin 6, V103, UVL + 140, LVL + 55, frequency 100Kc.

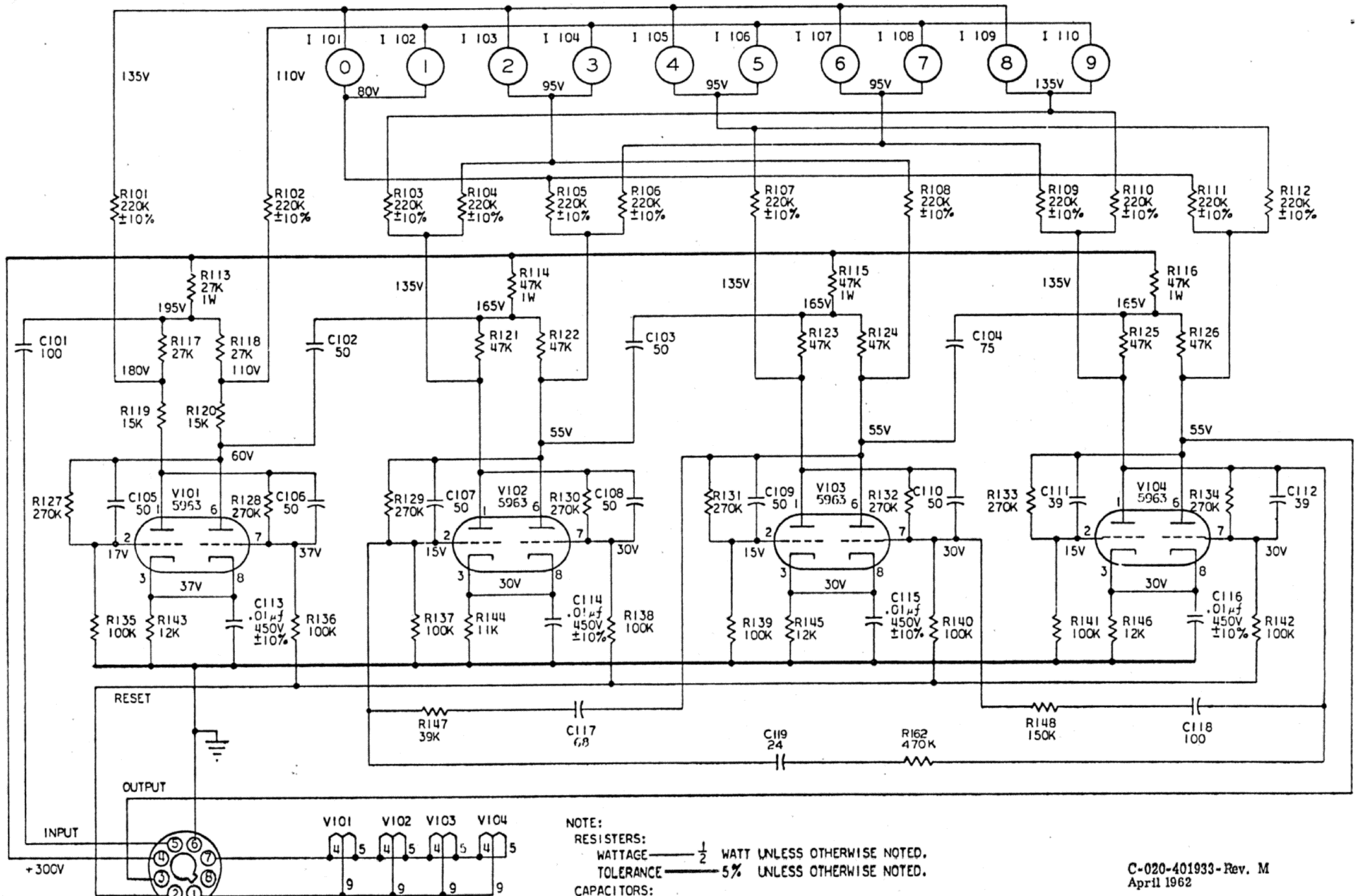


H. Fourth Stage, Pin 6, V104, UVL + 140, LVL + 55, frequency 100 Kc.

Note: UVL = upper voltage level
LVL = lower voltage level
All waveforms are blanked.



Parts Layout



NOTE:
RESISTERS:
WATTAGE——— $\frac{1}{2}$ WATT UNLESS OTHERWISE NOTED.
TOLERANCE———5% UNLESS OTHERWISE NOTED.
CAPACITORS:
CAPACITY———IN µµf UNLESS OTHERWISE NOTED.
VOLTAGE RATING-500V " " "
TOLERANCE———15% "
ALL VOLTAGES MEASURED WITH VTVM WITH COUNT AT "0".

C-020-401933-Rev. M
April 1962

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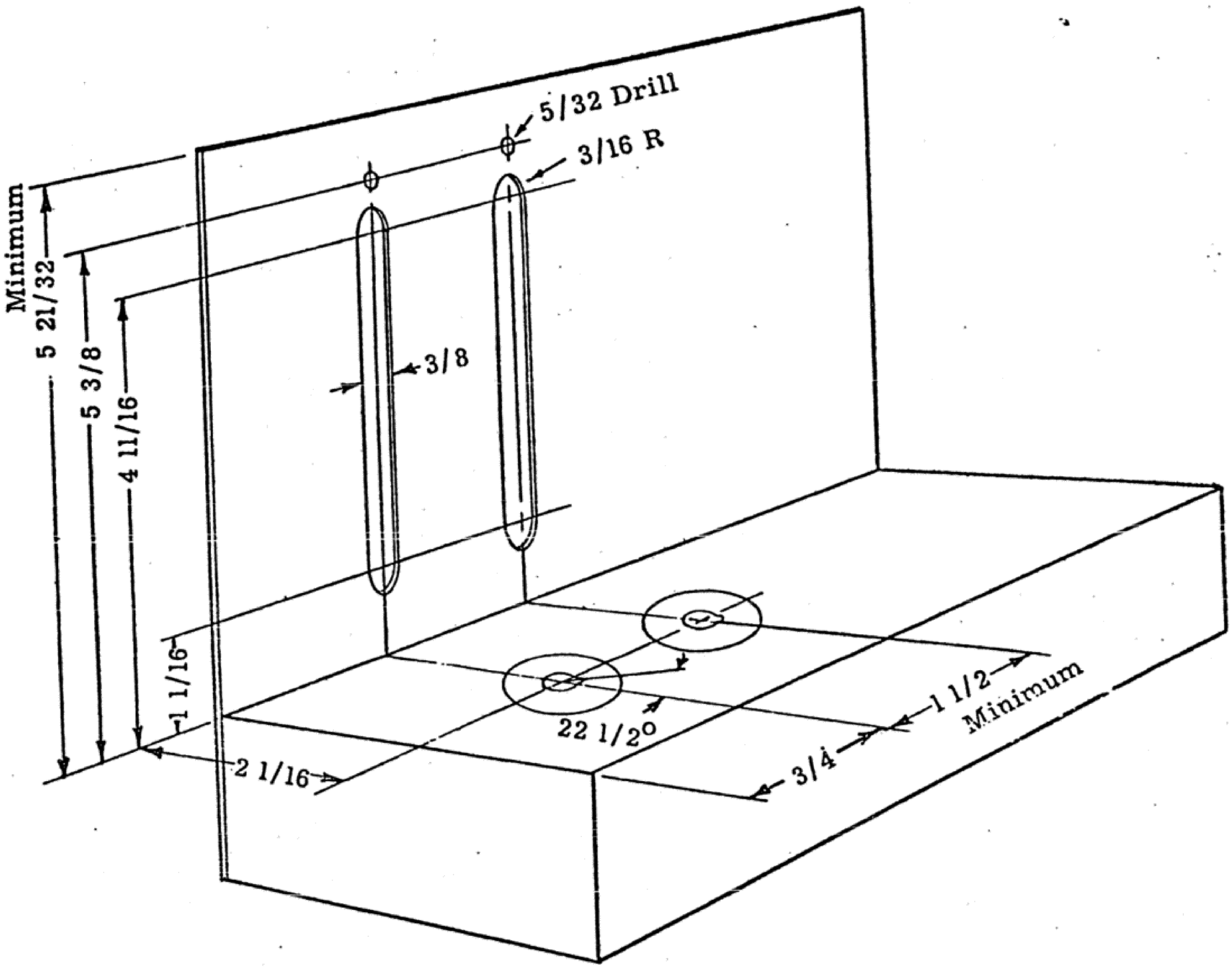
Figure 6 Schematic Diagram Model 705A



NOTE: Dimensions are based on the use of an Amphenol "MIP" 8 or 11-pin socket mounted above the chassis.

The drawing shows chassis dimensions for mounting two Model 705A DCU's side by side. All modifications of the Model 705A (705AH, 705AF, etc.) have precisely the same dimensions as the standard 705A.

Mounting Dimensions, Model 705A and All Modifications Thereof

INSTRUCTION

MANUAL

APPENDIX B

Model 705AZ
DECIMAL COUNTING UNIT

BERKELEY division

Beckman Instruments, Inc.

Richmond 4, California

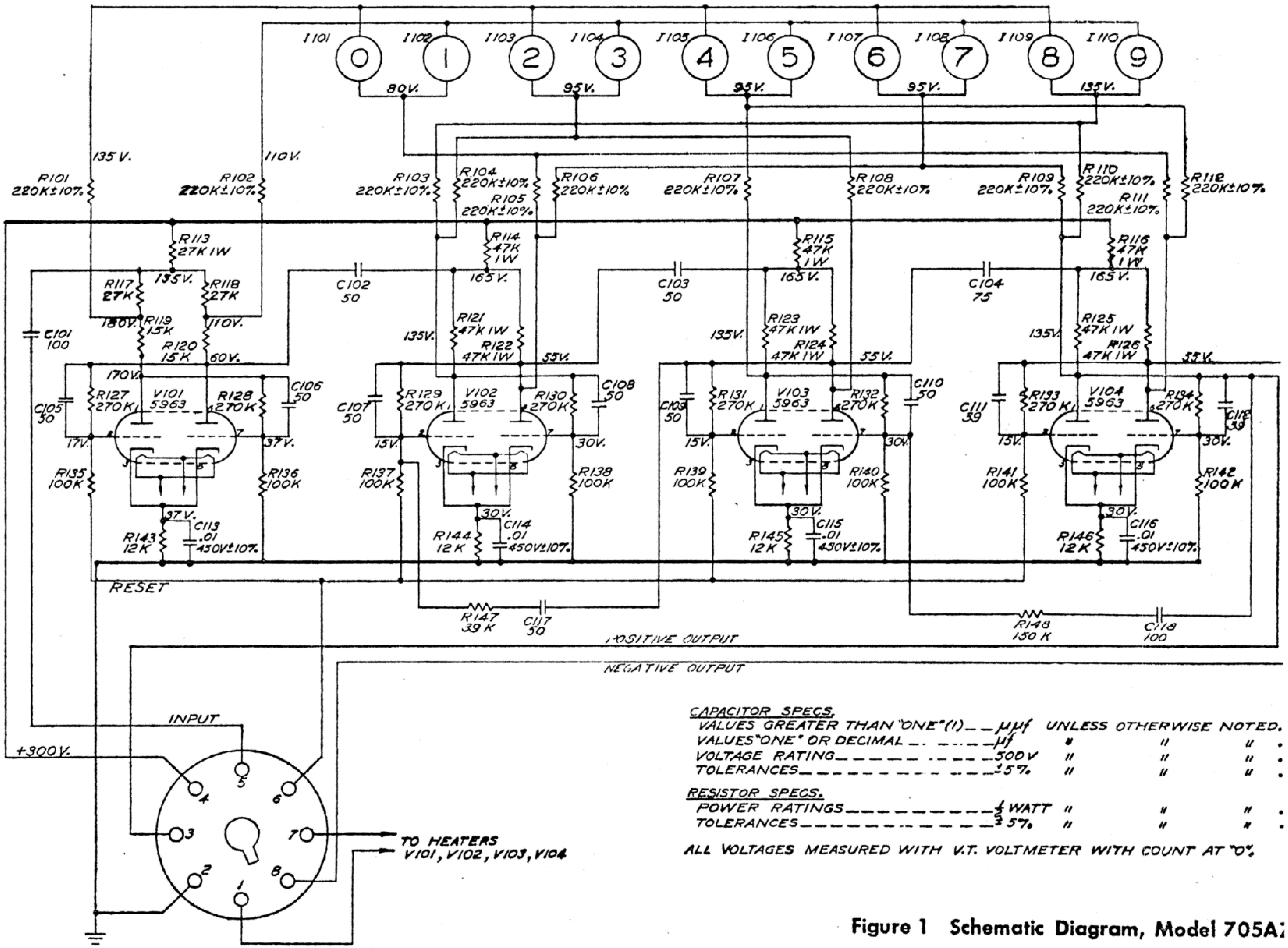
12 October 1954

The Model 705AZ, Decimal Counting Unit, has been designed especially for use as a scale-of-ten extension to time bases. Its schematic is essentially that of the 705A, except for two modifications (see Figure 1)

1. The voltage on the second plate of the last binary (pin 1 of V104) is led out to pin 3 of the DCU socket. Pin 8 on the DCU socket is connected to pin 6 on V104.

2. The 705AZ is returned to the "nine" condition by the RESET control. This is done by connecting the reset line.

A DCU reset at "nine" requires only one input count to generate an output and commence a new timing cycle. A DCU reset at "zero" would require ten input counts before transmitting a Start pulse to the gating circuitry.



CAPACITOR SPECS.

VALUES GREATER THAN "ONE" (1)	μμf	UNLESS	OTHERWISE	NOTED.
VALUES "ONE" OR DECIMAL	μf	"	"	"
VOLTAGE RATING	500V	"	"	"
TOLERANCES	±5%	"	"	"

RESISTOR SPECS.

POWER RATINGS	½ WATT	"	"	"
TOLERANCES	±5%	"	"	"

ALL VOLTAGES MEASURED WITH V.T. VOLTMETER WITH COUNT AT "0".

Figure 1 Schematic Diagram, Model 705A