

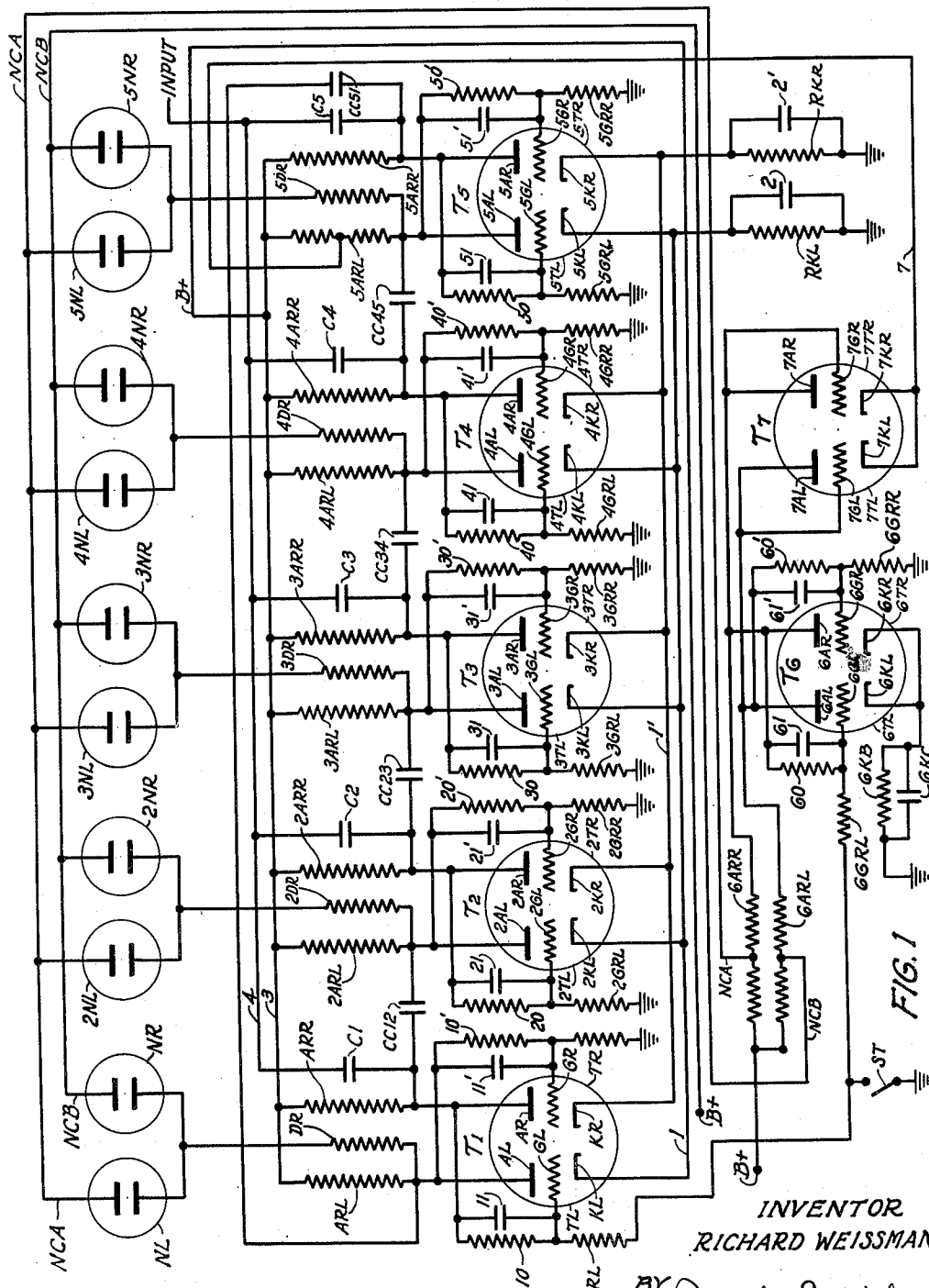
April 3, 1951

R. WEISSMAN
ELECTRICAL APPARATUS

2,547,511

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2 Sheets-Sheet 1



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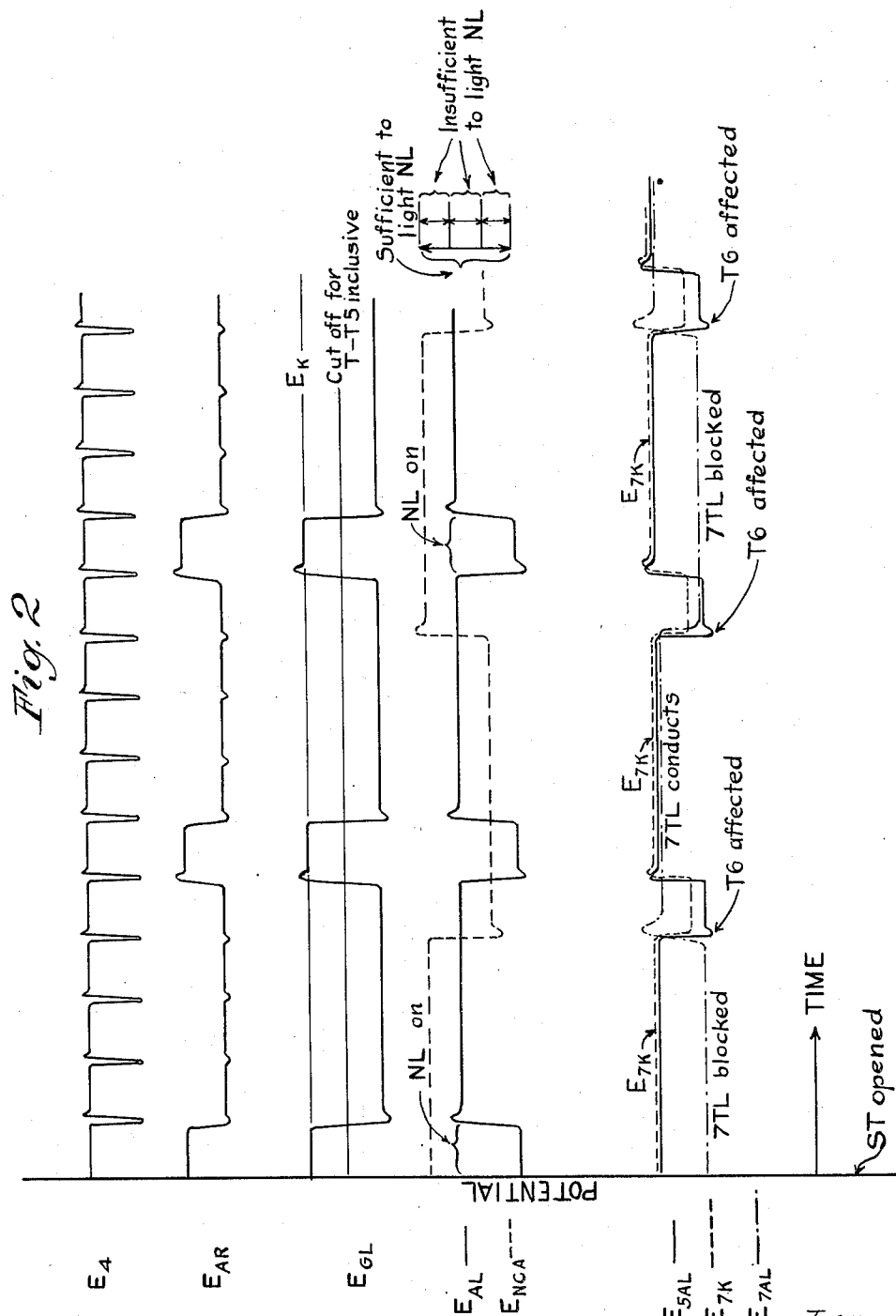
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ELECTRICAL APPARATUS

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1

This invention relates to an electrical apparatus and particularly to an electronic type of counter. While the invention is directed toward a ring type of counter, it is not necessarily limited thereto.

Electronic counters for high speed counting have become well known and are useful for many purposes. While many such counters have been devised and made for use in laboratories and locations where skilled and highly trained personnel is available, the field of such counters has expanded beyond such limits. Thus electronic types of counters are useful and advantageous in industrial locations where commercial requirements are important. Such commercial requirements include economy of manufacture, a minimum number of vacuum tubes, circuit simplicity, physical and electrical ruggedness, reliability of operation and high speed of operation.

Prior art counters have various drawbacks which have limited the utility of such counters. Thus some counters are elaborate and characterized by circuit complexity making the counter expensive to make and to maintain. Other counters of a simpler design have been subject to false triggering and thus lack reliability. Furthermore, many counters of the prior art operate the vacuum tubes in a deleterious manner and reduce the operating life of the tubes. A further objectionable feature of prior art counters has been due to the requirement of precision shaping and duration of trigger pulses for operating the same. In many instances, such counting circuits place a heavy load upon a pulse generator and thus increase the expense and complexity of the pulse generator. A common objection to prior art counters has been their inability to count at high rates of speed.

The invention provides a counter which is simple, and economical in the use of components, is rugged and not subject to false triggering, is operated with a comparatively low pulse power and is not critical of the pulse shape and is susceptible to operation at high pulse repetition rates. The counter embodying the present invention has other advantages and desirable properties all of which will be apparent after the invention has been disclosed.

The invention will now be described in detail in connection with the drawing wherein Figure 1 is a circuit diagram illustrating the invention and Figure 2 shows the potential characteristics of certain points of the circuit during operation.

The ring counter proper comprises five double unit tubes, T1 to T5 inclusive. While each unit

2

of a tube is shown as being a triode, it is possible to use tetrodes or pentodes. Thus tube T1 has cathodes KL and KR, grids GL and GR and anodes AL and AR. The letters L and R are used to designate the left and right units of a tube. For tube T2, the cathodes are indicated by 2KL and 2KR. The remaining electrodes are correspondingly indicated with a numeral 2 as a prefix to refer to the second tube. The higher tubes have their electrodes correspondingly marked.

Cathodes KL to 5KL inclusive are connected by lead 1 to grounded bias resistor RKL. Condenser 2 shunts resistor RKL. Similarly cathodes KR to 5KR inclusive are connected by lead 1' to grounded bias resistor RKR, shunted by condenser 2'. The ratio of resistances of RKL to RKR is substantially equal to $(n-1)/1$ where n is the number of counter stages. In this case, one resistor is four times the value of the other and it will be assumed that RKL is larger. The shunting condensers should each be large enough to by-pass pulses readily and may be equal.

All L grids are connected to resistors GRL to 5GRL respectively. With the exception of GRL, remaining resistors 2GRL to 5GRL inclusive are grounded. All GRL resistors are preferably of equal value. Similarly, grid resistors GRR to 5GRR are all connected between ground and the grids of the right unit of each tube. These resistors are also preferably equal to each other and to the GRL series of resistors.

Between the grid of one tube unit and the anode of the other tube unit for each tube there is connected a resistor. Thus resistor 10 is connected between GL and AR while resistor 10' is between GR and AL. Shunting resistor 10 is condenser 11 while condenser 11' is across resistor 10'. Tube T2 has resistors 20 and 20' shunted by condensers 21 and 21' respectively cross-connected. This is continued to tube T5 with resistors 50 and 50' and condensers 51 and 51'.

The AL series anodes are connected through load resistors ARL to 5ARL respectively to wire 3. The AR series anodes are also connected to wire 3 through individual ARR load resistors. A source of suitable potential is connected between wire 3 and ground in the usual manner.

The AR series anodes are also connected to wire 4 through individual condensers C1 to C5 inclusive. The input to the system is on wire 4. Anode 5ARR is connected through condenser CC51 to anode AL. The anode of the right hand unit of one tube is connected to the anode of the left hand unit of the next higher tube in the se-

ries. Thus AR is connected through CC12 to 2AL. Similarly CC23 is connected between 2AL and 3AR. Condensers CC34 and CC45 respectively couple the remaining tubes up to T5.

The AL series anodes are also connected through a series of dropping resistors DR to 5DR inclusive to a series of gas tubes NL and NR to 5NL and 5NR inclusive. Thus AL is connected through DR to a common terminal of gas lamps NL and NR. 2AL is connected through 2DR to lamps 2NL and 2NR. This continues to 5AL being connected through 5DR to 5NL and 5NR. The NL series of lamps is connected to common lead NCA while the NR series of lamps is connected to common lead NCB.

Tube T6 is also a double unit tube similar to tubes T1 to T5 inclusive. Tube T6 has cathodes 6KL and 6KR, grids 6GL and 6GR and anodes 6AL and 6AR respectively. The cathodes are connected together to grounded bias resistor 6KB shunted by condenser 6KC.

Grids 6GL and 6GR are connected to resistors 6GRL and 6GRR the latter being grounded. These grids are cross connected to the anodes of the tubes by resistors 60 and 60' shunted by condensers 61 and 61'. Anodes 6AL and 6AR are connected through dropping resistors 6ARL and 6ARR to a common junction for connection to a source of anode potential. Wire 3, also connected to a source of anode potential, may have the same potential source.

Wire NCA is connected to a point on 6ARR while wire NCB is connected to a point on 6ARL. The particular values of these resistors and points of connection may vary depending upon tubes, desired operating conditions and applied potentials.

Resistor GRL has its lower terminal connected to the lower terminal of 6GRL and the two are connected to grounded switch ST, normally closed.

The last tube, T7, is a double unit tube and is a double diode. This tube may be a triode like the others for the sake of uniformity and may have grid and anode connected together as a diode. Such an expedient is well known. Tube T7 has cathodes 7KL and 7KR connected together to wire 7 going to an intermediate point on resistor 5ARL. Anodes 7AL and 7AR are connected respectively to anodes 6AL and 6AR.

The operation of the counter will now be described. The counter may be set to a zero starting position by momentarily depressing switch ST. This switch is normally closed and in this condition provides a connection to ground for GRL and 6GRL. Upon the momentary opening of this switch, the positive potential present at the anode of 6TR will be impressed through resistor 60 and 6GRL upon the control grid of TL and render TL conducting. This will occur irrespective of the previous condition of the other tubes.

By virtue of the values of cathode bias resistors RKL and RKR, only one left tube section can be conducting at one time under conditions of equilibrium. It is possible that when the system is going through an operating cycle, such as when a negative trigger pulse occurs or when switch ST is depressed, that more than one left tube unit may be conducting for a very short time. However, when conditions have become stable the cathode bias resistors for tubes T1 to T5 inclusive will only permit one left tube section to be conducting at one time.

It has been found that the ratio of bias resis-

tors may depart from the precise ratio indicated by the formula and instead be fractionally higher or lower. Thus in this instance where n is 5, a ratio of about $3\frac{1}{2}$ has been found highly satisfactory.

By keeping the time constants in the anode and grid circuit low, the period of instability during which the tubes are changing their condition may be made very short, of the order of a fraction of a microsecond. This time will be substantially less than the duration of a trigger pulse or the time during which switch ST is open when starting.

When tube section TL becomes conducting or is on, tube sections 2TL to 5TL will therefore be nonconducting. The bias on the cathode responsible for this condition will predominate over all other tendencies to the contrary. Conversely, TR will be nonconducting and remaining sections 2TR to 5TR will be conducting. The counter is now ready for operating and is in condition to be triggered by negative pulses for counting purposes.

Referring to Figure 2, after switch ST has been opened, the potential at AL will be low while the potential at GL will be substantially the same as the cathode potential. It is assumed, that the grid potential cannot rise above that of the cathode since the tube will be conducting heavily. Hence the potential of GL will be at its maximum. The potential at AR will also be at its maximum. For the time being, the operation of T6 and T7 will not be considered.

Now assume that a series of negative pulses are provided on wire 4, this being shown in the first curve. The pulses are shown as being spaced evenly along the time axis. This however is not necessary and the pulses may occur at any desired intervals.

The first negative pulse coming in on line 4 will encounter coupling condensers C1 to C5 inclusive. Since tubes 2TR to 5TR are all conducting or on, it will be apparent that a low resistance path to ground will be provided at tubes T2 to T5 inclusive. Thus at the second tube, T2, the pulse will go from 2AR to 2KR then through condenser 2' to ground. It is assumed that the pulse terminals are between ground and wire 4. Because of the low resistance offered from 2AR to ground, it will be apparent that the pulse amplitude at 2AR will be negligible. The same is true of the remaining tubes. However, tube section TR is cut off and offers a high impedance to the pulse at AR. Hence the pulse will pass through condenser 11 to GL and drop the grid of TL below cutoff. This will result in TL cutting out and TR cutting in. At the same time, the negative pulse at AR will also pass through condenser CC12 and thence through condenser 21' to 2GR. This will tend to cut off 2TR. The tendency for 2TR to be cut off will be reinforced by the amplified negative pulse from AR when TR cuts in. The interaction between the left and right sections of a tube will be similar to the action in a multivibrator circuit and needs no detailed description.

The above potential changes are shown in the third curve when the grid potential is suddenly dropped because of the first pulse. It is to be understood that no accurate relationships between the various amplitudes are shown in the drawings. The pips at the beginning and end of any sudden change in potential are well known in circuits subject to steep wave fronts.

Thus after the first pulse has arrived, tube

section 2TL will be on and the other L sections will be off. Upon the arrival of the second pulse, the action will progress with the pulse having a substantial amplitude at 2AR and having negligible amplitude at the remaining anodes of the R tube sections. Thus as shown in the second curve, the potential at AR will dip slightly when this tube section is conducting at the time that a pulse reaches it.

It is thus apparent that the negative trigger pulses are effective only at the two tubes whose conditions are to be changed. At other tubes, the pulse has negligible amplitude and is completely ineffective. Thus successive pulses will cause the various tubes to change their condition. It should be noted that the low impedance provided across the bias resistors for the left and right series of cathodes functions in a dual manner. Thus for those tubes whose right hand section is conducting and where the pulse is to be ineffective, condenser 2' completes a now impedance path from the anode. Thus as an example, when tube 2TR is conducting, the path of a pulse is from wire 4 through condenser C2 through tube 2TR and through condenser 2' to ground. By having condenser 2' large, and since the resistance of 2TR when conducting is comparatively low, the major potential drop for the pulse path will be across condenser C2. If however, 2TR is open then the situation is entirely different. The pulse path is from wire 4 through condenser C2 and condenser 21 to grid 2GL. This path may be considered as a number of series connected condensers and it will be found that a major portion of the pulse potential will be impressed upon grid 2GL.

Another pulse path is from wire 4 through condenser C2, through condenser CC23 and condenser 31' to grid 3GR. By having coupling CC23 comparatively large, the amplitude of the negative pulse from wire 4 on grid 3GR may be made quite substantial. However, it will be noted that the negative pulse for the tube section 2TR, when it goes on, will reinforce the negative pulse going to grid 3GR.

In the above instance where the pulse amplitude at the anode of a right hand tube section, such as 2AR, is substantial it is due in a substantial manner to the presence of condenser 2'. Thus as far as a pulse is concerned, cathode 2KR is at ground potential. Hence if the pulse path from wire 4 to ground through open tube section 2TR is considered from a voltage dividing angle, it will be apparent that no potential drops are wasted upon the cathode to ground portion of the system. It is thus clear that for all pulses, the cathodes are at ground potential and never vary from that. Hence any variation of grid or anode potential is always with reference to a fixed cathode potential. It will also be noted that the two tubes to be changed are affected simultaneously by the negative pulse. Thus in the example given above where 2TR is to cut in and 3TR is to cut out, it will be apparent that the control grids of 2TL and 3TR are pulsed negatively at the same time. This means therefore, that tubes T2 and T3 will both change their conditions substantially simultaneously rather than successively as has usually been the practice.

When tube section 5TL will be cut in, a succeeding negative trigger pulse will be effective on tubes T5 and T1 by virtue of coupling condenser CC51. This makes a closed ring of the counter. If desired however, condenser CC51 may

be omitted and other means may be utilized for starting the cycle of operation over again.

The operation of gas discharge lamps NL to 5NL and NR to 5NR will now be described. When switch ST is momentarily opened, grid 6GL will be positively biased. This will render 6TL conducting and cut off 6TR. Thus the potential at 6AR will be high while the potential at 6AL will be low. In the fourth curve, the relationship between the potentials at AL and NCA via 6AR is shown.

It is clear that 7AL and 7AR will be respectively at low and high potential. The potential of 7KL and 7KR will be determined by the condition of tube section 5TL. At starting with switch ST, tube 5TL will be open and 5AL will be at maximum potential. Hence 7KL and 7KR will be at maximum positive potential. This is shown in the fifth curve. As shown in this curve, the cathode potential of T7 will be higher than the low potential at anode 7AL. Hence 7TL is blocked. At the same time the high potential at 7AR makes this positive with respect to 7K and tube 7TR will therefore conduct.

As stated before, 6TR is cut off so the anode potential is at maximum value. This is true even though 7TR is conducting and may bleed off some current. Hence the potential at wire NCA will be high. Of tubes T1 to T5 inclusive, only TL of the series is conducting when switch ST is operated. Hence, of all the gas discharge lamps, the lowest potential will be at the lower electrodes of NL and NR. It is evident therefore that the potential difference across NL will be greater than across any other lamp. This potential difference may be such that lamp NL will go on while the remaining lamps will be dark. This is shown in the fifth curve where the potentials at 5AL, 7K and 7AL are shown.

Also in the fourth curve there is shown the potential condition at AL and NCA via 6AR. Thus referring to the fourth curve, it will be noted that the potential at AL is low when TL is on and thereafter the potential remains at its maximum value when TL is off. It is evident therefore that the maximum potential across lamp NL exists only during the time that tube section AL is on and tube section 6TR is off. As will be shown later, this condition only occurs once every ten times.

When a negative trigger pulse arrives and causes 2TL to cut in, the maximum potential difference will now be shifted to 2NL. This will continue until 5TL cuts in. When 5TL cuts in, the potential at 5AL will drop and cause the potential in wire 7 and cathodes 7KL and 7KR to drop. This is shown by the dotted line in the fifth curve. Inasmuch as tube section 5TL conducts until a succeeding pulse arrives, it will be clear that the potential of the cathode of tube T7 will be low for the time interval corresponding to the time that tube 5TL conducts.

The drop in potential of the cathodes of tube T7 will cause a rush of current from 7AR to cathode 7K. It should be remembered that 7AR is still at high potential due to the fact 6TR is open or off. The sudden rush of current will drop the potential of 6AR and the resulting negative pulse will be transmitted through condenser 61 to the grid of 6TL to cut 6TL off. Hence tube T5 will go through a multivibrator cycle with 6TL being now open and 6TR being now on. As shown in the fifth curve, when the anode potential at 6TR drops, this will result in the potential at the anode of the diode section dropping below the po-

tential of the cathode. Thus in the fifth curve, the potential conditions of the anode for the left section of tube T7 is shown. It is understood that the potential conditions for the right section are the same but displaced in phase. In any event, it is clear that when tube section 5TL is not conducting that the diode section blocks for that portion corresponding to the section of tube T6 which is conducting.

When a negative pulse arrives to change 5TL from conducting to nonconducting conditions, the resulting rise in potential of the cathode for tube T7 will not trigger tube T6. Diode T7 has both sections blocked when the cathodes are at maximum potentials and this will occur when tube section 5TL is off.

Thus as an example, let it be assumed that 6TL is conducting by virtue of a pulse having just arrived to cut in 5TL. This means that the cathode for T7 will be at a relatively low potential to 7AR. The cathodes however, will be positive to 7AL so that 7TL will be blocked while 7TR will be conducting. Now if a succeeding pulse arrives at wire 4, tube section 5TL will cut out and tube section TL will cut in at the same time. The potential for the cathodes of T7 will rise to maximum value. Inasmuch as 7TL was previously blocked, the rise in cathode potential will have no effect. However, the sudden blocking of 7TR will cause a sudden jump in potential at 6AR. This will be communicated to 6GL. However, since 6TL has been conducting, the positive pulse will have no effect. Thus tube T6 will be triggered only when tube 5TL cuts in and will not be affected by the cut-out of 5TL.

When tube T6 changes its condition, the high potential present in line NCA will change to NCB or vice versa. When tube T6 has changed its condition, the corresponding series of gas lamps will be susceptible to operation. Thus a distinction will be made when TL is on for example, as to whether NL or NR will be lit.

Thus if NL corresponds to zero in a counting cycle, 2NL will correspond to 1 and so on up to 5NL which will correspond to 4. Thereafter NR will correspond to 5 and this will continue until 5NR is reached which will correspond to 9. Then of course the counting cycle will repeat.

The counting circuit itself comprising tubes T1 to T5 inclusive has five stages but obviously may have any desired number of n stages. Each stage consists of two vacuum tube units whose control grids and anodes are cross connected. The additional tubes, in this instance tubes T6 and T7, increase the flexibility and range of operation of the counting circuit.

By virtue of the invention a rugged counter is provided which is not sensitive to substantial variations of anode and filament potentials. While no cathode energizing means are shown, it is understood that such means are essential. Prior art systems have been sensitive to line voltage fluctuations and have required voltage regulated power supplies. This is not true in applicant's case and conventional power supplies common in conventional radio receivers may be used. Furthermore, a system embodying the present invention may be assembled without too much care as to precise values of components, condition of tubes, etc. Thus the RKL and RKR resistors are the most critical and these may vary by 10% from assigned values. Other components may vary more widely. Tube aging in general has little effect on system operation. The system as a whole is not critical of the trig-

ger pulse shape or amplitude. Thus the entire system embodying the invention is rugged enough and sufficiently uncritical to be susceptible to quantity production and maintenance by relatively unskilled personnel.

In the system described, only one left tube unit is conducting while the remaining stages have the right units conducting. The coupling condensers C1 to C5 inclusive, feed signals to the right tube units. It is possible, however, to reverse the tube units so that four of the left units will be conducting and only one of the right unit will be conducting. In such case, this is accomplished by having the right bias resistor RKR larger than RKL resistor. In such case, it will also be necessary to change the connections from the coupling condensers C1 to C5 to the left tube unit anode respectively. Also, the coupling condensers between anodes, such as for example CC12, will be between the left unit of the first tube and the right unit of the second tube. In other words, each tube will have the two units reversed.

What is claimed is:

1. A counting circuit comprising n cascaded vacuum tube stages, each stage comprising left and right tube units forming a pair of vacuum tube units, each unit having at least a cathode, control grid and anode, the grids and anodes of a stage being cross-connected by resistors shunted by condensers, a grounded resistor for each control grid, a grounded bias resistor common to all left cathodes, a grounded bias resistor common to all right cathodes, the left bias resistor being substantially $n-1$ times the right bias resistor and each bias resistor being shunted by a by-pass condenser, load resistors for each anode going to a common terminal for connection to a grounded source of high potential, an interstage condenser directly coupling the right anode of a stage to the left anode of the next succeeding stage, a coupling condenser from a common input line directly to each right anode, the cross-connections for each stage permitting only one tube unit of a stage to be conducting at any one time and the bias resistors permitting only one left tube unit to be conducting at any one time to provide an odd stage condition whereby a negative trigger pulse at the input line will result in successive stages being in an odd condition.

2. The counting system according to claim 1 wherein a pair of voltage responsive indicating means for each stage have one terminal of each connected to the anode of the left tube unit of each stage, to provide left and right indicating means for each stage, a common connection for the other terminal of the left indicating means for all stages, a common connection for the other terminal of the right indicating means for all stages, and means operated by the n th stage for alternately impressing a high potential on said common connections, said high potential having such a value that when a left tube unit is conducting the reduced potential at such anode and the high potential at one of the two other aforementioned other terminals will result in a sufficient difference of potential across an associated indicating means to operate the same whereby said n stages may go through two cycles of operation for one complete cycle of operation of the indicating means.

3. The system according to claim 1 wherein each left anode has connected thereto the common terminal of two voltage responsive indi-

cating means to provide a left and right indicator for each stage, a common connection for the other terminals of the left indicators, a common connection for the other terminals of the right indicators, an additional double unit tube stage having the control grids and anodes cross-connected and having grounded resistors for the control grids, load resistors for the anodes of the added stage, a connection from the left indicator common connection to one of the load resistors of the added stage, a connection from the right indicator common connection to the other load resistor of the added stage, and means for deriving a trigger pulse from the n th stage to trip the added stage so that the left unit of the added stage is conducting when the counting circuit is going through one complete cycle and the right unit of the added stage is conducting when the counting circuit is going through a succeeding complete cycle, the potential in the common connections for the left and right indicators being alternately raised or lowered depending

upon the condition of the added stage and when raised being sufficiently high to operate a voltage responsive indicating means at the one stage of the n stages where a left tube unit is conducting.

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