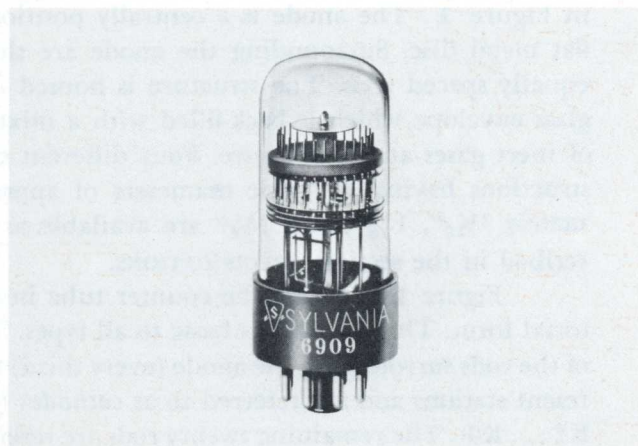


Sylvania
counter tube
handbook

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Introduction

The Sylvania Counter Tube is a cold cathode device that boasts the unique characteristic of counting and displaying simultaneously. Counting is accomplished by the sequential stepping, in response to the input pulses, of an ion glow about a closed circular course consisting of 10 equally spaced stations. Visual readout is obtained by observing the position of the glow through the face of the tube. Electrical readout information in the form of a pulse can be derived from one or more of the 10 stations, depending on the tube type.

Two basic counter tube designs provide for operation at input rates up to 100 Kpps. These are *low-speed* types which have an operating frequency range of 0-4 Kpps and *high-speed* types which have an operating range of 0-100 Kpps.

Since the actual counting operation is performed by the counter tube, associated circuitry is comparatively simple, being limited to that required to shape and amplify (if necessary) the input signal. This can be done with either vacuum tubes of the receiving class or transistors.

In addition to straight counting, the device is capable of subtracting, frequency dividing, timing, keying, and various other functions.

The balance of this handbook contains detailed information on: operating principles; operating requirements; circuit design considerations and practices; circuits for typical applications; and electrical and mechanical specifications of Sylvania Counter Tubes.

The information contained herein is supplied without assuming any responsibility for its use, from a patent viewpoint or otherwise and no license under Sylvania's patent rights is granted thereby either expressly or by implication.

Principles

The Structure/A typical counter tube is pictured in Figure 1. The anode is a centrally positioned flat metal disc. Surrounding the anode are thirty equally spaced rods. The structure is housed in a glass envelope which is back-filled with a mixture of inert gases at low pressure. Four different constructions having envelope diameters of approximately $1\frac{1}{16}$ " , $1\frac{1}{8}$ " , and $1\frac{3}{8}$ " are available as described in the section, SPECIFICATIONS.

Figure 2 presents the counter tube in pictorial form. This diagram is basic to all types. Ten of the rods surrounding the anode (every third) represent stations and are referred to as *cathodes* (K1, K2 . . . K0). The remaining twenty rods are referred to as *guides* and are connected together in two groups, each rod in a group being separated from the next by a cathode, and a guide of the other group.

In all counter tubes, the two guide groups are brought out to individual base pins and are referred to simply as Guide No. 1 (G1) and Guide No. 2 (G2). In some tubes, all ten cathodes are brought out to individual base pins. In others, certain cathodes are internally connected together and share a common base pin. The tenth cathode (K0) is always brought out separately. The various basing arrangements of the counter tubes are detailed in the section, SPECIFICATIONS.

Electrical Readout/In operation, output signals can be obtained from each cathode which is brought out separately. In simple counting applications where visual readout of the total count is of primary interest, only K0 need be available separately and serves to couple one counter tube to another and provides for resetting. Types with individual connections for all cathodes are for counting applications where it is desired to activate an external circuit following a certain number of input signals such as in batching, timing, etc.

Visual Readout /When the tube is counting, an ion glow advances sequentially from one cathode to the next in step with the input signals. The glow is formed about the tip of the cathode and is clearly displayed through the top of the tube. Low-speed counters give off a bright red-orange light; high-speed types, bright red. Associating numbers with the ten cathodes by means of a bezel provides for direct visual readout. (Suitable bezels are available commercially as described in the final section, SPECIFICATIONS.)

Operation/A simplified counter tube circuit is shown in Figure 3. The anode is connected via resistor (RA) to a dc supply of approximately +400 volts. The guides (G1 and G2) are shown connected via separate resistors to a common dc guide bias supply delivering +35 volts.

When the anode voltage reaches the *cold* anode-to-cathode breakdown voltage (300-400 volts), a glow discharge occurs between the anode and one of the cathodes. The cathode which ionizes under this condition is known as the *preferred* cathode. The bias voltage applied to the guides prevents the discharge from taking place between the anode and one of the guide rods, i.e., the anode-to-guide voltage is less than the anode-to-cathode voltage by the amount of the guide bias. As soon as the discharge is established on the *preferred* cathode, the anode voltage drops to the sustaining value (low-speed counter tubes, 187 volts nominal; high-speed types, 235 volts nominal). Here the discharge becomes stable since the anode voltage is below that required to cause breakdown to any other electrode.

Referring to Figure 3, it will be assumed that the glow discharge is on K0. Guide rods g2k and gla immediately adjacent to K0 are therefore *primed*. That is, these two guide rods share in the ionization field about K0 with the result that the voltage required to establish the glow on either of these guide rods is considerably less than that necessary to cause breakdown between the anode and any other unprimed guide rods. The voltage required to cause breakdown between the anode and a primed adjacent electrode is known as the *transfer* voltage and is approximately 35 volts negative with respect to the ionized cathode.

Transfer of the glow discharge from cathode to cathode around the counter tube is accomplished by applying double negative pulses to the guides. With the glow discharge resting on K0, a negative pulse having an amplitude of 70 volts (transfer voltage plus guide bias voltage) is applied to the Guide No. 1 bus (G1). Guide rod gla, being primed, ionizes. As gla ionizes, the anode voltage drops by the amplitude of the applied guide pulse to a value below that required to sustain the discharge between the anode and K0. The ionization is now concentrated on guide rod gla, and guide rod g2a is primed (as is K0). Transfer of the ionization to g2a is accomplished by applying the second negative pulse to the Guide No. 2 bus (G2) just before the

Guide No. 1 pulse decays. Then, as the Guide No. 1 pulse decays, the anode voltage will rise to the level at which breakdown occurs between the anode and guide rod g2a. The ionization is now established on g2a and K1 is primed (as is g1a). As the Guide No. 2 pulse decays, the anode voltage will again increase until primed cathode K1 ionizes. The ionization is actually forced to K1 from g2a since the decay of the Guide No. 1 pulse restores positive bias to g1a. One cycle has now been completed and the glow rests on K1. Guide rods g1b and g2a are, of course, primed.

By a repetition of this process the ionization is advanced around the tube from cathode to cathode, each step requiring a sequence of pulses. By reversing the order of the guide pulses the counter tube will work in the opposite direction, hence it can be used for subtracting as well as adding.

Operating Requirements

The counter tube is an extremely reliable device offering tens-of-thousands of hours of trouble-free operation. Like all other active electronic components, the counter tube has certain characteristic operating requirements that must be understood and satisfied in application to achieve satisfactory performance.

Table I shows the general electrical characteristics and ratings for *high-speed* and *low-speed* counter tube types. The respective differences must be observed for satisfactory operation. Particularly significant differences are discussed in detail in the following text.

Anode Supply Voltage and Current / In general, the anode supply voltage must be high enough to assure breakdown between the anode and cathodes, in the unprimed or *cold* state. The minimum permissible values are specified in Table I for both *high-speed* and *low-speed* types. Any value of supply voltage within the specified limits generally can be used. It should be noted that the specified minimum anode supply voltage limit is for normal room illumination conditions. Operation in complete darkness requires that this value be increased by 15 percent.

When the ionization is established on a cathode, the counter tube acts similar to a voltage regulator of the glow-discharge type. That is, within its

TABLE I
GENERAL COMPARATIVE ELECTRICAL DATA*

RATINGS (Absolute Values)	Low-Speed Counter Tubes		High-Speed Counter Tubes	
	Min.	Max.	Min.	Max.
Input Frequency	0	4.0	0	100 Kpps
Anode Current (I _b)	0.3	0.6	.6	.8 Ma
Voltage Between Electrodes				
(Other than Anode)	-	140	-	140 Vdc
Anode Supply Voltage	350	800	400	800 Vdc
Transfer Voltage	35	140	35	140 Vdc
Ambient Temperature	-55	+60	-55	+60 °C
OPERATING CHARACTERISTICS				
Minimum Anode Supply Voltage		350		400 Vdc
Nominal Tube Drop		187		235 V
Minimum Guide Bias		+35		+45 Vdc
Minimum Square Double Pulse				
Drive Amplitude		-75		-85 V
Minimum Square Double Pulse Duration				
(Each Guide)		60		4 μsec.
Minimum Forced Reset Pulse Amplitude	-120		-120 V	
Minimum Reset Pulse Width		50		4 μsec.
Maximum Cathode Load Resistor		150		50 K-Ohms

* Consult COUNTER TUBE SPECIFICATIONS Section for individual differences.

current limitations, the voltage between the ionized cathode and the anode will be quite constant. This voltage is known as *tube drop* and is specified nominally as 187 volts for *low-speed* types and 235 volts for *high-speed* types. The anode current, therefore, is determined by the value of the anode resistor (RA), for a given supply voltage. The approximate value for the anode resistor can be computed by subtracting the nominal tube drop from the supply voltage and dividing the remainder by the desired operating current:

$$RA = \frac{E_{bb} - E_{td}}{IA}$$

where:

- RA** = Anode Load Resistor
- E_{bb}** = Anode Supply Voltage
- E_{td}** = Tube Voltage Drop
(High-speed types, 235 V; low-speed, 187 V)
- IA** = Desired Anode Current

The average anode current should be restricted to the specified range. The lower limit is the value

below which the guides and cathodes would not be sufficiently primed to assure consistent ionization transfer. Operation near the lower limit is most favorable for applications where the ionization rests on one cathode for long periods of time, such as in *standby*.

Operation near the upper current limit provides the greatest transfer sensitivity and highest-intensity light output. However, caution must be exercised to assure that the maximum permissible current is not exceeded, since operation above this limit may cause a detrimental change in transfer sensitivity and a reduction in the light transmittance of the glass envelope.

In general, a high anode supply voltage and high anode load resistor have these advantages:

- 1| High supply voltage assures *cold state* ionization;
- 2| The combination of high voltage and high resistance creates a reasonably good constant-current-supply which keeps the anode current within limits despite the wide voltage excursions of the cathodes and guides;
- 3| High-impedance anode source permits the guides to be driven by comparatively high impedance generators.

High-speed counter tubes operating at rates between 50 and 100 Kpps are particularly affected by stray circuit capacitance. All such capacitance should be minimized, and the anode resistor should be mounted not more than 1/2" away from the anode terminal.

Guide Pulse and Bias Amplitude /The voltage required to transfer the ionization from an ionized electrode to a primed electrode is known as the *transfer* voltage and is specified for both *high-speed* and *low-speed* counter tubes at 35 volts. On new tubes the transfer will frequently occur at less than 10 volts, but this parameter increases with tube life, therefore a safety factor is allowed.

Transfer of the ionization from a Guide No. 2 rod to the nearest cathode is the result of the positive guide bias, since the decay of the Guide No. 2 pulse leaves the bias as the only potential difference between these two elements. For proper operation, the guide bias must, therefore, be equal to or greater than the 35 volts specified for transfer. A second function of the guide bias is to prevent the ionization from returning from a Guide No. 2 rod to a neighboring Guide No. 1 rod. Guide bias also has an upper practical limit of approximately 60 volts. Above this value excessive sublimation occurs be-

tween cathodes and guides resulting in shortened tube life and possible *sticking* problems.

To complete a transfer cycle, the guides must be driven more negative than the cathodes by at least the minimum specified transfer voltage. With the guides biased at the recommended value of +35 volts, the amplitude of the guide drive pulses must therefore be 70 or more volts negative. Specified minimum values for the various counter tubes range from 70 volts to 85 volts depending on the tube type. The maximum value of guide pulse voltage is generally 140 volts negative. At more negative voltages, breakdown between elements (exclusive of the anode) may occur resulting in permanent damage to the counter tube.

Guide Pulse Width and Phasing /A minimum period of time is necessary for counter tubes to perform the various stepping operations. When the Guide No. 1 pulse is applied, finite times are required to ionize the primed guide rod, deionize the neighboring cathode, prime the adjacent Guide No. 2 rod and remove the prime from the previous Guide No. 2 rod. In like manner, when Guide No. 2 is pulsed, time is required for the primed Guide No. 2 rod to ionize, the Guide No. 1 rod to deionize, the following cathode to become primed, and for the prime to leave the previous cathode. As with all gas-filled devices, ionization and deionization each require a matter of several microseconds. Moreover, several of the necessary functions occur in sequence rather than simultaneously since one is a result of another, i.e., a guide rod must ionize before its neighbor begins deionizing, and removing the prime from a cathode only begins after the neighboring guide rod is deionized. The ionization must rest on a cathode for a period of time to allow the prime to leave the Guide No. 1 rod which has just been passed in the transfer. If the rest period is too short, the ionization may move back to this rod when the next Guide No. 1 pulse is applied instead of moving ahead to the next Guide No. 1 rod. After the transfer is complete the ionization will then be back on the cathode it started from and an apparent *sticking* problem results. This rest period must be added to the guide pulse widths to determine the minimum period for one transfer cycle, and hence, the maximum frequency of tube operation.

Low-speed counter tubes require a minimum pulse of 60 microseconds width for each guide. *High-speed* types require a minimum pulse of 4

microseconds width for each guide. Proper operation also demands that the guide pulses overlap or that the leading edge of the Guide No. 2 pulse coincide with the trailing edge of the Guide No. 1 pulse. For *low-speed* tube types, overlap must be limited to a fraction of the guide pulse width. *High-speed* types require a minimum pulse overlap of 2 microseconds.

The overlapping requirement is most critical on the *high-speed* counter tubes operating at or near 100 Kpps. Without the proper overlap, the ionization is not allowed to rest on a cathode for a sufficient time to result in stable operation. For example, the period of a 100-Kc signal is ten microseconds. With adjacent four-microsecond pulses, the double-pulse duration is eight microseconds, leaving only a two-microsecond rest on the cathodes which is insufficient. The same pulses with a two-microsecond overlap result in a six-microsecond double-pulse and a four-microsecond rest on the cathodes which produces satisfactory performance. Figure 4 illustrates several typical guide-drive waveforms and the phasing between them.

Figure 4A is an ideal double-pulse for minimum requirements on a *low-speed* counter tube. The glow must rest on each guide at least 60 microseconds, hence a 120-microsecond double-pulse duration is a minimum requirement. As the pulses are widened, some overlap is allowed. There is no limit on maximum guide pulse width. Care is only required on the minimum pulse width to meet maximum frequency requirements.

Figure 4B is an ideal double-pulse for minimum requirements of *high-speed* counter tubes.

Figure 4C illustrates pulses which will not transfer properly since they are not adjoining. A very slight gap between the trailing edge of the Guide No. 1 pulse and the leading edge of the Guide No. 2 pulse can be tolerated for *low-speed* counter tubes if it is a small portion of the required 60-microsecond pulse. *High-speed* counter tubes, however, with a much faster response time require truly adjoining (leading edge of Guide No. 2 pulse and trailing edge of Guide No. 1 pulse) or overlapping pulses.

Figure 4D illustrates pulses with excessive overlap. Such a condition will fail to operate either *high-speed* or *low-speed* counter tubes since the Guide No. 1 rod does not hold the ionization long

enough for its neighboring cathode to deionize before the Guide No. 2 pulse is applied. The result will be ionization of the wrong Guide No. 2 rod (the one nearest the incompletely deionized cathode).

Figure 4E is a typical sinewave drive pulse for a high-frequency counter tube. Transfer will be successful if the two negative peaks are 4-microseconds or more apart and the amplitude of the common valley between the two peaks remains within the minimum transfer requirements of the tube. The latter requirement remains essential as the peaks are separated in time.

Figure 4F shows typical pulses for *high-speed* tubes which deviate from the ideal. The Guide No. 2 pulse is slightly greater in amplitude than the Guide No. 1 pulse. This is often advantageous to assure positive transfer from Guide No. 1 to Guide No. 2 and prevent the condition described next.

Figure 4G illustrates a pair of drive pulses which are somewhat similar to those shown in Figure 4F. However, the pulse decay time of Guide No. 2 is faster than Guide No. 1 resulting in crossover. If the crossover occurs below the minimum transfer voltage of the tube, the ionization will go from Guide No. 2 back to Guide No. 1 instead of advancing to the next cathode.

Cathode Termination /The cathode of a counter tube can be returned directly to B- potential, Figure 5A. However, in many applications, an output signal is desired to control an external circuit and/or for coupling one counter tube to the next where several are used in cascade. Such signals can be obtained readily from the cathodes (one or all) of counter tubes by employing series resistors in the return circuits, as shown in Figure 5B.

The inherent characteristics of counter tubes do place some restrictions on how the cathodes can be terminated. For all practical purposes, the anode supply voltage and anode resistor determine the anode current. With these two parameters fixed, the anode current may be considered essentially constant during operation. Since the majority of the anode current is carried by a single cathode (between transfer operations), the voltage drop across a cathode resistor is approximately equal to the product of the anode current and resistance of the cathode resistor. Tube voltage drop remains quite constant over the rated current range of a tube. Therefore, the anode voltage of an ionized tube,

when referred to any *cold* cathode, equals the tube drop plus the drop across the resistor of the ionized cathode. The anode voltage, then, varies directly as the voltage drop across the cathode resistor. As the value of the cathode resistor is increased, the anode voltage rises until it reaches the breakdown voltage to one of the *cold* cathodes and jumping occurs. Such undesirable transfer can occur whenever the voltage between two cathodes exceeds the differential between unprimed breakdown voltage and tube drop. Observing the maximum specified value of cathode resistor will avoid this situation. For *high-speed* counter tubes the value is 50,000 ohms, and for *low-speed* tubes it is 150,000 ohms.

In Figure 5C the cathode is shown returned through a resistor to a voltage which is more negative than B-. This arrangement is sometimes used when output is required from only one cathode, but a large signal is preferred. This system effectively increases the output signal by the voltage of the negative return. The negative return supply should be limited to approximately twenty volts, and the minimum guide-pulse amplitude should be increased by the value of the negative supply. If the negative drive pulse is not sufficient to drive the guides below the negative supply by the transfer voltage of the tube, current sharing may occur between the cathode and a neighboring guide thus priming two guide rods of the opposite group, resulting in *sticking*.

It is essential that the potential of an ionized cathode remain below the guide bias voltage. It is possible with *low-speed* types, when using the maximum value of cathode resistor returned to B- potential, that a cathode will attempt to run as high as 75 volts positive. The immediate result is a sharing of the ionization between the cathode and a neighboring guide. This results in priming two guide rods of the opposite group which, when pulsed, allows the ionization to transfer in either direction. The best remedy for the condition is to return the cathode resistor to a source of negative voltage and, if necessary, reduce the value of the cathode resistor. Maximum positive cathode voltage should be at least five volts below the guide bias.

The shape of the cathode output pulse is influenced by the shape of the input pulses to the guides, i.e., the leading edge of the cathode pulse resembles the trailing edge of the Guide No. 2 pulse; the trailing edge resembles the leading edge of the

Guide No. 1 pulse. The width of the cathode pulse equals the time between cycles.

The signal obtained from a cathode will not drive another counter tube directly. A coupling circuit which provides amplification, inversion, and possibly shaping must be used. Several suitable circuits are presented and discussed in the next section.

Reset Voltage/It is frequently desired to return the ionization to a certain cathode, such as the zero cathode at the end of a counting cycle. This can be done by applying a negative pulse of sufficient amplitude to the reset cathode to cause the ionization to transfer from the ionized cathode directly to the reset cathode. The amplitude of the reset pulse is specified as -120 volts minimum for both *low-speed* and *high-speed* counter tubes. The minimum pulse width for *low-speed* types is 50 microseconds; for *high-speed* types, 4 microseconds.

There are several different circuits or ways in which reset can be accomplished. These are discussed in the next section of this handbook.

Drive, Coupling and Reset Circuits

General Design Considerations/A multitude of different circuits are used to drive the counter tube guides in various applications. No single circuit can fulfill all requirements and yet be practical from a cost standpoint. Before attempting to design a counter tube circuit for a particular application, serious consideration should be given to all of the functions the tube will be expected to perform and to the characteristics of the signal which will drive the input stage (and indirectly the following stages if more than one is required). The factors influencing the circuitry are:

- 1|The frequency, amplitude, and waveshape of the signal to be counted.
- 2|The load circuit which the first counter tube will work into and the required amplitude of the output.
- 3|The reset functions of the counter tube.

The characteristics of the signal to be counted determine the method in which it should be handled before being applied to the counter tube guides. The frequency dictates whether a *low-speed* tube is satisfactory or if a *high-speed* tube is required. The amplitude and polarity of the signal

must be correct to drive the tube. One or both of these factors can often be corrected by amplification and inversion if necessary. The waveshape of the signal requires the most consideration. If pulses of very short duration compose all or part of a signal, a shaping circuit is necessary to lengthen the pulses to the time required for proper counter tube operation. Signals with long rise-times must be shaped to produce the proper phasing between the two guide pulses. In general, a wide frequency range can be covered with fairly simple circuitry if the signal is either a square wave or a sharp pulse. Simple circuitry can also be used with a fixed-frequency sine-wave signal. However, a sinewave drive with a wide frequency range immediately requires some form of shaper circuit. Signals of a steady repetitive nature are often more easily handled than random bursts at varying intervals.

The load circuit which the counter tube will work into must be considered. A single counter tube used as a time-base or for frequency dividing merely delivers a voltage pulse to some form of control mechanism and is not influenced appreciably by the load. The drive circuitry must simply be capable of indexing a single counter tube. However, if the tube is the first of several cascaded tubes the requirements become more involved. The following stages must differentiate the output from the first counter tube for drive purposes. If the rise-time of the output pulse is long, the differentiated pulse will be low in amplitude and may require amplification. It should be remembered that the leading edge of the voltage on a cathode resembles the trailing edge of the Guide No. 2 pulse; the trailing edge of the cathode voltage resembles the leading edge of the Guide No. 1 pulse; and the width of the cathode signal equals the time between index cycles. For this reason, shaping a signal prior to the first stage of a cascaded counter often simplifies coupling circuitry between subsequent stages. A steep wave-front follows through the entire chain resulting in improved operation.

Figure 6 illustrates an excellent circuit for fast guide-bias recovery following a driving pulse without appreciable loading of the driving source. The guides are clamped to the guide bias supply by current from Ebb flowing through resistors (R), guides G1 and G2, and the low forward resistances of diodes (D). A negative guide pulse will cause the majority of the anode current to flow through the

guide and coupling capacitor (C) without drawing current from the bias supply due to the high reverse resistance of diodes (D). Following the driving pulse, the guides return rapidly to the guide bias potential with the aid of the bleeder current through resistors (R) which may be as much as 1 Ma.

The amplitude of the cathode output signal is normally in the range of 25 to 30 volts positive with the cathode resistor returned to B-. The effective amplitude can be increased by returning the cathode resistor to a more negative potential as illustrated in the preceding section under "Cathode Termination." This arrangement is particularly useful to compensate for the reduction in amplitude with differentiation when the rise-time of the cathode signal is long.

Reset/Resetting a single counter tube to zero poses very few problems. A negative pulse, of proper amplitude and width, applied to the reset cathode is the only requirement. Cascaded stages, however, require some consideration. Several excellent techniques are available and are explained in conjunction with the composite illustration presented as Figure 7. Counter tubes can be reset either by manual or automatic means via relays, thyratrons, and various pulse circuits.

Referring to Figure 7, switch S1 when opened, places all the guides and cathodes, except the zero cathode (K0), at a positive potential thus raising the anode voltage until *cold* breakdown occurs to the zero cathode.

Switch S2 places a negative pulse on the reset cathodes resulting in *cold* breakdown. Counter tube V4 uses cathode K9 as the reset element in this case since in returning to normal conditions cathode K0 of tube V2 places a positive pulse on the grid of triode V3 and transfers counter tube V4 to produce a zero reading. A chain of counter tubes without this feature would result in a reset reading of 011111...

Switch S3 resets counter tube V2 by driving the cathode of triode V3 negative. The grid of V3 then acts as a diode plate and follows the cathode negative. The grid of V3 draws the zero cathode (K0) of counter tube V2 negative until it resets. As the negative voltage is removed from the cathode of V3 the tube generates a positive pulse which does not affect the following counter tube V4.

Practical Drive and Coupling Circuits/The drive and coupling circuits presented next are a few basic designs which, if properly used, can satisfy a

large percentage of counter tube applications. They do not attempt to cover all applications since this field is open to an unlimited number of design ideas. Possible revisions to the included circuits are numerous to satisfy individual applications even though the basic operating principle remains unchanged.

Basic Vacuum Tube Driver/Coupler/Figures 8 and 9 show a basic triode circuit that can be used to drive a single counter tube or as a coupler between two cascaded counter stages. When driven with a positive pulse of the minimum duration required by the counter tube (60 μ sec. for *low-speed* tubes up to 4 Kpps, and 4 μ sec. for *high-speed* tubes up to 100 Kpps) it will operate up to the maximum specified rate of the tube being used. The values of R and C can be changed to delay the Guide No. 2 voltage the proper amount for the type counter tube used. For *high-speed* types R = 33K ohms, and C = 50 pf assures operation through 100 Kpps. The circuit can also be driven by fixed-frequency sine-waves with the proper adjustment of R and C for the frequency of the driving signal.

When used as a coupling circuit between counter tube stages, the 0.5 μ f input coupling capacitor is reduced in value so that it will differentiate the output pulse from the cathode of the preceding stage. The circuit as shown produces a Guide No. 2 pulse slightly greater in amplitude than the Guide No. 1 pulse. For certain types of drive-waves this helps assure positive transfer of the ionization by effectively increasing the Guide No. 2 delay.

Basic High-Speed Driver/Coupler/Figure 10 is a variation of Figure 8, but with minor changes, and indicates the flexibility of the basic circuits to obtain the desired results. The triode amplifier is operated with cathode bias (heavily by-passed) instead of fixed bias, which reduces the number of different voltages required. The circuit is designed for a *high-speed* counter tube and uses a damped inductance to delay the Guide No. 2 pulse. For *high-speed* tubes this arrangement has several advantages. The delay is constant, the Guide No. 2 pulse is slightly greater in amplitude than the Guide No. 1 pulse, and the decay of the Guide No. 2 pulse is rapid. For *low-speed* types the inductance required is too large to be economically practical and R/C delay can be used. When opened, the reset switch places all tube elements except the zero cathode at a high positive voltage thus forcing transfer to this element.

Basic Transistorized Driver (Overdriven Amplifier)/Driving pulses can be formed with overdriven amplifiers where the incoming pulse is differentiated to form the proper output pulse width. Such a circuit is shown in Figure 11. The output pulse of the first transistor is coupled to the base of the second transistor through a differentiating capacitor. There is no effect from the pulse leading edge, but the differentiated trailing edge drives the transistor to cutoff producing a negative pulse on the collector. The negative pulses are coupled to the counter tube guides and index the tube. Capacitor C1 must be adjusted for the amplitude and rise-time of the driving signal to provide the required output pulse width of 60 microseconds.

This same circuit can be used for driving *high-speed* counter tubes by reducing the size of both capacitors C1 and C2. Some difficulty may be encountered reaching 100 Kpps operation since the transistor turn-on and turn-off times are too slow to produce well formed pulses in the 3-microsecond region particularly when the input is derived from a differentiated pulse. Improvement is possible by including a pulse forming network before the stage required to go to 100 Kpps. Slower stages may be operated with wider pulses where long rise- and fall-times become less important.

Both transistors are in a conducting state when this circuit is not counting. This is a drain of approximately 14 Ma on the power supply with the circuit values shown. It is possible to increase the collector resistance to lower this current, but it is done at the expense of rise- and fall-times so each circuit design becomes a compromise between current drain and pulse waveshape.

Narrow-Band Sinewave Driver (100 Kc) Figure 12 is a 100-Kc sinewave drive circuit which uses a triple triode tube such as the Sylvania Types 6EZ8 or 6J9. The operating frequency range of this circuit is quite limited, but it is excellent for frequency dividing from a standard signal source such as a crystal controlled 100-Kc oscillator. The operating frequency can be varied by changing the time constant of capacitor C and grid resistor R. With proper values it will operate *low-speed* counter tubes as well as *high-speed* types. The arrangement illustrated operates the cathodes of the counter tube 120 volts above ground potential and the B+ for the driver tubes 170 volts positive, thus automatically biasing the guides 50 volts positive. This

eliminates the need for guide coupling capacitors and biasing networks. It also provides simple reset action by connecting the reset cathode to ground and operating it 120 volts below all other cathodes.

Broad-Band Shaper-Driver/Figure 13 is a broad-band shaper-driver which uses a trigger circuit to produce sharp wave fronts. It will also function as a coupler between counter tube stages, but other more simple circuits will serve equally as well in this capacity. The circuit can be driven by any positive signal of a duration longer than the minimum guide pulse width required by the counter tube being used. The output of V1b is a square wave which is differentiated by C1 and R1 to provide a pulse on the grid of the third triode stage V2a. The width of the pulse is determined by the C1/R1 time constant to match the *high-* or *low-speed* counter tube used. Triode stage V2a drives the counter tube as described in Figure 8. Components R2 and C2 determine the delay in the Guide No. 2 pulse and must be adjusted for either the *high-* or the *low-speed* tubes. Using a *high-speed* counter tube with a sinewave input and C1 = .001 μ f, R1 = R2 = 33K, and C2 = 50 pf, the circuit will operate through 100 Kpps.

Short-Pulse Driver for Low-Speed Counter Tubes/When counting pulses of a duration shorter than the minimum guide pulse width specified for a counter tube, it becomes necessary to lengthen the drive pulse. The short pulse driver circuit shown in Figure 14 fulfills this requirement. Triodes VIA and VIB serve as a single-shot multivibrator producing a negative pulse which is fed to Guide No. 1. The width of the pulse will be constant as determined by C1 and R1. The Guide No. 1 pulse is also fed to grid of VIC through a differentiating network. The leading edge of the Guide No. 1 pulse results in a negative pulse on the grid of VIC, which is ineffective since VIC is already cut-off due to the common cathode resistor. The trailing edge of the Guide No. 1 pulse, however, results in a negative pulse on Guide No. 2 thus advancing the ionization from Guide No. 1. The action results in adjacent (rather than overlapping) pulses on the two guides, as required by *low-speed* counter tubes. This type of pulse "stretching" is encountered primarily with *low-speed* counter tubes requiring a 60- μ sec. guide pulse. The circuit will work, however, with *high-speed* types at lower frequencies. *High-speed* types at the upper frequency

limit would require driving VIC from the plate of VIB, and inserting a 2- μ sec. delay between the plate of VIC and Guide No. 2. Both guides cannot be driven from the plate of VIA since this would interfere with the action of the multivibrator. Typical values for *low-speed* counter tubes are C1 = 150 pf, and R1 = 1M. The +45 volt supply to the triode stages serves as positive bias for the guides. The circuit can be used for coupling two counter tube stages if the input is differentiated to prevent the dwell time on the signal cathode from approaching the recovery time of the multivibrator.

With the components specified, this circuit will operate at a repetition rate of 0-5 Kpps.

Short-Pulse Driver for High-Speed Counter Tubes/Figures 15 and 16 illustrate a blocking-oscillator-type short-pulse driver for *high-speed* counter tubes. Figure 15 shows the NPN circuit and Figure 16 the PNP configuration.

These circuits will operate at counting rates up to the 100-Kpps limit of *high-speed* counter tubes and are capable of being controlled by a wide variety of positive input signals. They may be used as interstage couplers as well as first-stage drivers. The input capacitor should be adjusted for the rise time of the input signal to provide proper oscillator triggering.

Typical Applications

The preceding section of this handbook presented a variety of "building block" driver, coupler, and reset circuits that will satisfy the needs of most straightforward counting applications when tailored by the design engineer to meet individual requirements.

Presented in this section is information in the form of text and circuits representing several "end" applications. In addition to counting, circuits are included which demonstrate the capabilities of the counter tube as a pulse generator, frequency divider, switch, and keyer.

Add-Subtract Counter/Figure 17 shows the circuit for a reversible counter that both *adds* and *subtracts*. Two inputs are provided; pulses fed into one steps the counter forward adding the pulses to the total count. Pulses fed into the other input steps the counter backwards subtracting from the total count.

Both *add* and *subtract* signals are assumed to

be positive going pulses of 13 volts amplitude with a duration of approximately 100 microseconds.

Signals to be added are simultaneously applied to the *add* channel inputs of the *Delay Amplifier* and the *Add-Subtract Switch*. The signals applied to the *Add-Subtract Switch* trigger the binary thereby enabling the *add* channel of the *Interstage Driver* and disabling the *subtract* channel.

The *add* signals applied to the *Delay Amplifier* are delayed in this circuit by a pulse width and are then fed to the *First-Stage Driver*. The output of the *Delay Amplifier* is a positive going pulse with a duration equal to the required Guide No. 1 pulse width. This pulse is coupled directly to transistor T12 which produces the Guide No. 1 pulse. The positive pulse output of the *Delay Amplifier* is also applied to the base of transistor T14 via capacitor C1. The trailing edge of the pulse turns T14 "off" producing a positive voltage on its collector which is coupled to and turns "off" T13, thereby producing the Guide No. 2 pulse. *Subtract* signals operate in a similar manner.

The *Interstage Driver* contains two similar circuits, only one of which will be operating at any one time. Both of these circuits are connected through "or" diodes to the same guide lines; the only difference being that the *add* channel produces signals of G1 then G2, while the *subtract* channel produces signals of G2 then G1. The circuit which will operate is determined by the signal from the *Add-Subtract Switch*. Since the *Add-Subtract Switch* is operated before the signals to be counted are applied to the *First-Stage Driver*, the circuits are set up one pulse width before they can receive an input signal. The *subtract* channel is connected to the "Zero" cathode and the *add* channel is connected to the "Nine" cathode of first-stage counter tube. Both circuits produce pulses when the glow leaves their respective cathodes.

This circuit is presented through the courtesy of Dynapar Corporation, Skokie, Illinois.

Counter Module with Supplementary Visual Readout/In the counter module of Figure 18 counting is performed by a Type 8035 *high-speed* counter tube. A Type 6844A numerical indicator supplements the counter tube to provide direct visual readout. The two devices are coupled via transistors Q1-Q10 which serve as switches for the indicator tube and are triggered by pulses derived

from the cathodes of the counter tube. The driver circuit is designed for a positive pulse input and is comprised of transistors Q11, Q12, and Q13.

This circuit is presented through the courtesy of Digtol Corporation, Houston, Texas.

Telephone Dialing Recorder/The circuit of Figure 19 illustrates a system of recording on counter tubes a telephone number which is dialed.

Removing the handset from the phone closes switch S1 thus energizing the double-pole-double-throw relay and connecting phone terminals "C" and "D" to the -150-volt supply. Closure of the relay applies B+ to the *Recording* counter tube and its driver tube. A momentary negative 150-volt pulse is also applied to the "Zero" cathode of the *Selector* counter tube thus resetting it to zero. The first number is then dialed. As the dial leaves the stop, the normally closed phone switch S2 opens triggering the driver tube for the *Selector* counter tube and advancing the ionization to cathode K1. The positive voltage on the *Selector* counter tube cathode energizes the screen grid of the pentode driver tube for the first *Recording Counter*. It also fires the reset thyatron and returns the ionization of the first recorder to cathode K0. When the dial is released, phone switch S3 opens and closes a number of times depending on the position of the dial when released. Each interruption places a positive pulse on the grids of all the driver tubes for the *Recording Counters*. Since only the first driver is energized it will respond to the pulses, advancing the glow about the first *Recording Counter*, one cathode for each pulse. In similar manner, the subsequent *Recording Counters* and their associated circuitry will be switched-in and will count the pulses for the next numbers dialed. The read-out is a record of the telephone number which was dialed.

Replacing the handset on the cradle opens the relay, thereby removing B+ from the *Recording* counter tubes (which will then deionize), and discharging the reset capacitor for the *Selector* counter tube thus priming it for further use. With proper adjustment, the +300-volt supply can be adjusted so that the *Recording* counter tubes will not ionize until the individual reset thyatrons fire. The recorders then become illuminated in sequence as their turn to record is reached.

This circuit is an excellent illustration of how a counter tube can be used for switching.

Staircase Generator/Counter tubes can be readily used for staircase generators. Figure 20 illustrates such a device which delivers 1000 steps.

Consider first counter tube V1. By connecting equal resistances between successive cathodes, the voltage at cathode K9 will increase in equal steps as the tube is indexed. The result will be a staircase output. Three counter tubes are cascaded with the cathode resistors in each stage increased over those in the preceding stage by a factor of ten. The input to the unit can be driven by a signal generator (sine or square-wave). The period of each step will be determined by the frequency of the generator. Identical shaper-driver circuits are used to drive each of the three stages.

Frequency Divider/Figure 21 illustrates how a counter tube can be used as a frequency divider.

A 12AU7 multivibrator oscillator is used as the signal source to feed the 6C4 counter tube driver stage. The divider switch is shown connected to cathode K5 of the counter tube. The ionization advances from K0 to K5, one cathode for each cycle of driving frequency. The output pulse from K5 fires the 2D21 thyatron which resets the counter tube to K0. If the output is taken across K1, the output will be a positive pulse with a repetition rate of one fifth the driver frequency. In a similar manner, the driving frequency can be divided by any factor up to *ten*. For a single dividing factor less than *six* it may be possible to combine cathodes for simplification. As an example, to divide by *three*, cathodes K2, K5, and K8 could be connected together as output cathodes, and the reset generator would fire only on K9. To divide by *five*, cathodes K5 and K0 could be common output cathodes and a reset generator would not be necessary.

This technique has various uses. A 60-cycle power line frequency can be reduced to one pulse-per-second. A crystal controlled oscillator can be subdivided into a needed frequency. A constant-percent duty-cycle can be provided by using the signal from one or more cathodes.

Electronic Switch/Figure 22 is a basic circuit which demonstrates how a counter tube can be used for switching. The guide pulse generator is an L/C circuit comprised of capacitor C1 and relay RY1. The ionization circulates continuously about the counter tube cathodes. The cathodes of the counter tube are connected in pairs and terminate in neon lamp relaxation oscillators. As the ionization ad-

vances from cathode to cathode, the respective oscillators are activated and their outputs appear sequentially across the transformer connected in the anode circuit. The relaxation oscillator is a convenient means of generating signals of different frequencies for the purpose of demonstration. In actual application, the source of the signals applied to the cathodes may take various forms.

Electronic Keyer/The circuit shown in Figure 23 is an electronic key for use in sending code; it provides equally timed dots and dashes.

The basic principle consists of an oscillator driving a counter tube through a suitable switching system to advance the glow in either direction. Homing to one particular cathode is achieved by means of a thyatron used for resetting. The ionization advances one cathode and is then reset for a "dot" and advances three cathodes in the opposite direction and is then reset for a "dash." A common resistor in the signal cathode lead of the counter tube gates the screen of a pentode amplifier tube, the grid of which is excited by the tone frequency. Output is taken from the plate of the pentode.

Referring to the circuit, triode section VIA of the 6U8 acts as a blocking oscillator to drive the counter tube. The frequency can be varied via R1 to suit the operator's sending speed. The 6BU8 tube, along with its circuitry and the key, serves as the switching device and counter tube driver. Both sections of the 6BU8 are normally cutoff. Closing the key in either direction energizes one section of the 6BU8 allowing the oscillator to drive the counter tube. Once energized, a 6BU8 section remains conducting until cutoff by the reset pulse. When the counter tube glow has advanced to either cathode K3 or K9 the 2D21 thyatron tube fires causing a negative reset pulse on cathode K5 which de-energizes the 6BU8. While the glow is on either cathodes K4, K6, K7, or K the screen of V1B (6U8 pentode section) is positive and the tube conducts. A relaxation oscillator in the grid of V1B provides a tone for aural monitoring, and the output is heard on a speaker connected to the plate circuit.

Specifications

Table II lists the mechanical data, ratings, operating characteristics, and pin connections for Sylvania counter tubes. Figure 24 shows their over-all dimensions and the pin designations.

TABLE II/SPECIFICATIONS

TUBE TYPE	6476A	8353	6802	6879	8035	6910	6909	7155
MECHANICAL DATA								
Mounting Position	Any	Any	Any	Any	Any	Any	Any	Any
Zero Position (Cathode 10)								
Aligned with Pin No.	12 ± 10°	**	6 ± 10°	5 ± 10°	**	12 ± 10°	6 ± 10°	5 ± 10°
Bulb	T11	T9	T9	T5½	T9	T11	T9	T5½
Base	Modified Duodecal*	13 Pin*	Octal	7 Pin Min.	13 Pin*	Modified Duodecal*	Octal	7 Pin Min.
RATINGS (Absolute Values)								
Input Frequency Range (Kpps)	0-4	0-4	0-4	0-5	0-50	0-100	0-100	0-100
Max. Total Anode Current (mA)	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8
Min. Total Anode Current (mA)	0.3	0.3	0.3	0.3	0.65	0.6	0.6	0.6
Min. Anode Supply Voltage (Vdc)	350	350	350	350	400	400	400	400
Min. Transfer Voltage (Vdc)	35	35	35	35	35	35	35	35
Max. Voltage Between Electrodes								
Other than Anode (V)	200	140	140	140	140	140	140	140
Max. Ambient Temperature (°C)	60	60	60	60	60	60	60	60
OPERATING CHARACTERISTICS (Typical)								
Anode Supply Voltage (Vdc)	+350	+350	+350	+350	+400	+400	+400	+400
Nominal Tube Drop (V)	187	187	187	187	235	235	235	235
Min. Guide Bias (Vdc)	+35	+35	+35	+35	+35	+45	+45	+45
Min. Square Double Pulse Drive Amplitude (V)	-75	-75	-75	-75	-70	-85	-85	-85
Min. Square Double Pulse Duration (Each) (μsec)	60	60	60	60	4	4	4	4
Min. Forced Reset Pulse Amplitude (V)	-120	-120	-120	-120	-120	-120	-120	-120
Min. Reset Pulse Width (μsec)	50	50	50	50	4	4	4	4
Max. Cathode Load Resistor (Ohms)	150K	150K	150K	150K	50K	50K	50K	50K
PIN CONNECTIONS								
1	Cathode 0	Cathode 0	Common Cathode	Cathode 8	Cathode 0	Cathode 0	Common Cathode	Cathode 8
2	Cathode 9	Cathode 9	Cathode 5	Guide 1	Cathode 9	Cathode 9	Cathode 5	Guide 1
3	Cathode 8	Cathode 8	Guide 1	Common Cathode	Cathode 8	Cathode 8	Guide 1	Common Cathode
4	Cathode 7	Cathode 7	Anode	Guide 2	Cathode 7	Cathode 7	Anode	Guide 2
5	Cathode 6	Cathode 6	Guide 2	Cathode 0	Cathode 6	Cathode 6	Guide 2	Cathode 0
6	Cathode 5	Cathode 5	Cathode 9	Cathode 9	Cathode 5	Cathode 5	Cathode 9	Cathode 9
7	Cathode 4	Cathode 4	Cathode 0	Anode	Cathode 4	Cathode 4	Cathode 0	Anode
8	Cathode 3	Cathode 3	Cathode 8		Cathode 3	Cathode 3	Cathode 8	
9	Cathode 2	Cathode 2			Cathode 2	Cathode 2		
10	Cathode 1	Cathode 1			Cathode 1	Cathode 1		
11	Guide 2	Guide 2			Guide 2	Guide 2		
12	Guide 1	Guide 1			Guide 1	Guide 1		
13	Anode	Anode			Anode	Anode		

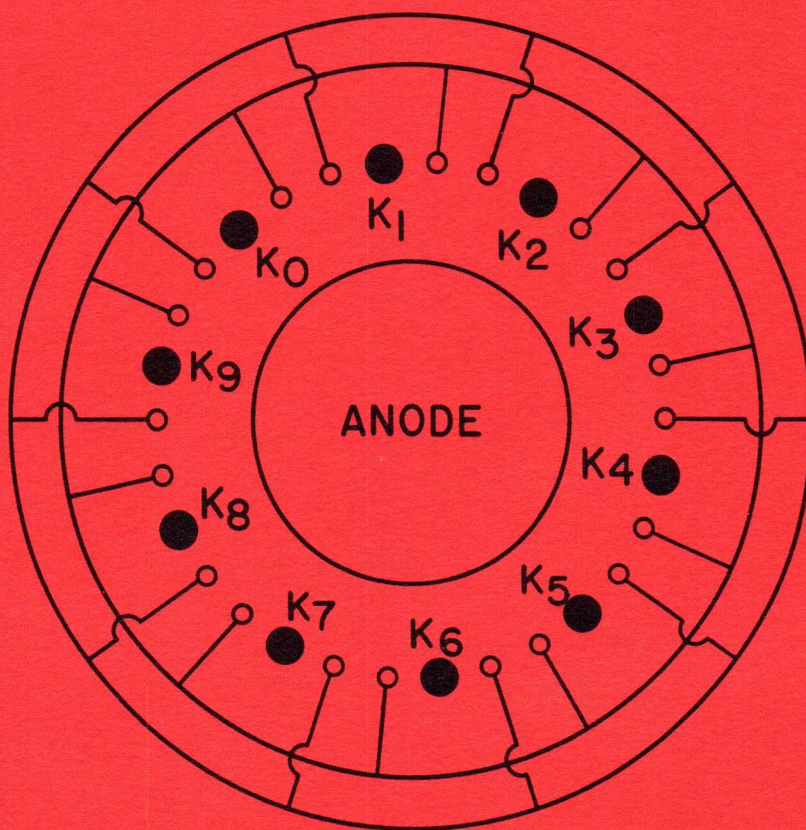
* The special sockets for these bases are available from Sylvania Electric Products Inc., 1035 Westminister, Williamsport, Pennsylvania:

Tube Type	Socket Part No.
8035	70-780-1
8353	70-780-1
6476A	7460-0008
6910	7460-0008

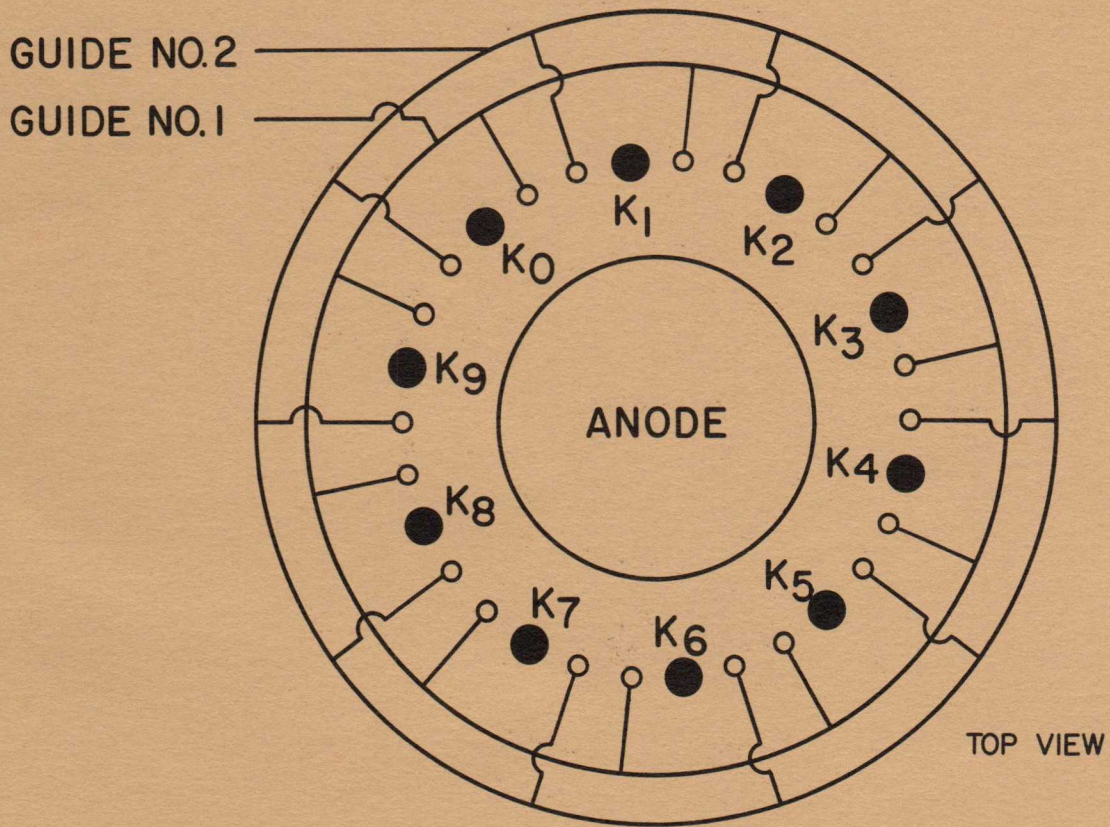
** Centered between Pins 12 and 13 ± 10°.

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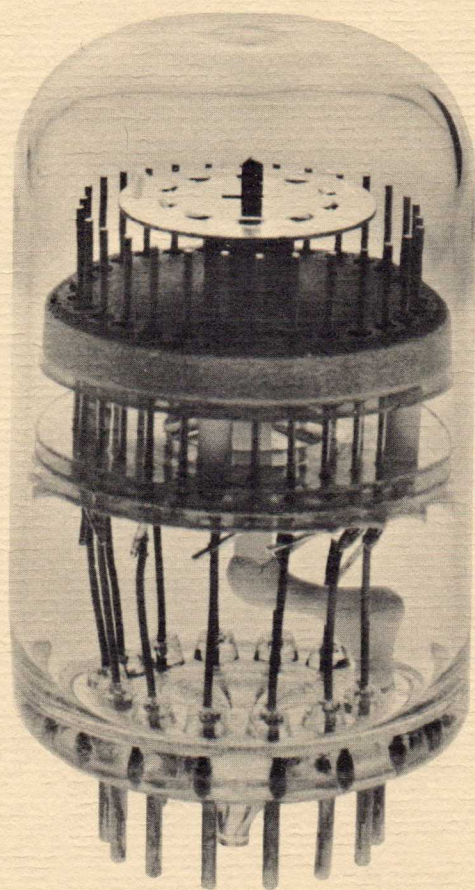
Circuits



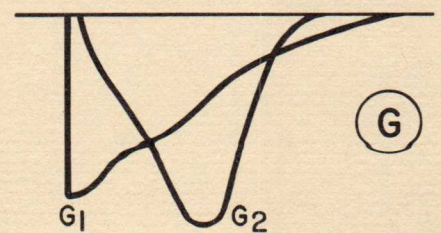
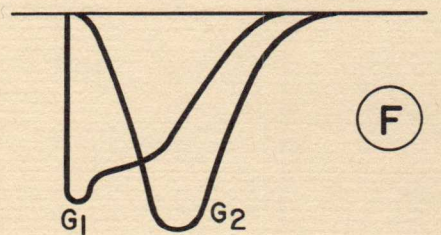
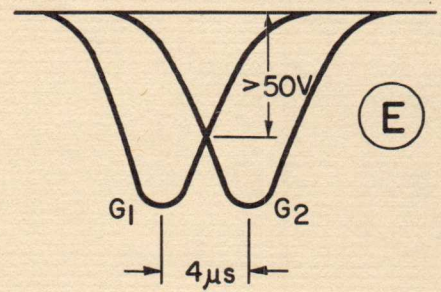
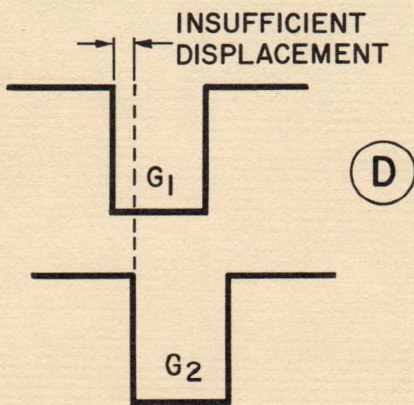
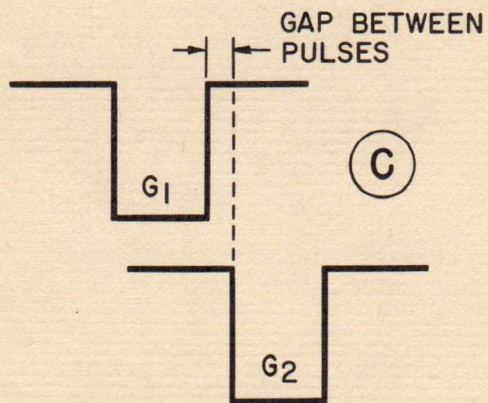
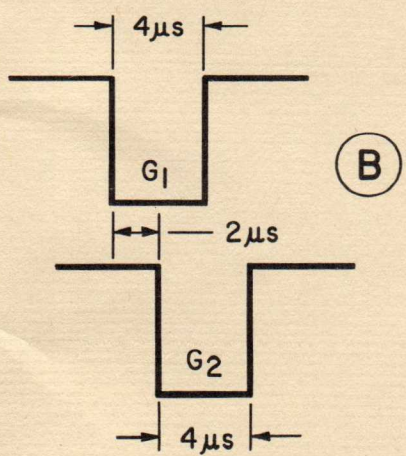
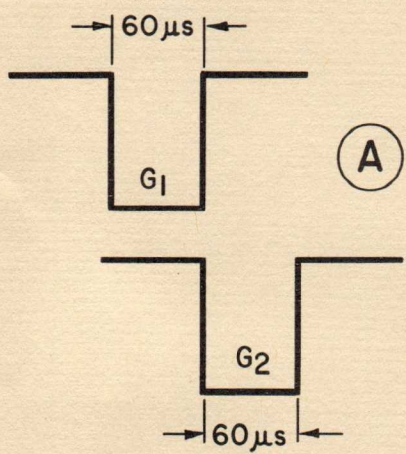
2|Pictorial diagram of counter tube. Diagram is basic to all tube types.



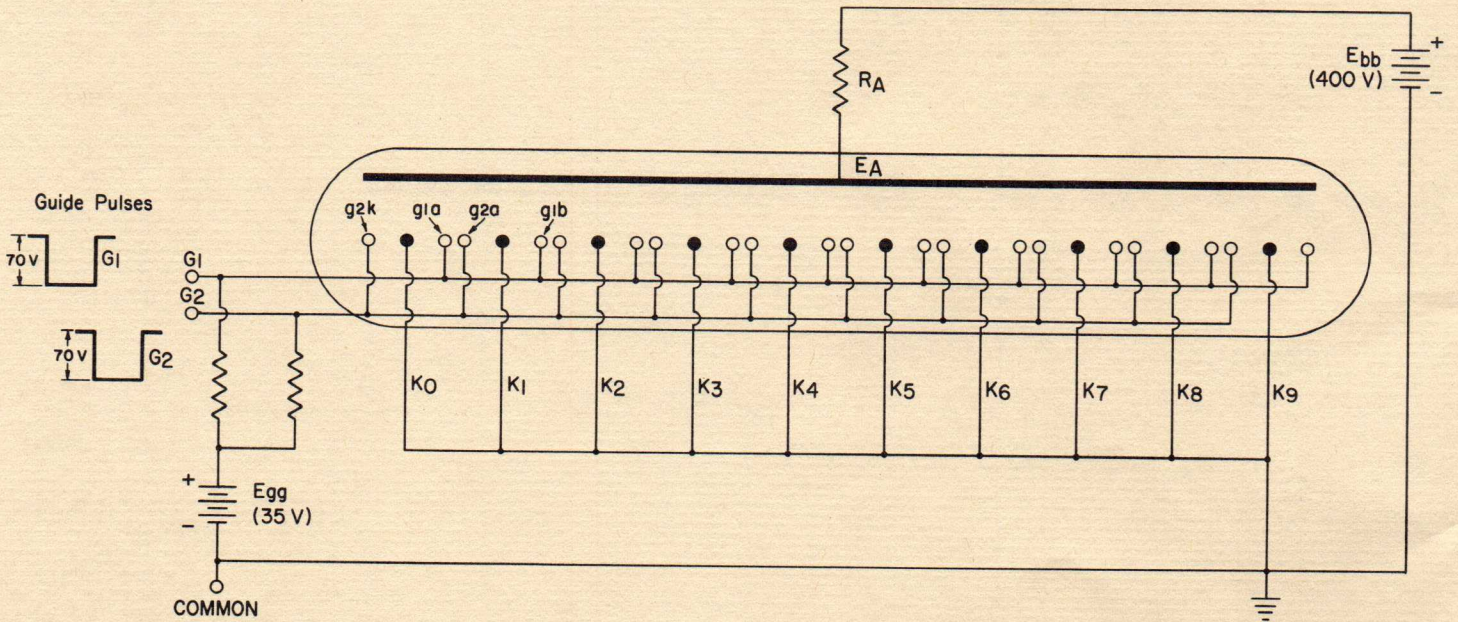
1|Sylvania 8035 counter tube.



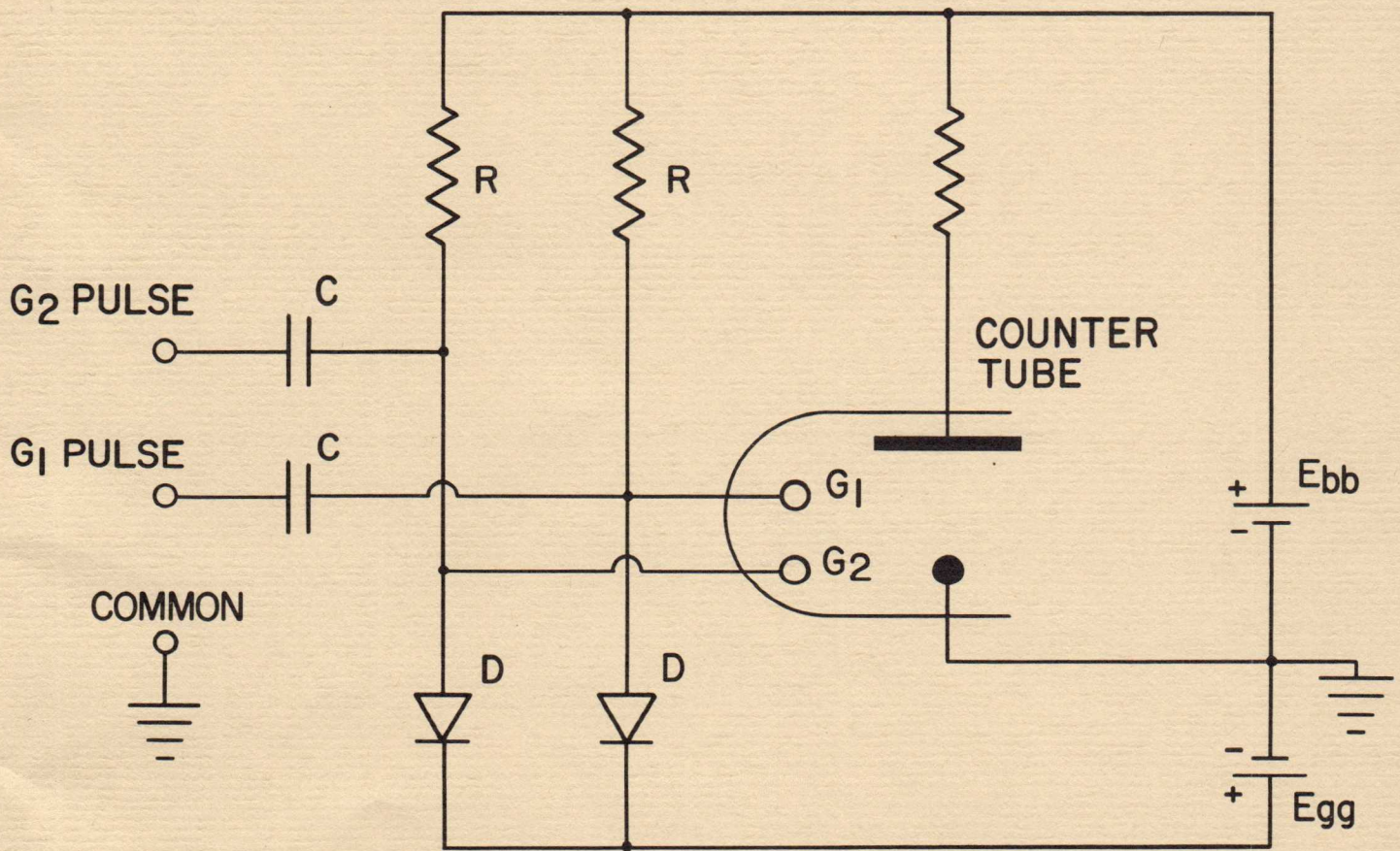
4|Guide pulse waveforms.



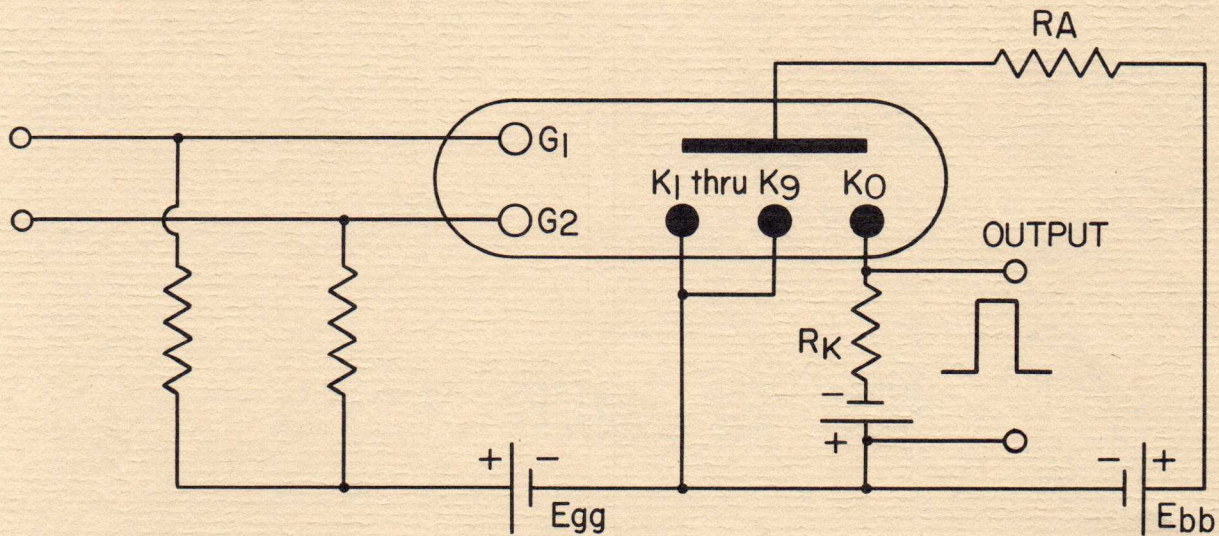
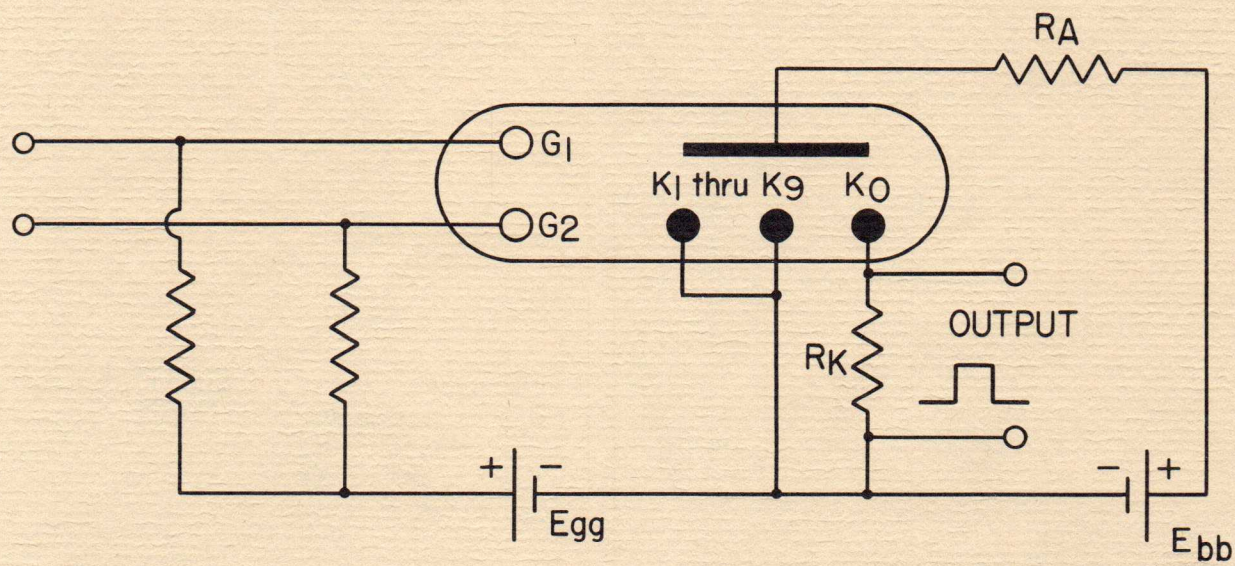
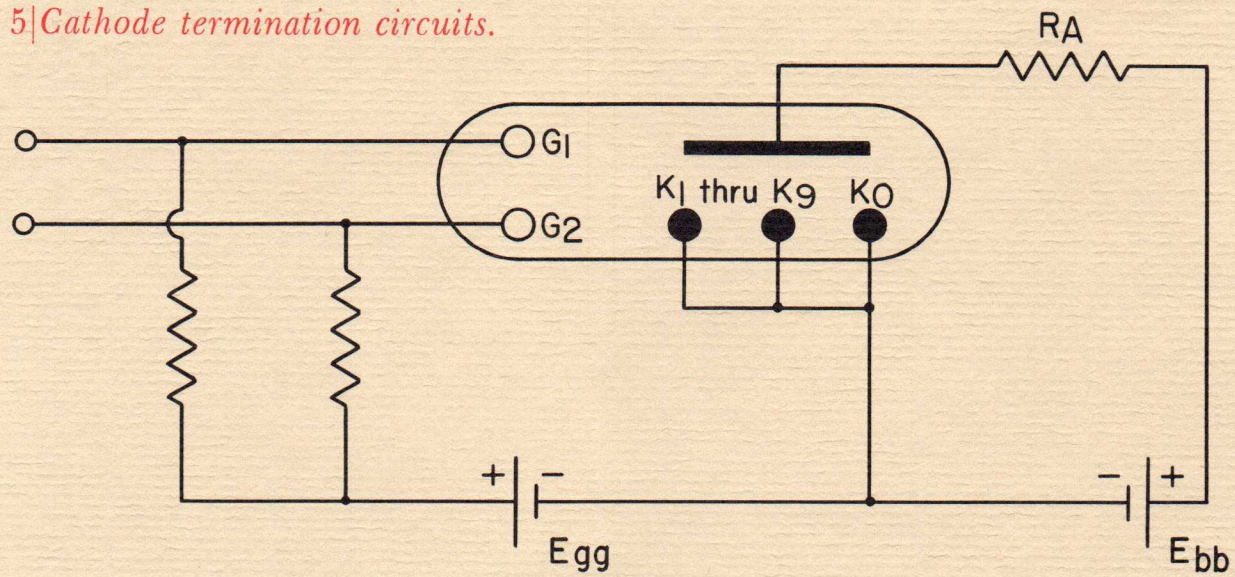
3|Basic counter tube circuit.



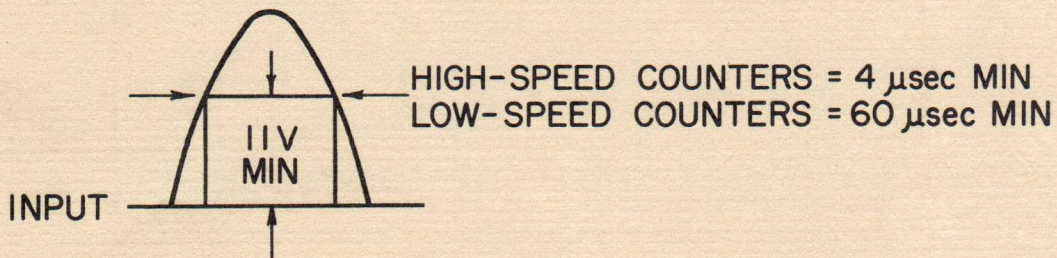
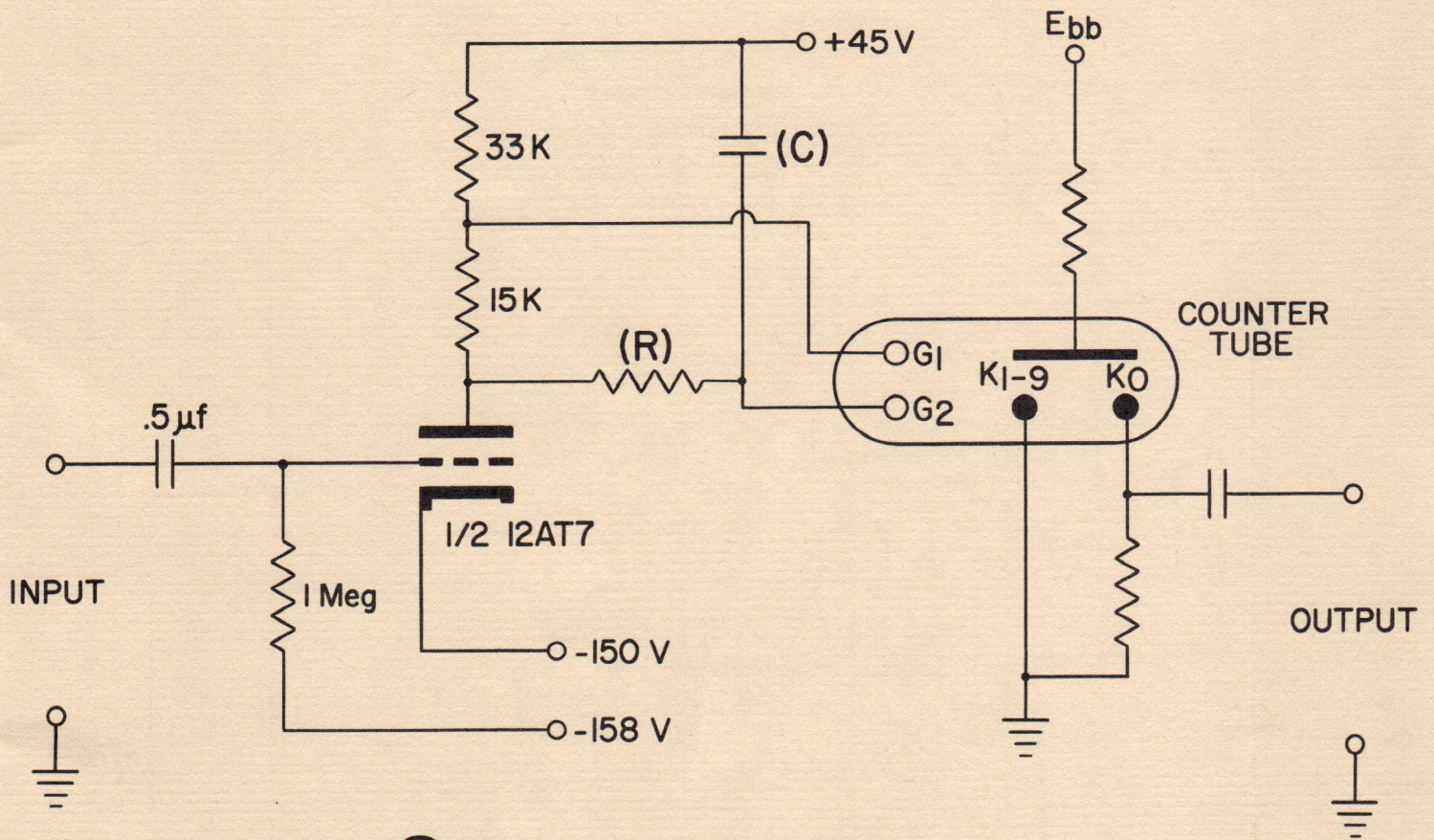
6| *Guide circuit for fast bias recovery.*



5| Cathode termination circuits.

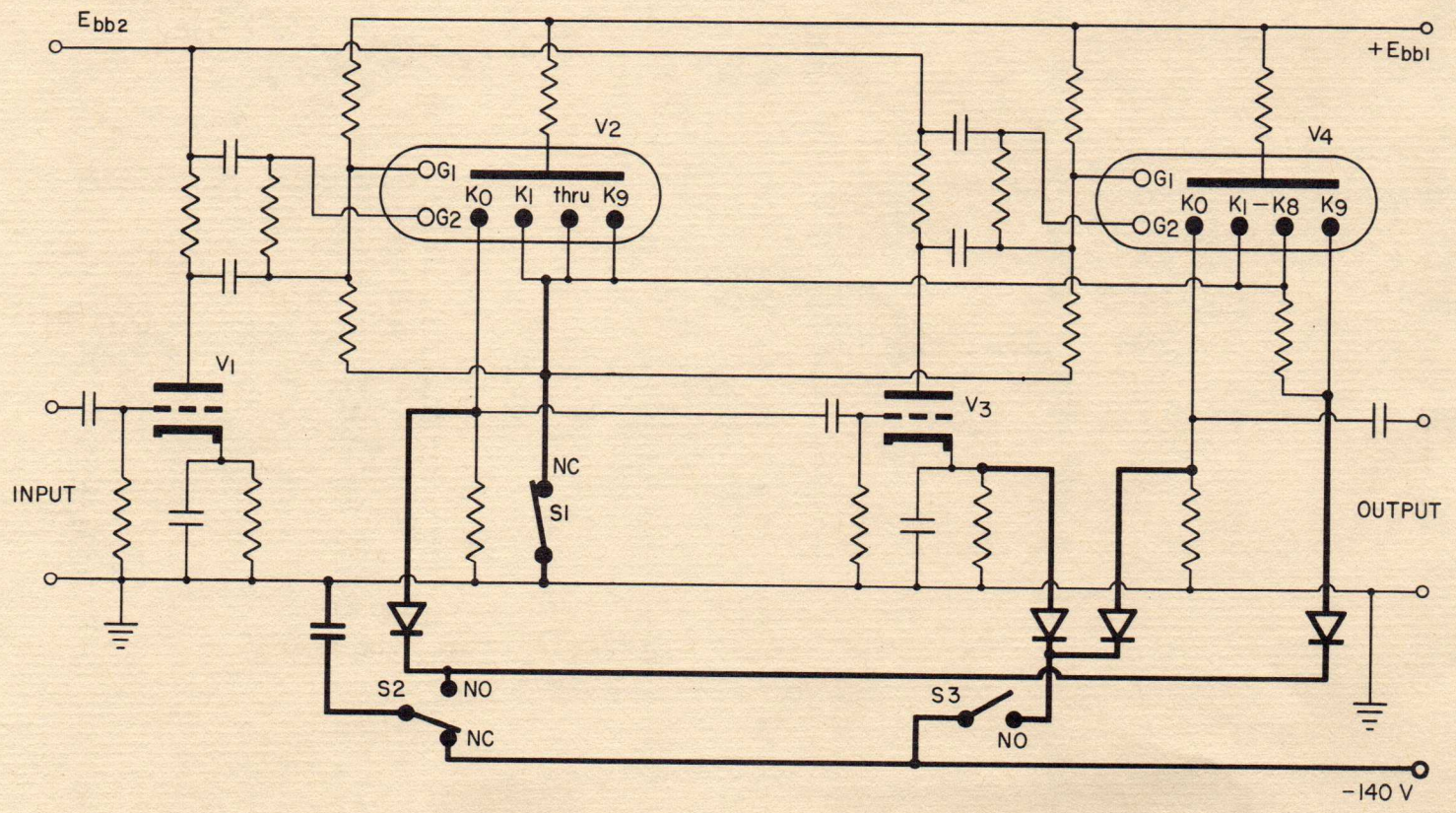


8|Basic vacuum tube driver/coupler.

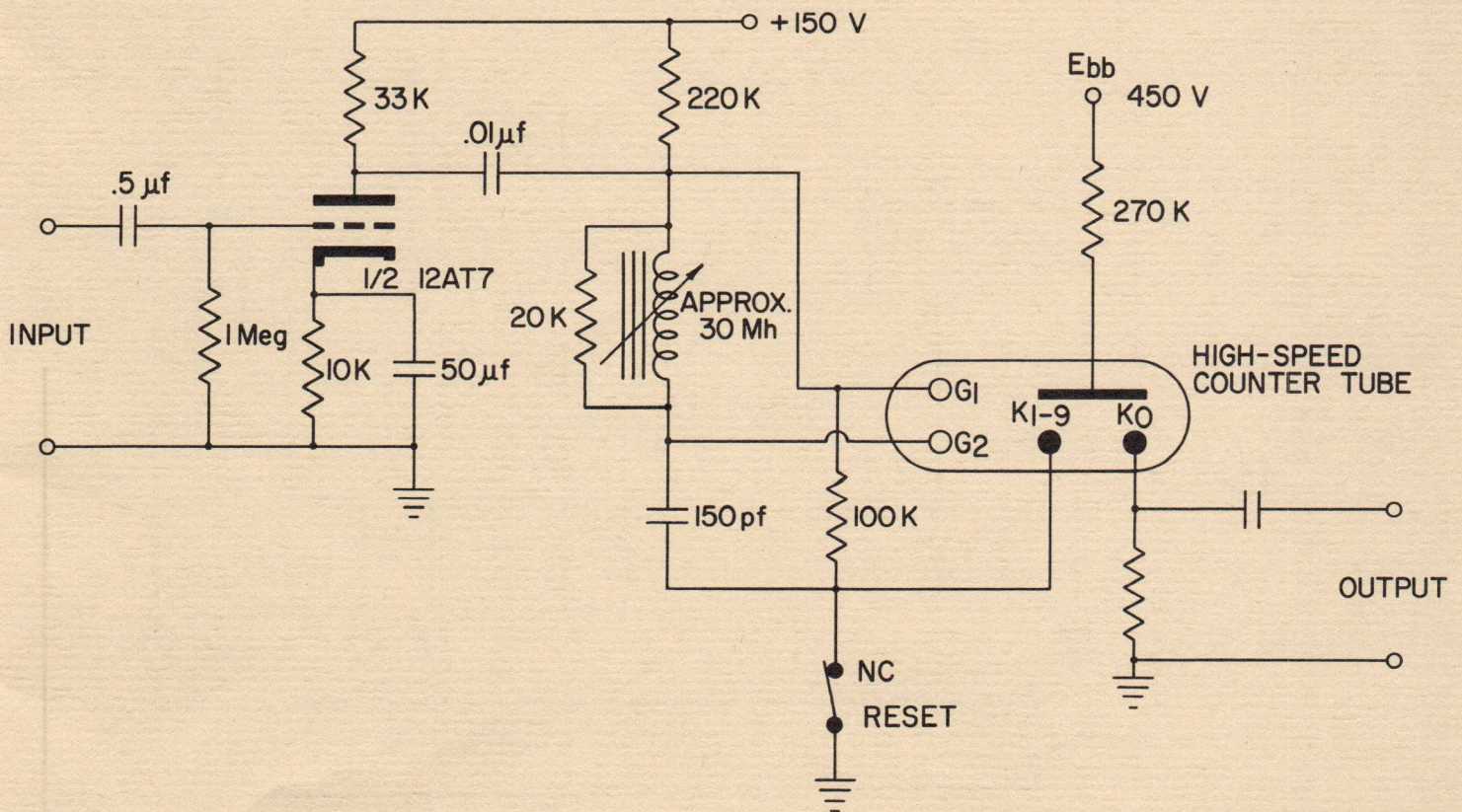


7| Various reset arrangements.

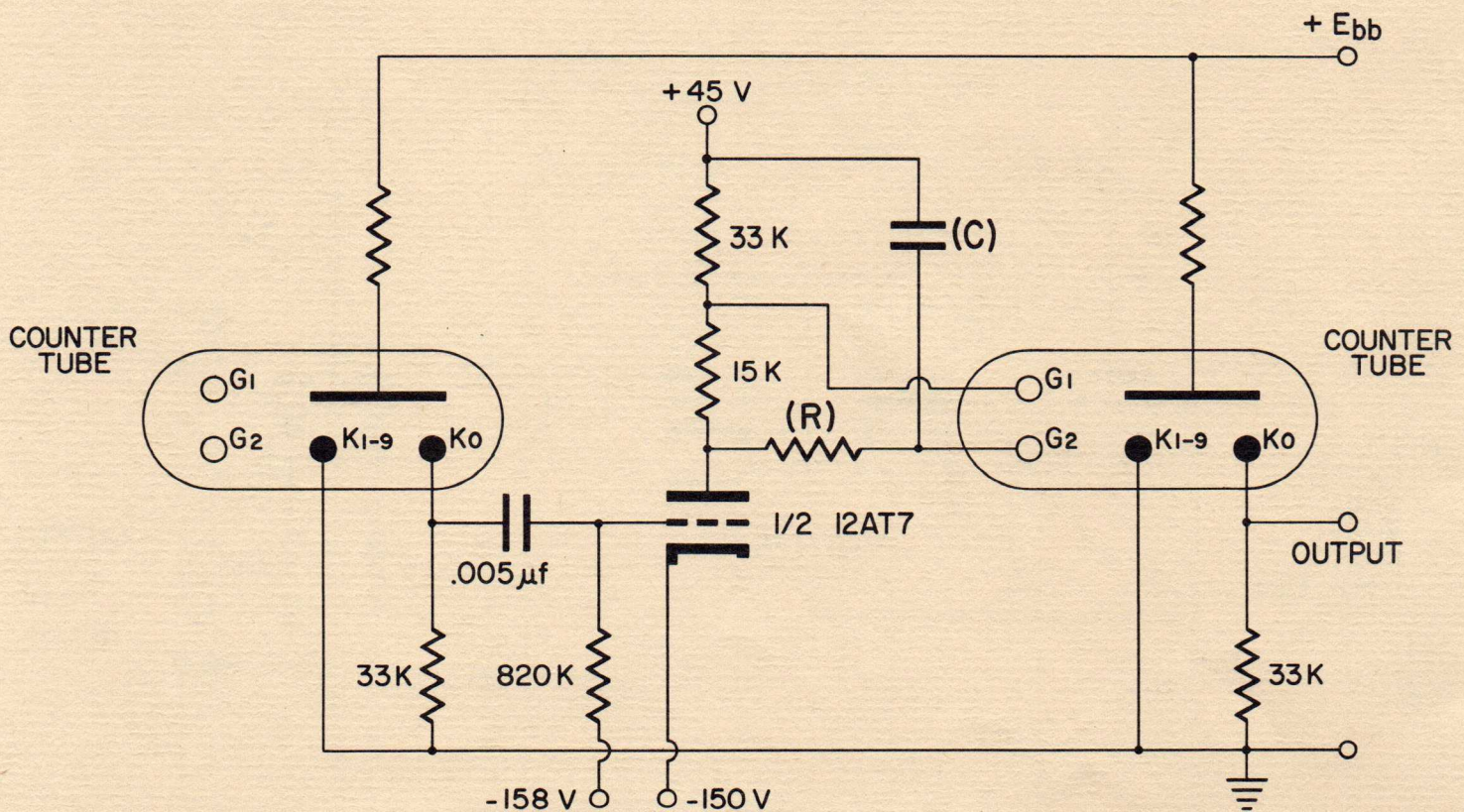
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10 | *Variation of basic vacuum tube driver/coupler for high-speed tubes.*

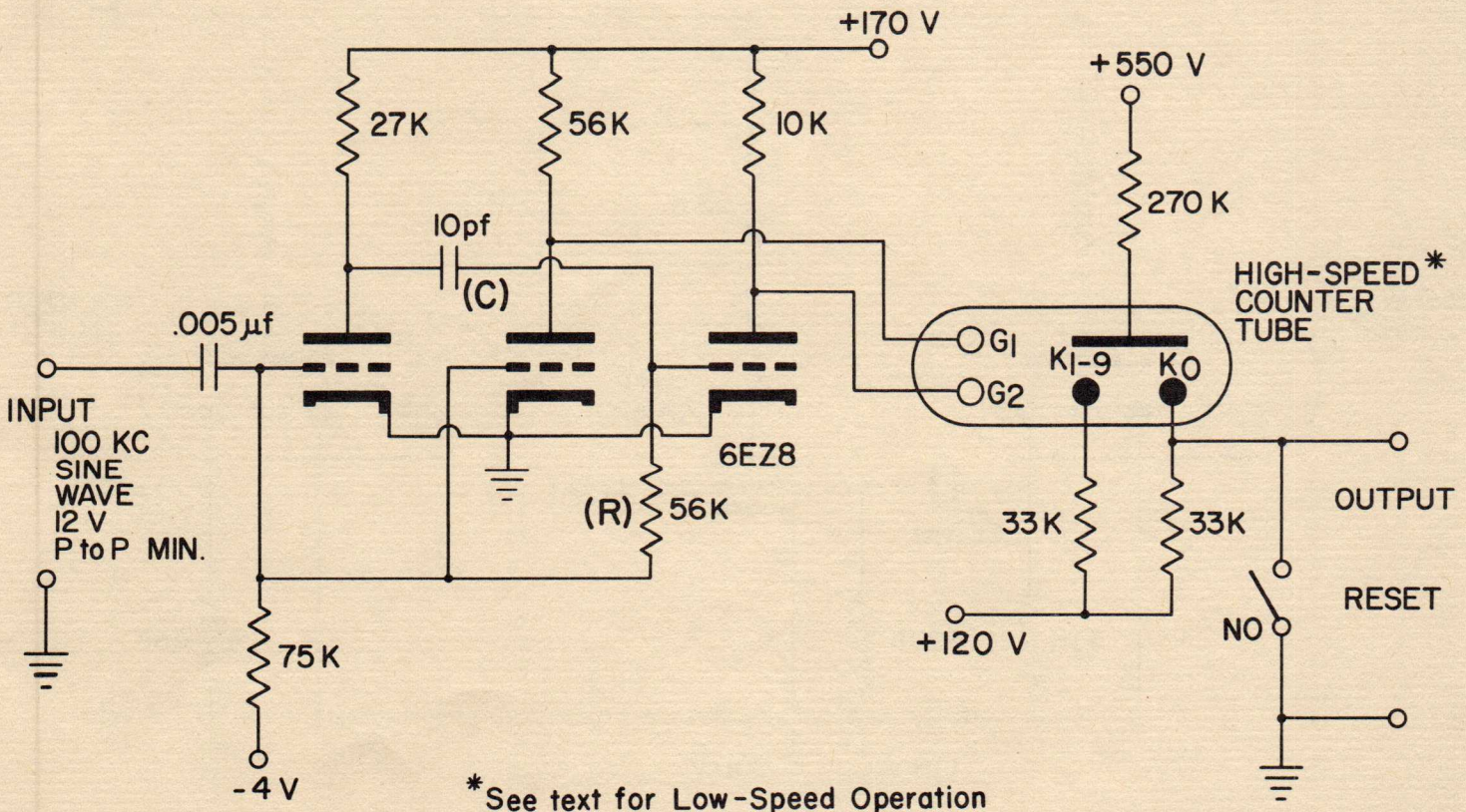


9|Basic circuit of Figure 8 as interstage coupler.



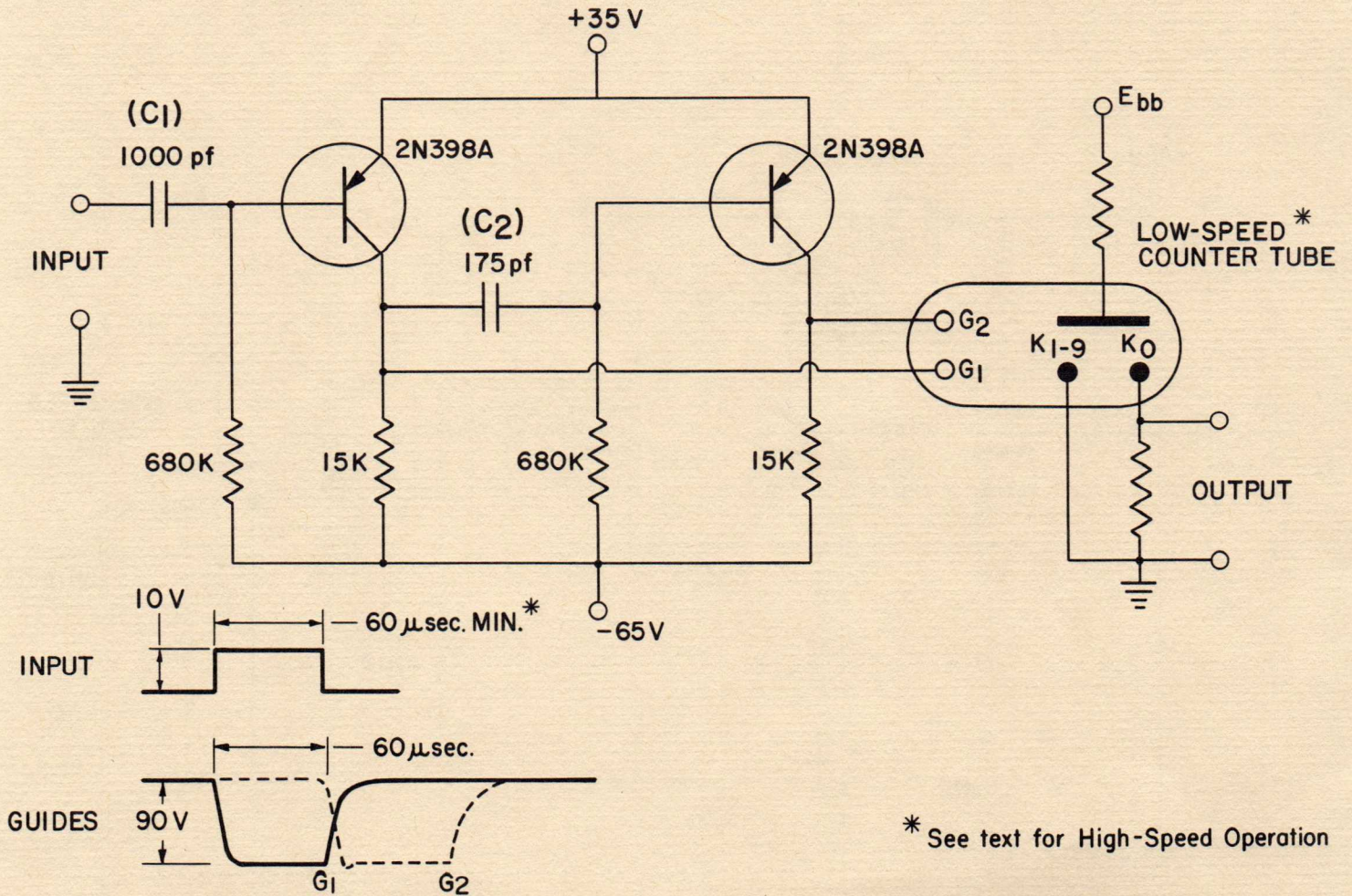
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12 | *Narrow-band sinewave driver.*

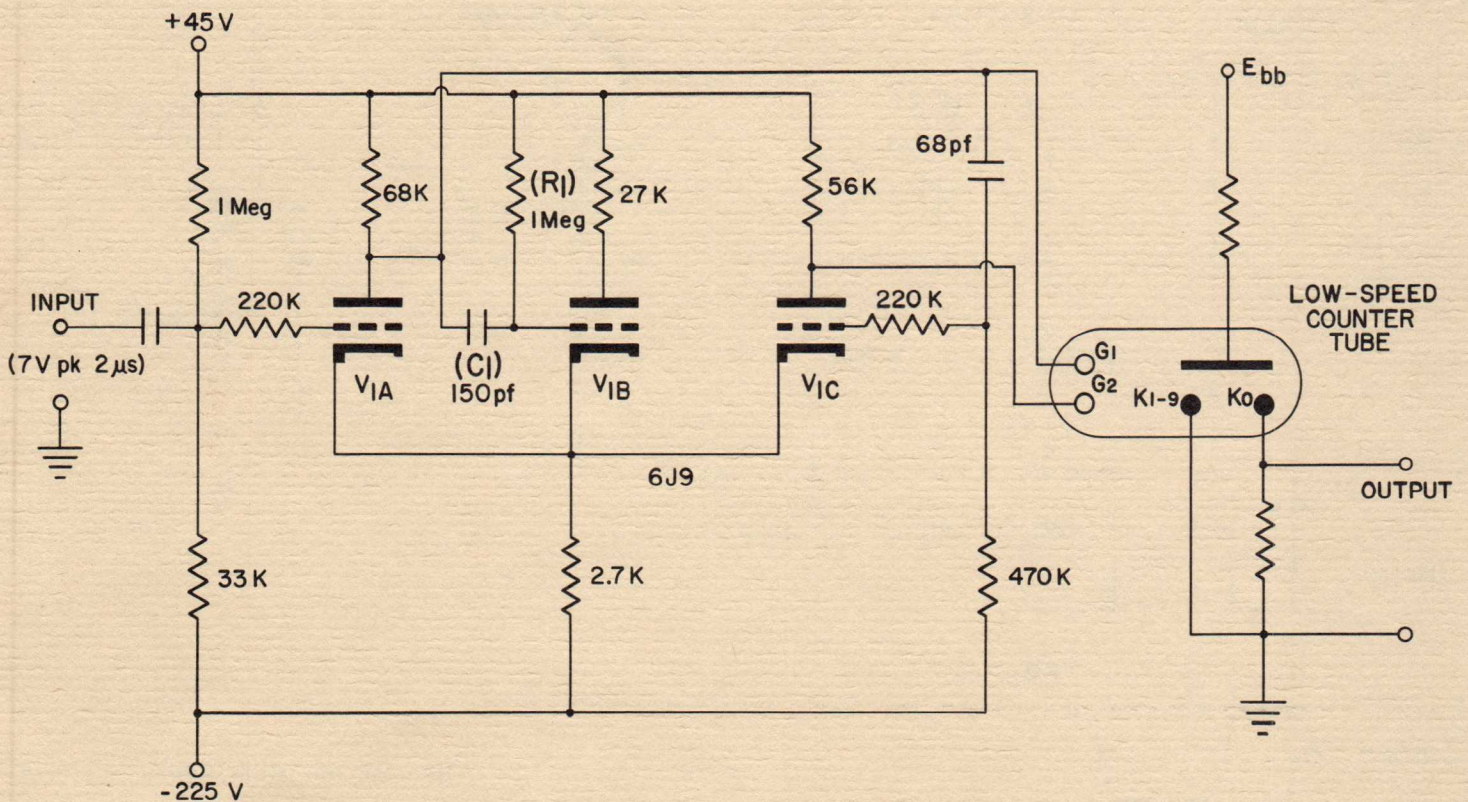


11 | *Basic transistor driver.*

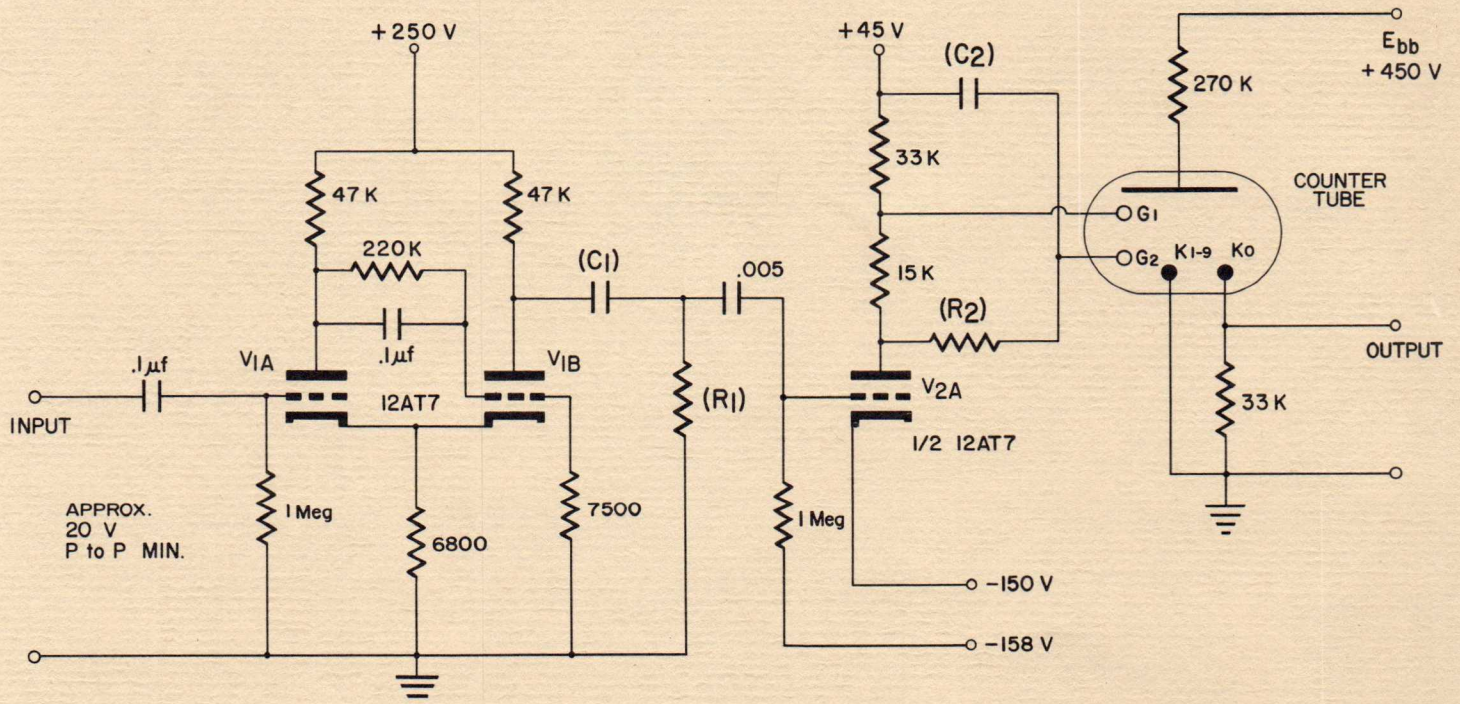
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14 | Short-pulse driver for low-speed counter tubes.

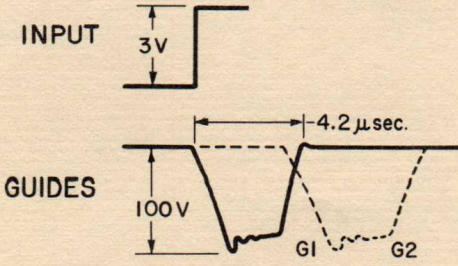
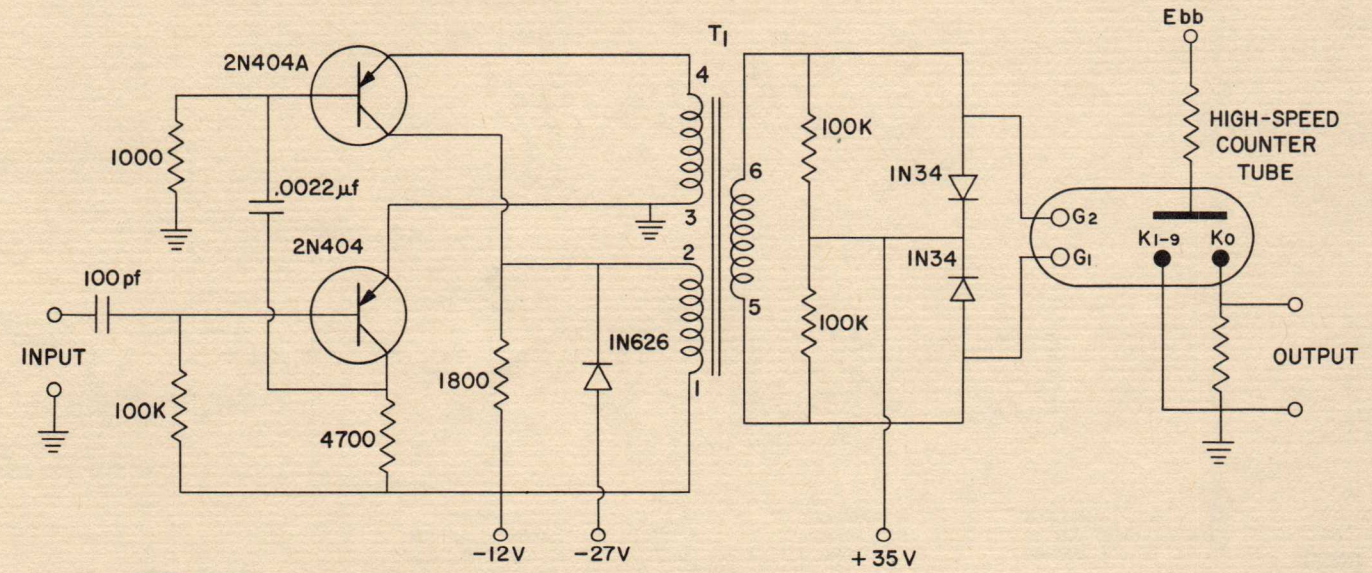


13 | *Broad-band shaper-driver.*



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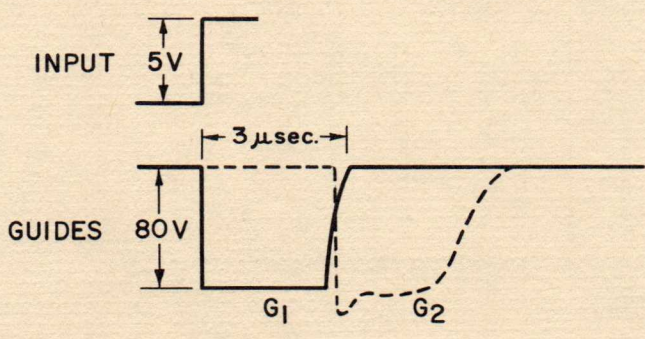
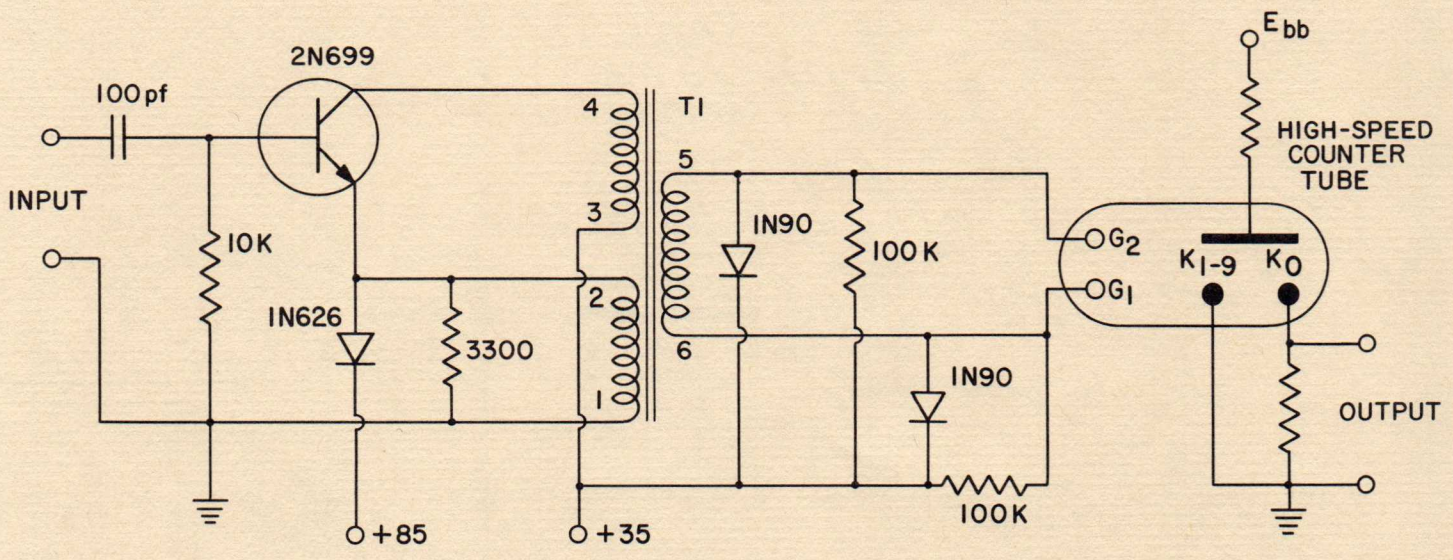
16|PNP transistor short-pulse driver for high-speed counter tubes.



T₁ - ALADDIN NO. 02-1636
5.7:1:33.3

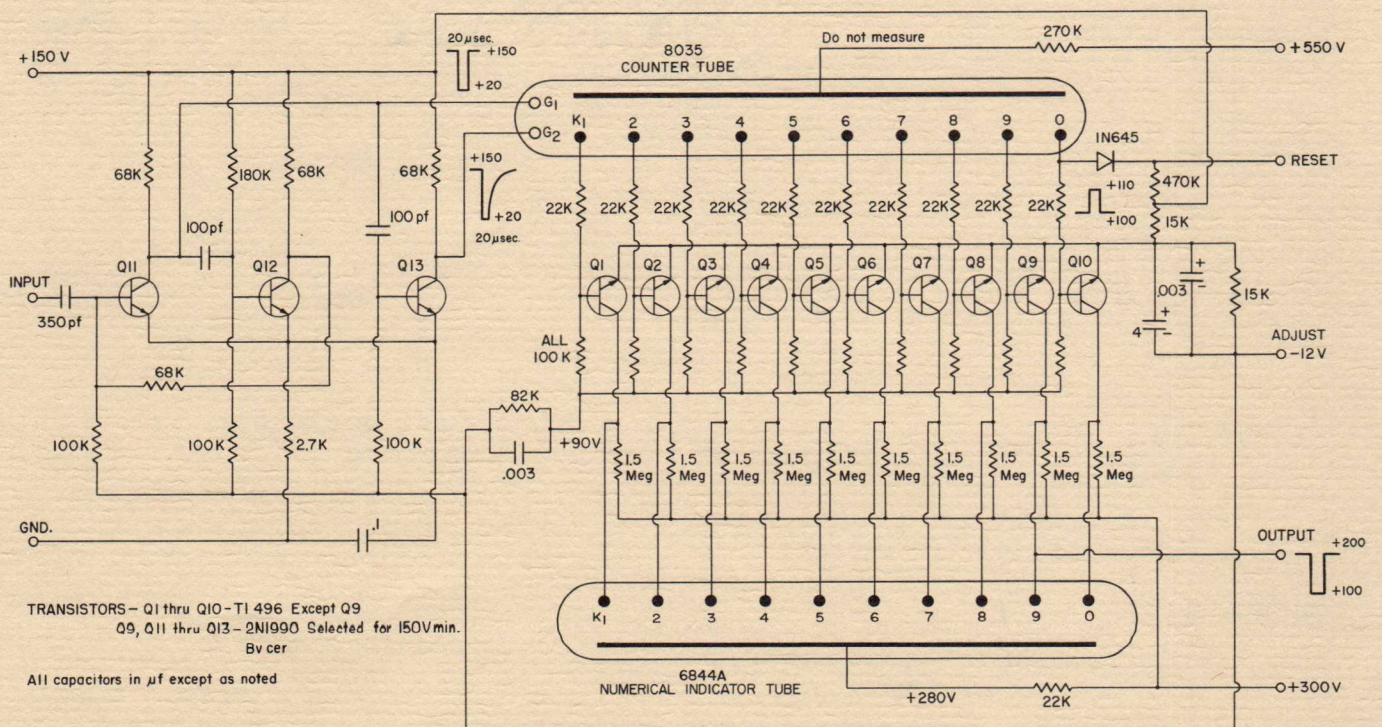
15|NPN transistor short-pulse driver for high-speed counter tubes.

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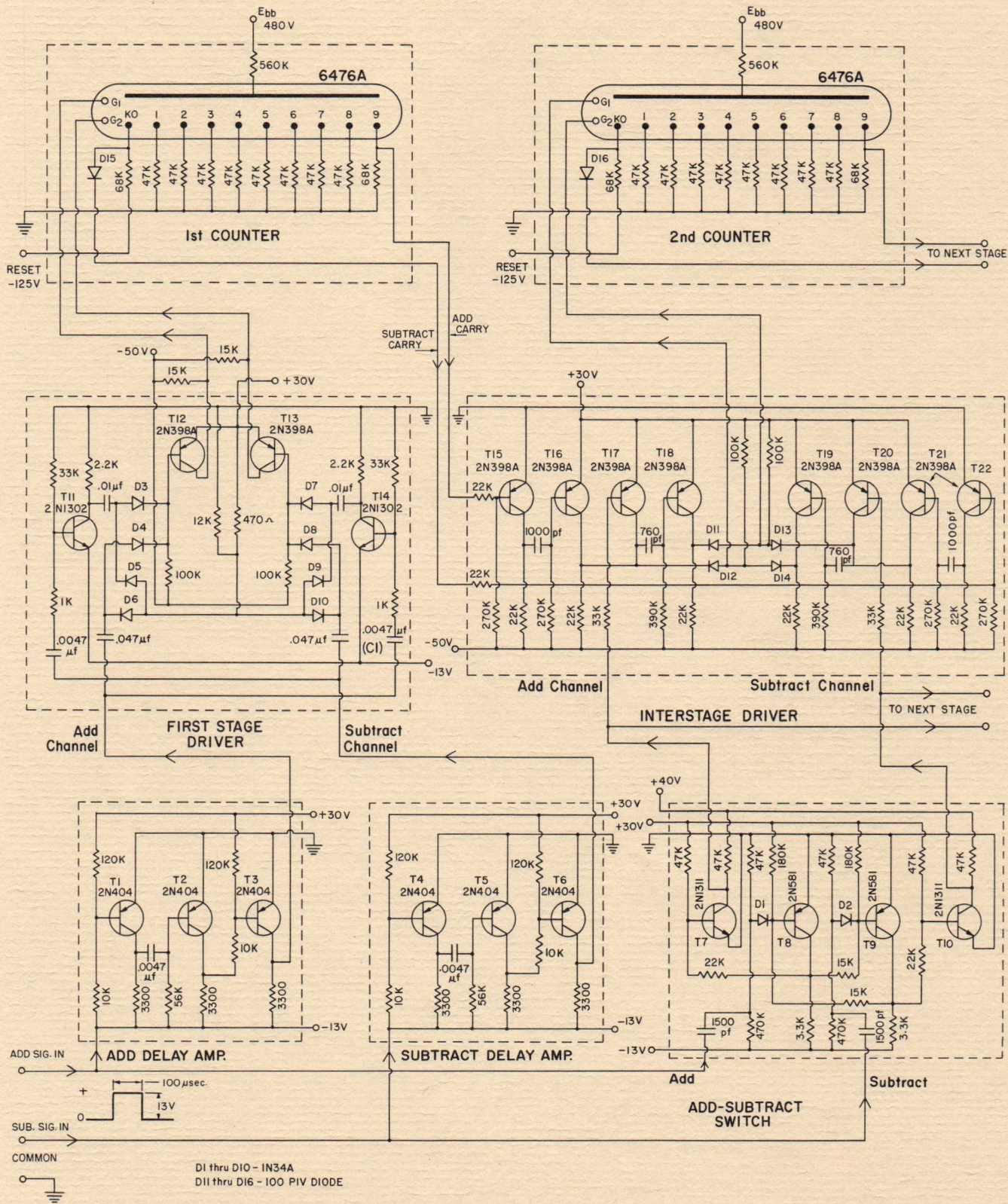


T1 - ALADDIN NO. 02-1639
5.0:1:10

18 | Counter module with supplementary visual readout (courtesy Digitool Corporation).

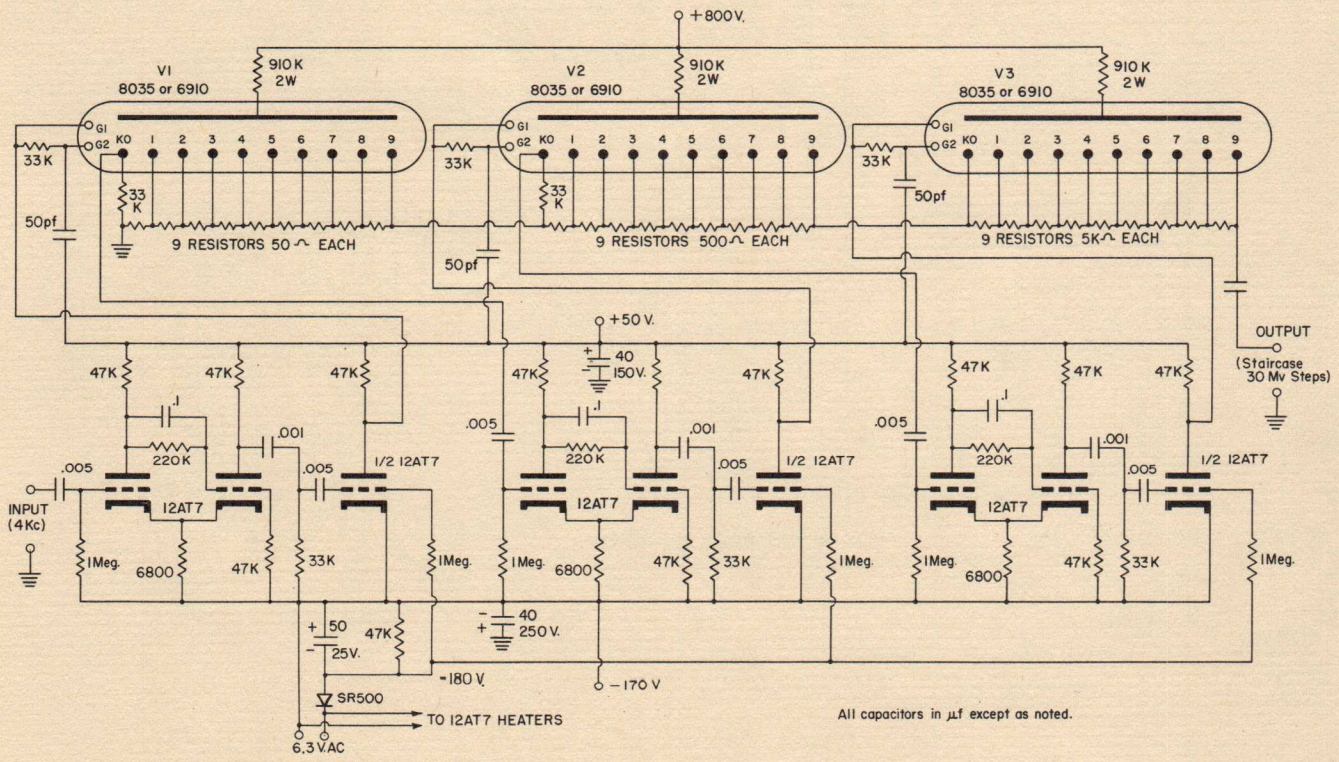


17 | Add-subtract counter (courtesy Dynapar Corporation).

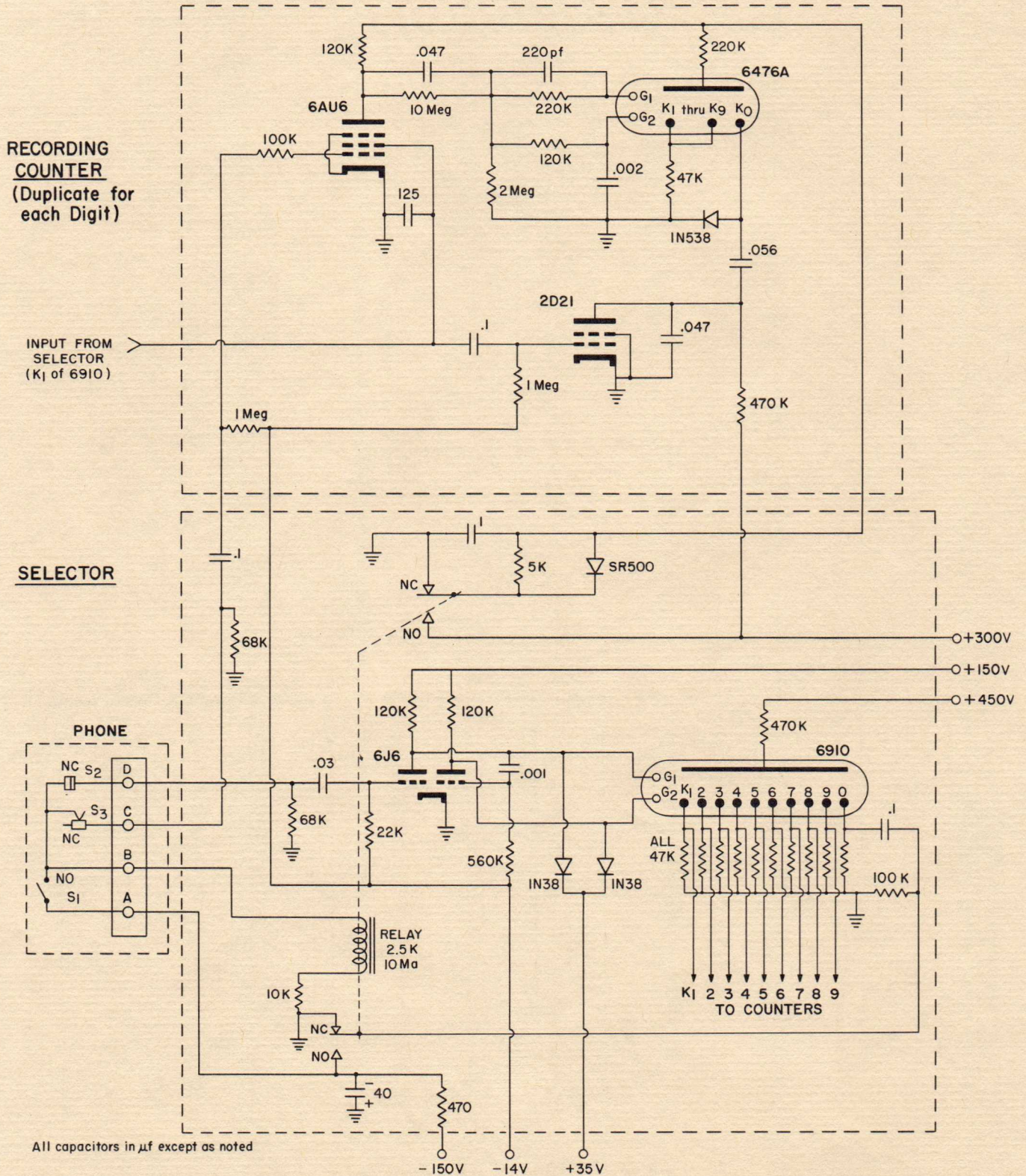


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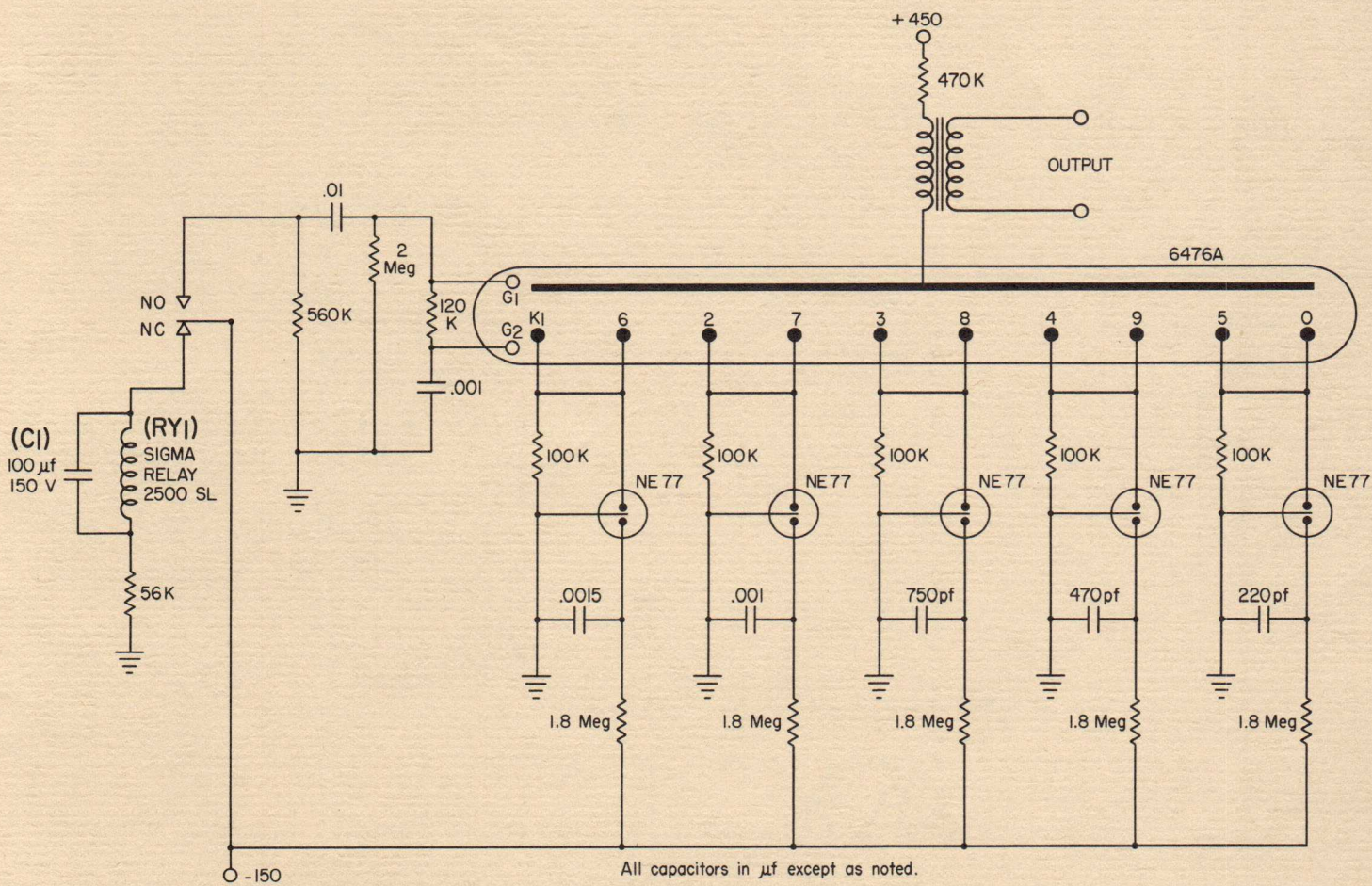
20 | Staircase-wave generator.



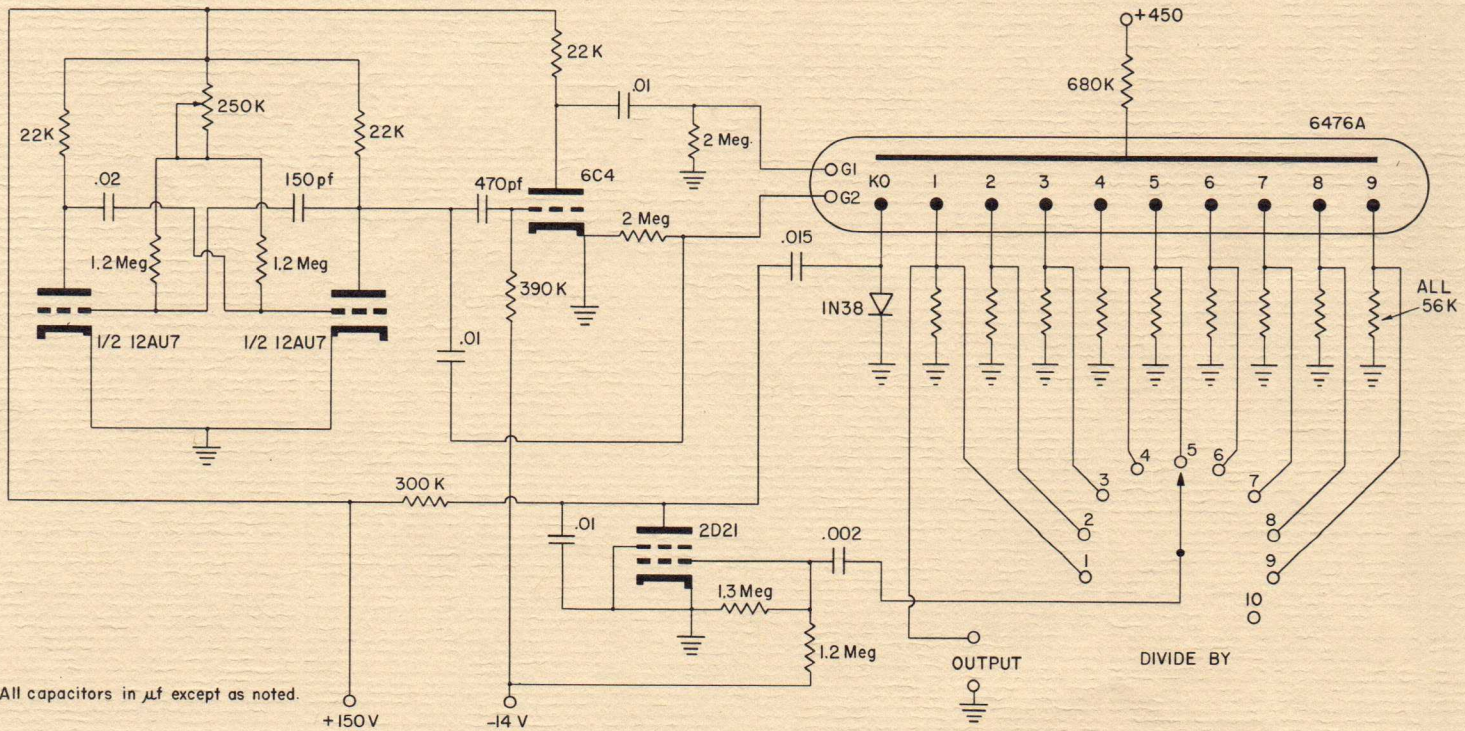
19 | Telephone dialing recorder.



22 | *Electronic switch.*

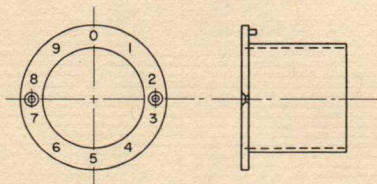


21 | Frequency divider.

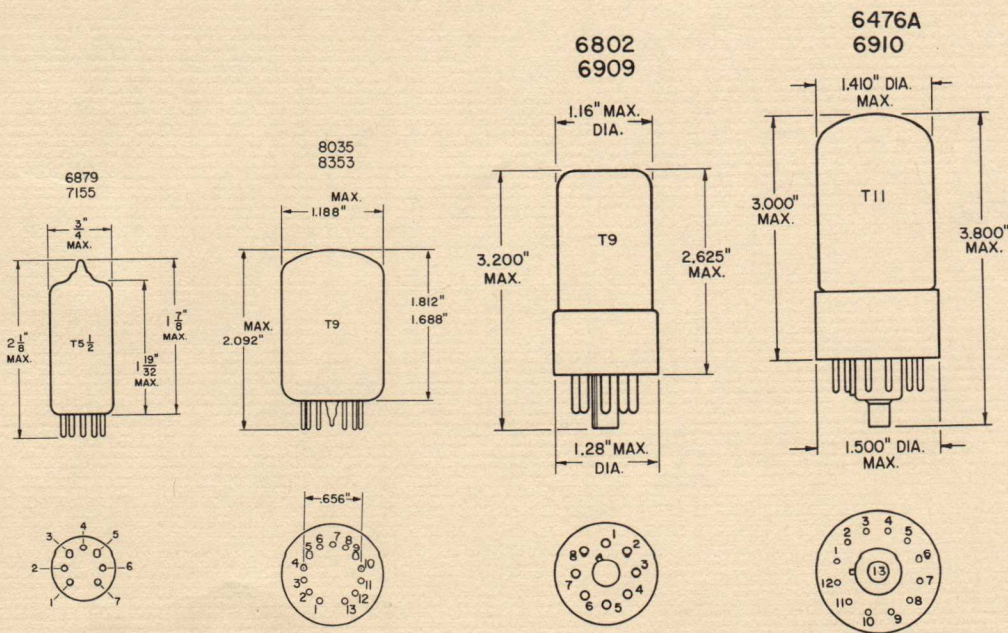


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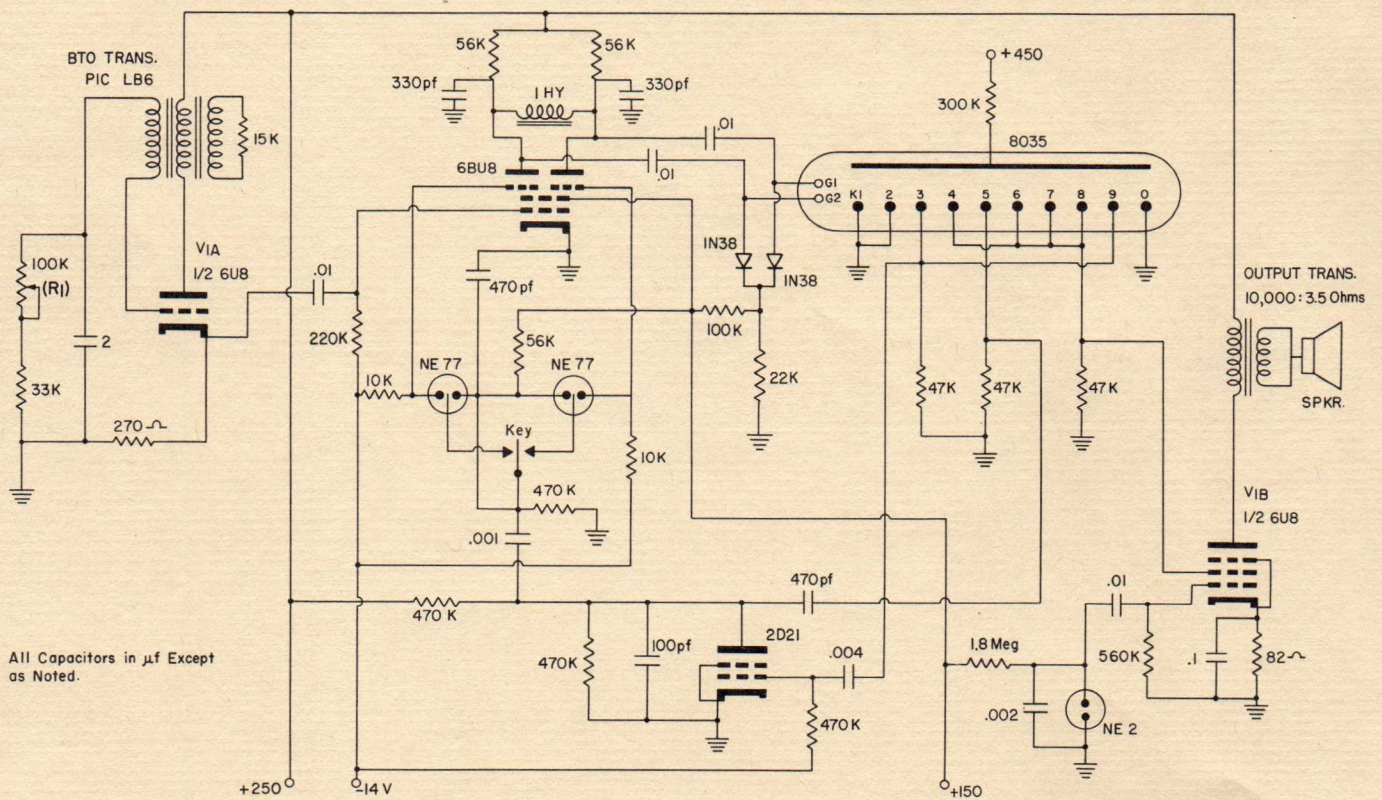
24 | *Over-all dimensions and pin designations.*



BEZELS of the type shown
are available from:
William T. Kelley and Company
77 Lovett Street, Beverly, Massachusetts



23 | *Electronic keyer.*



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Orlando, Florida/32804
305-CHerry 1-9681

FORT WAYNE:

L. R. FISHER
4740 Coldwater Road
Fort Wayne, Indiana/46805
219-483-1145

LOS ANGELES

F. E. GILBERT, JR.
6505 East Gayhart Street
Los Angeles, California/90054
213-RAymond 3-5371

MASSACHUSETTS:

N. C. WHITE
100 Sylvan Road
Woburn, Massachusetts/01801
617-WELLS 3-4784

NEW YORK:

J. D. CONROY
1000 Huyler Street
Teterboro, New Jersey/07602
201-ATlas 8-9484
in N.Y.C.—CHickering 4-8820

NEW YORK-UPSTATE:

G. E. FOGG, JR.
Seneca Falls, New York/13148
315-568-5881

PHILADELPHIA:

S. R. SISAK
4700 Parkside Avenue
Philadelphia, Pennsylvania/19131
215-GRGreenwood 7-5000

SAN FRANCISCO:

D. L. KLEINENDORST
1811 Adrian Road
Burlingame, California/94010
415-OXford 7-3500

WASHINGTON, D.C.:

P. A. LUHR
1120 Connecticut Avenue, N. W.
Washington, D. C./20006
202-FEDeral 7-6600

INTERNATIONAL:

730 3rd Avenue
New York, N. Y./10017
212-551-1000

CANADA:

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