COLD CATHODE GAS-DISCHARGE TUBES.

Report "Magnet Int. 11" described the general outline of the programming system for the magnetic lenses. In the 3 counters and the 160 relay units mentioned there, cold cathode tubes will be used because of their reliability. This report gives a brief general description of the principles and the properties of the tubes. Only trigger- and scaling tubes, and no diodes, are considered. Tables with data of existing types are included.

In the second part of this report the relay unit and the choice of scaling tubes for the counters are described. Some other applications are given.

The report contains the following parts:

Abbreviations:

V_o = anode supply voltage
V_a = " voltage
V_{ab} = " breakdown voltage
V_{am} = " maintaining voltage
V_t = trigger voltage
V_{tb} = " breakdown voltage
V_{tm} = " maintaining voltage

T_i = ionization time
T_d = de-ionization time

a = anode
c = cathode
t = trigger electrode.

i_a = anode current
i_t = trigger current
i_o = zero current

1. Principles of Trigger Tubes.

The cold cathode trigger tube is a three-electrode tube, the three electrodes being anode, cathode and trigger electrode. The glass bulb is filled with a gas having a pressure of some mm Hg to some tens mm Hg. As gas mostly neon, argon or a mixture of both is used, and sometimes hydrogen is added.

In principle the tube works in the same way as the thyratron. The difference is that in the cold cathode tube the current is formed by positive-ion bombardment on the cathode instead of by thermionic emission.

We consider in fig. 1 (page 18) the main gap (anode - cathode) with the current limiting resistance R_a in series. The current-voltage characteristic for this gap is given in fig. 2, curve I; V_{ab} being the voltage for which the gap is fired. If the same characteristic is measured with a small biasing current in the tube curve II will be obtained with the much lower breakdown voltage V'_{ab}. This effect is used in the trigger tube in such a way, that when the anode supply voltage V_o is fixed somewhere between V_{ab} and V'_{ab}, the tube is fired only when a biasing current is introduced in the tube, big enough to bring the breakdown voltage point below V_o. This biasing current is generated by firing the trigger-cathode gap. The trigger is placed much closer to the cathode than the anode and will discharge for much lower voltages according to Paschen's Law x). The required current i_t in the trigger gap is 10^2 to 10^4 times smaller than the anode current i_a, which gives the tube power amplifying properties.

To fire the trigger gap, sufficient free electrons are needed in the gas, because otherwise the gas behaves as an insulator. Some electrons are always present from the ionization caused by cosmic rays in the gas, but this is not always sufficient and fluctuates strongly 3). In many tubes cathode materials have been used with low work functions from which electrons are liberated by photo-emission. These tubes need some light on the cathode but too much (e.g. direct sunlight) must be avoided, because it could trigger the tube immediately. Generally the tubes are more or less blackened to suppres too strong light. As materials for these cathodes nickel or iron are used, covered with a layer of potassium or barium-oxide (covered cathode). Tubes with these cathode-materials have fairly low breakdown and maintaining voltages (see Table I: Z50T, Z900T, G 150.2D etc.)

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x) $V_b = f(p \cdot D)$ P = pressure, D = distance electrodes.

See for general theory of breakdown processes in gases ref. 1) and 2).

A second method to get some ionization in the gas is to build a very weak radioactive source in the tube. Tritium [x] and uranium-oxide [xx] are used for this purpose. Tritium is used in Z804u and Z900T.

The third method makes use of a very small priming discharge (1 - 10 μA) between a fourth electrode and cathode (fig. 9) or anode (fig. 11). This system is often used in tubes with pure metal cathodes because of their higher work functions.

2. Reliability and Life.

Because there are no heaters, reliability and lifetime must be judged in terms of changes in tube characteristics. These changes depend on the following 3 factors:

a) shocks
b) the value of the cathode current
c) the mean value of the ratio "standing period" over "current flowing period". The higher this ratio, the longer the tube life.

Shocks can generally be avoided, so tube life depends mainly on b) and c). With the covered cathodes, the coating is deteriorated by the positive ions, especially for higher tube currents. Philips gives for example for Z50T [4] a life of 6000 hours at 6 mA d.c. (= max. rating). If this tube is used at a mA ($a > 6$), tube life will be shortened by a factor $(6/a)^3$ to $(6/a)^4$. For $a = 7$ mA already 50 o/o. Smaller currents on the other hand will increase life considerably. For the pure metal molybdenium cathodes of the Cerberus and Elesta tubes 25000 hours of operation are giv
by normal current.

In telephone equipment cold cathode tubes are used more and more, and the expected tube life is hoped to be 40 years [5].

Philips and Mullard brought some tubes on the market (Z 70 u, Z 803 u, Z 804 u) with cathodes of molybdenium prepared to the so-called "sputtering technique" [4] [6], which have very little change in properties. The same material is also used in the 85 A 2 reference diode. For the Z 803 u, which we intend to use in the relay units, the following stability figures are given in ref. 7: Five tubes were continuously operated during the first 5000 hours; the maximum change in V_{tb} found was 1,3 V, the minimum 0,3 V. Thirteen other tubes were switched on and off with a frequency of 50 x per sec.; mean value of $i_a = 8$ mA (= max. rating), peak value $i_a = 50$ mA.

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[x] Half-life = 12 years

[xx] Half-life $\approx \infty$.

After 10,000 hours of operation the maximum change in V_{tb} was ± 1,2 volt.

The Z 803 u has a specially rigid construction to avoid change in characteristics as a result of shocks.

3. Characteristics.

a) Breakdown characteristics.

Fig. 3 demonstrates the general form of the trigger tube breakdown characteristic. Point P represents the "standby" point where $V_a = V_o$ and $V_t = V_{bias}$. As soon as P passes the characteristic somewhere, breakdown takes place between the electrodes, as indicated in figure 3. Spread in tubes and changes as a result of ageing may be indicated bythe dotted lines.

Tubes for d.c. mostly work in the Ist quadrant with V_a and V_t positive. As can be seen V_{tb} is very constant over a wide range of anode voltage V_a. V_{tb} is mostly 70 - 90 volts for tubes with covered cathodes and 100 - 150 for pure metal cathodes. For spread in V_{tb} see table I on page 9. We measured V_{tb} for eight Z 803 u tubes and found a spread of ± 1 volt.

V_{ab} for d.c. tubes is mostly > 300 V, and for 220 volts a.c. tubes > 350 volts. Tubes made for 117 volts a.c. can be used for very low d.c. voltages.

If at the inside of an a.c. tube the anode is properly shielded, and the cathode has a lower work function than the anode, then the tube has rectifying properties D.c. relays may now be used in the anode circuit (GR 16, GR 17, Z 804 u). A.c. tubes are mostly operated with positive trigger voltages, some are specially constructed for use with negative pulses (GR 17, Z 804 u).

b) Transfer characteristic. $(i_t = f(V_o))$

This characteristic gives the minimum required trigger current to fire the main gap, as a function of the anode supply voltage (fig. 4). This current, called the transfer current, is needed just for a moment, shorter than the ionization time.

c) Ionization time T_i. (20 - 100 μsec.)

Ionization time is defined as the time between the beginning of the trigger pulse and moment in which the main gap breaks down; and consists of two parts.

i time to build up the t → c discharge.

ii time to transfer this discharge to the main gap (transfer time).

i depends on ......
1. Gas filling and construction
2. Overvoltage on trigger
3. Priming current i_o

ii depends on
4. Anode voltage V_o
5. Trigger current i_t

Fig. 5[x] gives T_i as a function of the trigger overvoltage. Curve I for a trigger impedance of 5,6 k , curve II for the input circuit used in the relay unit.

d) De-ionization time T_D. (200 µsec - 2 msec.)

De-ionization time is defined as the time after which no breakdown takes place if normal plate voltage V_o and normal trigger voltage V_{bias} are re-applied. T_D is much longer than T_i and limits the maximum speed of operation of the tube.

T_D depends on the following points:

1. Construction.
2. Gas filling (Hydrogen is often used as an agent to decrease T_D).
3. Tube current before de-ionization (the smaller i_a, the smaller T_D)
4. Re-appled anode voltage during de-ionization.
   (for Z 803 u the relation is given in fig. 6
   a minimum T_D is found for $V_a \approx 45$ volts.)
5. Remaining i_o

Standard Telephones and Cables Ltd. have developed a very fast trigger tube (G1-371K) having a T_D as low as 30 µsec. The tube is constructed in such a way that a continuously glowing gap $a_2 - c_2$ (see fig. 7) absorbes the positive ions from the $a_1 - c_1$ gap, immediately after the voltage over this gap is smaller than the sustaining value.

e) Current ratings.

Tube currents are limited to a maximum of about 50 mA because of deterioration of the cathode surface (see also 2). Too small tube currents, however, cause instability by increase in the maintaining voltage (region b, fig. 2) and should be avoided.

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[x] Figures 5 (curve I), 6, 12 and 14 have been copied from ref. 7.

4) Some remarks about basic circuits. 7) x)

Figure 8 shows the basic trigger tube circuit. The conditions are:

$$V_o < V_{ab}$$

$$V_{in} > V_{tb} \quad , \qquad t > T_i$$

$$R_a = \frac{V_o - V_{am}}{i_a}$$

$$R_t < \frac{V_{in} - V_{tm}}{i_t} \quad , \qquad i_t = \text{required transfer current.}$$

$R_{t\ min.}$ is determined by the max. allowable trigger current.

In figure 9 a circuit is given with high input current sensitivity. This sensitivity is obtained by connecting trigger and cathode with a small condensor C_t. When the tube is triggered, the input current is supplied by the discharge of C_t over the t-c gap, to a voltage a little lower than V_{tm}, after which this gap extinguishes. The duration of the discharge must be longer than the transfer time, and c_t therefore must not be too small. C_t is re-charged to the trigger bias voltage, some volts below V_{tb}, through R_t which may be very high. The limit for R_t is determined by the d.c. resistance of the condensor, the insulation resistance of the trigger electrode, or the pre-breakdown current in the tube. For these high sensitivities special tubes are made, e.g. G R 19 for which an insulation resistance of $10^{14}\ \Omega$ and a current sensitivity of 10^{-12} Amp are given in the data. The pre-breakdown currents in the t-c gap depend on various factors.

For the Z 803 u the pre-breakdown current is of the order of $10^{-9} - 10^{-8}$ Amp. 7) which limits R_t to $\approx 10^8\ \Omega$.

Sometimes C_t is fairly high. In this case a resistance R_c is required to limit the peak current. The circuit demonstrated in Fig. 9 gives some delay, which may be a disadvantage.

Figure 10 gives the required C_t as a function of the anode supply voltage V_o.

In fig. 11 a circuit is demonstrated for pulse coupling. No delay is obtained with this circuit, and R_t may be extremely high. After the breakdown some time is needed to re-establish $C_T.R_T$. The minimum pulse width required depends on the overvoltage (fig. 12).

Extinguishing.

To extinguish the tube the maintaining voltages must be reduced below the sustaining values during a time longer than T_D. Relay contacts may be used to break off the cathode lead, or negative pulses may be applied to anode and trigger. Besides, pulsed power supplies are used 8). Fig. 13 shows a circuit where extinguishing takes place automatically. C_a is charged normally to V_o but discharges just below V_{am} when the tube is fired.(like C_t in fig. 9). R_a must be large enough in order to get a current which is too small to maintain the discharge and the tube is extinguished. C_a recharges again to V_o. R_aC_a must be longer than the de-ionization time of the anode gap. From R_1, a positive and from R_2 a negative pulse may be obtained, and both resistors may, at the same time, limit the peak currents. The maximum trigger frequency is about 600/sec.

Some remarks about other types of possible circuits are found in 10).

5) Summary of the tube properties:

a) Long life
b) Directly ready for operation
c) No power consumption during standby periods
d) High input impedance
e) High current gain.
f) Stable characteristics
g) Low price
h) Little temperature effect
i) Visual "on" indication
j) Wide anode voltage range.
k) Low operating frequency.
l) Limited current capacity.
m) Extinguishing is complicated.

6) TABLE I

cold cathode trigger tubes

Type	Manuf.	i_a mA			Va	Vam	Vtb	i_{t_r} *)	T_i *)	T_d *)	Sockel	Remark
		min.	max.	peak	Volts	Volts	Volts	μA	μs	μs		
Z50T	Philips	2	6	24	175	61	66 - 90	50	50	200	S.M.	
Z70U	"		3	12	310 - 330	118	139 - 151	3			S.M.	3 KC
Z300T	"		25	100	225 - 310	70	70 - 90	100			O	
Z804U	"	5	40	125	160 - 400	110	- 115 - 131	50			N	A.C.
Z900T	"		25	100	200 - 290		80 - 105	50	20	500	N	
Z800U	Mullard		2,5	10	220 - 285	110	141 - 151				N	
Z801U	"		2,5	10	150 - 170	105	nég				N	
Z803U	"		8	50	170 - 290	105	128 - 137	50	100	2 m	N	
G150.2D	S.T.C.	1	30	50	150	74	60 - 80	10		6 m	O	
G240.2D	"		30	50	230	90	75 - 90	15			O	
G1.236G	"	0,5	1,5		235	70	85	3	100	400	S.M.	
G1.371K	"	2	10	15	270 - 360	175	170		0,5	30	M	20 KC
3 N 1	Siem.Br.		30		230	100	65 - 90	15	50	6 m		
3 N 2	"		10		230	80	60 - 80	15	50	1 m		
3 N 3	"		1		230	80	60 - 80	15	50	500		
GTE 175 M	ETELCO		3,5		180 - 310	150	168 - 180	8		500	M	1 KC
1.C.21	R.C.A.		25	100	180	73	66 - 80				O	
OA4 - G	"		25	100	225	70	70 - 90	100			O	
5823	"		25	100	290	62	80	50	20	500	M	A.C.
C C T 6	G.E.C.	1	5	40	190 - 250	75	70 - 90			500	S.M.	
GR 15	CERBERUS	10	40		150 - 270	107	120 - 140	10^{-3}(C)			N	
GR 16	"	10	40		270 - 400	111	120 - 140	150			N	A.C.
GR 17	"	5	40		300 - 450	113	- 120 - 150	200			N	A.C.
GR 18	"	6	20		330 - 450	115	120 - 140	400			N	
GR 19	"	4	20		315	108	135	10^{-6}(C)			N	

TABLE I (continued)

cold cathode trigger tubes

Type	Manuf.	i_a mA min.	max.	peak	Va Volts	Vam Volts	Vtb Volts	i_{t_r} *) µA	T_i *) µs	T_d *) µs	Sockel	Remark
GR.20	CERBERUS	4	30		300 - 350	109	120 - 140	100			N	2. T**)
GR.21	"	2,5	8		320 - 320	110	145	400			S.M.	2. T
ER. 1	ELESTA	10	40		300 - 350	110	130	50			N	
ER..2	"	15	40		370 - 590	110	125 - 140	200			N	
ER. 3		6	40		300 - 350	107	130	50			N	2. T
ER. 21	ELESTA	6	40		260 - 420	111	88 - 110	200			N	A.C.
XC. 11	HIVAC		1		190	80	60 - 85	20	50	700		
XC. 13	"		7,5		200	55	75					
GK 32/33	Ferranti		20		140	80	85 - 98	10		1 m		
GK 40 /41	"		20		140	73	79 - 85	4				
GK 50	"				220	85	120	10^{-4}(C)			N	

*) These values depend very much on the tube conditions?; generally, maximum values are given.

**) 2 trigger electrodes

7) Principles of cold cathode scaling tubes.

All fundamental gas discharge phenomena applying to trigger tubes apply also to cold cathode scaling tubes. A decatron scaling tube consists of a cylindrical anode placed in the centre of the tube with 20 cathodes placed symmetrically around it (Fig.15) Ten of the cathodes, $(b_1, b_2, \ldots b_{10})$ namely the transfer cathodes, are connected together and serve as the trigger input. All cathodes are asymmetric in order to let the discharge take place at the extremities y,z etc (fig. 16) of the cathodes. Supposed, that the discharge takes place between the anode and cathode C_1, an incoming trigger pulse will take all the transfer cathodes 80 volts down, but only $a-b_1$ fires because the gas there is more ionized than near the other cathodes. The extra current causes the anode voltage to fall down and the $a-c_1$ gap is extinguished. The discharge on b_1 is meanwhile displaced to point Z and ionises there more gas around c_2 than around c_1. At the end of the pulse V_a increases about 80 volts and fires now $a - c_2$ which immediately extinguishes $a - b_1$ and so on. It is clear that the pulse width must be long enough. At higher frequencies pulse height and width are critical. For better stability, sometimes suitable capacitors across the cathode resistors are needed to hold the foregoing cathode a little higher in potential for a moment. However, these condensors give bad output pulses.

In fig. 17 the Ericsson type of triggering is demonstrated. Two transfer cathodes are placed between each pair of main cathodes. Triggering is obtained by applying successive negative pulses to inputs b and b'. The direction of scaling can be reversed (subtraction) by interchanging b and b' with respect to the input pulses. Capacitors in the cathodes are not needed here.

For using more stages in series the positive pulse of the last cathode must be amplified, shaped and reversed in phase. For this purpose the trigger tubes GTE 175 M and G1-371 k have been designed. An input stage with G1-371 k is described in ref. 9.

In table II most of the existing tubes are gathered.

Type 6167 has a second anode[10] from which immediately the input pulse for the following stage may be obtained. Unfortunately the tube is not obtainable for civil use.

In the new EZ-10 hydrogen has been used to get a very low de-ionization time. In the data a max. frequency of 50 kc is given, but 100 kc may be obtained by very accurate adjustment of circuit conditions.

If the discharge takes place during a long time at a fixed cathode, the breakdown voltage for this gap may change. In applications where this happens often the fatal consequence may be that the scaler sticks to such a cathode. The effect appears especially in high current tubes such as DZ.10 and G10.241E. A remedy for this effect is described in ref. 11.

More detailed descriptions of scaling tubes will be found in ref. 12.

TABLE II

cold cathode scaling tubes

Type	Manuf.	Directions	MAX. FREQ. p.p.s.	Step puls volts	OUTPUT Volts	MA MAX	number	Va min. volts	Vam Volts
GC 10 B	ETELCO	2	4000	- 80	35	0,55	1	350	190
GC 10 4B	"	2	4000	- 80	40	0,55	4	350	190
GC 12 4B	"	2	4000	- 80	40	0,55	4	350	190
GC 10 D	"	2	20000	-150		1,2	1	420	215
GS 10 C	"	2	4000	- 80	35	0,55	10	400	192
GS 12 D	"	2	4000	- 80	35	0,35	12	400	191
GS 10 D	"	2	20000	-120	35	0,9	10	440	208
6167 x)	Bell.Tel.	1	10000			3	10		
DZ. 10 xx)	CERBERUS	1	2000	- 50	20	8	10	220	112
EZ. 10	ELESTA	1	50000	-120	20	1,7	10	500	280
G10. 241E	S.T.C.	1	20000	-120	40	3,7	10	310	180
CH 1047 xxx)	CHATAM	1	2000	-150		4,5	10	340	160

Notes

)x Is for military use only
)xx Can not be recommended
)xxx Is out of production

II

1) The relay unit.

In fig. 18 a relay unit with coincidence circuit and the first stage of the counter are demonstrated. We have chosen for the counter stages the GS-10c scaler (see table II) because more reliable operation may be expected with this tube than with the other types considered. The low cathode current rating is a disadvantage for our purpose as will be seen hereafter. As described in report MM-Internal 11, the counter is in principle a timer, and the coincidence circuit is used to obtain from the cathodes of the scalers a trigger pulse at a defined instant. The minimum interval in which trigger pulses in this way can be obtained is about 0,8 msec. They are used to trigger the relay unit, of which we expect an operating precision of about 0,2 msec.

We consider now figure 18. With 0,4 mA tube current, the GS-10c requires 82 k in the cathode in order to obtain output pulses of 30 volts. This fairly high value of R_K fixes R. in the coincidence circuit to very high values in order to avoid too high biasing of the scaler cathode potentials by the currents i_{d1} , i_{d2} and i_{d3} The maximum value of R_1 is determined by the input circuit of the Z803 U, which is a combination of the input circuits we discussed in the figures 9 and 11.

According to the tube data the minimum C_t required is 1 kpF. To get fast enough ionization we want at the trigger a voltage rise of at least 50 V/msec. This rise is determined by the speed by which C_t can be charged through R_1, So $\frac{dV}{dt} = \frac{i_d}{Ct}$.

With the figures given $i_d = 50$ µA fixing R_1 to a maximum of (300 V/50 µA) = 6 MΩ. With these circuit conditions we found the ionization curve of Fig. 5 (No II).

To meet the requirements of our operating precision it is safe to decide for an overvoltage on the trigger of at least 6 volts. The change in trigger time resulting from T_i if trigger pulses of varying amplitude are used is smaller than 150 µsec in that case. By fixing the trigger bias voltage 5 volts below the breakdown level a pulse on the trigger electrode of 6 + 5 = 11 volts is required, which means 14 volts at the input terminals because of 25 o/o attenuation.

With a value of 6 MΩ for R_1 the current through the diodes $i_{d1} + i_{d2} + i_{d3}$ equals 50 µA. We consider the situation in which there are 30 volts input pulses at the inputs b and c but not at input a. The currents i_{d2} and i_{d3} are then zero, and $i_{d1} = 50$ µA. If Germanium diodes are used, which have a back resistance of about 1 MΩ , a back current of 2 x 30 µA is still added to i_{d1}, causing about a 10 volt bias at the cathode C_8, which might disturb the operation of the counter and which lowers the effective trigger pulse by the same order of magnitude. It is clear that the system is not reliable if more relay units are operated from the same cathode, also not if about a factor of two in improvement is obtained by using silicon diodes with 50 MΩ back-resistance. Cathode followers therefore will be used to transform the cathode impedances to about 500 Ω.

To meet the stated precision in time, also the closing time of the relay in the plate circuit must be accurate enough. We have made tests on closing time and bouncing with different marks of inexpensive high speed relays. The Siemens type rls 154 seems to suit best our wishes. A high inverse voltage selenium rectifier is used to suppress the induction peak as the high voltage V of the unit is broken off at the end of each cycle of the machine. The series resistance of the relay is 6 times higher than the d.c. resistance of the relays, causing constant pull in current and a minimum closing time of 3 msec. This closing time may be expected to be constant within ± 0,15 msec during at least 50 million operations.

2) Applications.

A brief survey will be given of the main fields of applications of cold cathode trigger and scaling tubes.

Relays are advantageously operated in a great many applications with trigger tubes, supplied either with A.C. or D.C. voltages. For triggering only small signals are needed 4).

In timing circuits: Simple timers with one trigger tube having a maximum precision of about 3 o/o and maximum delays of 3 hours can be used in applications such as motor starting circuits, in photographic work etc. Decatron tubes are used in more complicated timing circuits such as the Linac timer (2 DD 132), the counters in our programming system and the precision Tachometer for speeds up to 80000 R.P.M. described in reference 13.

In Protection and Control circuits. Because of the 3 properties: long life, no power consumption during standby and immediately ready for operation, the trigger tube is very suitable for these circuits.

Examples are: Protection of power distribution lines, big transformers and electric motors 7). Overvoltage protections. A.C. 7) and D.C. 3) voltage control, Touch control, control from light sources, remote control etc.

In telephone equipment: See references 4, 14 and 15.

In counting and logical circuits: Astable, monostable and bistable binary circuits relaxation oscillators etc. with low time response have been described 7) 8). Besides "and" and "or" gate circuits as well as shift registers 8). Subminiature trigger tubes in printed circuit ring counters with maximum frequencies of 10 kc/s 4) 16), or for use in scales other than 2 and 10.

Decatron scaling tubes are used in computing circuits, industrial counters, batching counters 16) 17), nucleonics counting, etc.

Trigger tubes may be useful in battery operated equipment, such as for example the fence controller demonstrated in reference 4.

3. REFERENCES.

1. F. Llewellyn Jones: Ionization and breakdown in gases.

2. S. Flügge: Handbuch der Physik, Band 22.

3. C.H. Tosswill: Relaisbuizen met koude cathode. Philips Technisch Tijdschrift
Aug. 1956

4. Philips: Cold cathode tubes, publ. 20/241/D/E - 1-'57.

5. H.L. von Gugelberg: Kaltkathodenröhren. Bull. des Schweizer Elektr. Verein Nr. 3, 1953

6. F.M. Penning et al.: Philips Research Reports I. 1946

7. K.F. Gibson et al.: A new type of cold cathode trigger tube.
Electronic Engineering, 29, Oct., Nov., Dec. 1957.

8. J.E. Flood et al.: The design of cold cathode tube circuits.
Ibid. 28, Oct., Nov., Dec. 1956.

9. C.D. Florida et al: A cold cathode scaling unit.
Ibid. 26, May 1954, p. 186.

10. D.S. Peck: A ten stage cold cathode stepping tube.
Electtical Engineering 71, Dec. 1952, p. 1136.

11. G.H. Hough et al: Multicathode gas tube counters.
Electrical Commun. 27, Sept. 1950, p. 214.

12. K.M. Kandiah: Multi-electrode counting tubes.
Brit. Inst. Rad. Engrs. April 1953, p. 221.

13. W.R. Bland et al.: A high speed precision tachometer.
Electronic Engineering 26, January 1954.

14. J. Domburg et al.: Eine Gasentladungsröhre mit kalter Kathode als Schaltelement
in Fernsprechwählanlagen.
Philips Technische Rundschau 15, 1954, p. 321.

15. S.T. Brewer et al.: A telephone switching network and its electrical controls.
Bell System Technical Journal 34, 1955, p. 361.

16. R.W. Brierly: An industrial batching counter.
Electronic Engineering 26, April 1954, p. 157.

17. P.E. Toohe: A cold cathode batching counter.
Ibid. 26, April 1954, p. 160.

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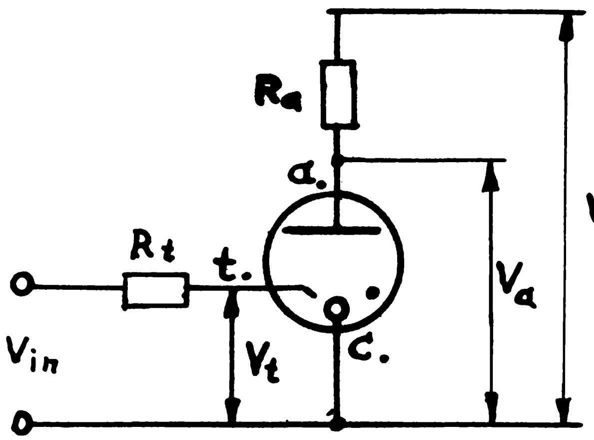


a = anode
c = cathode
t = trigger

Fig 1

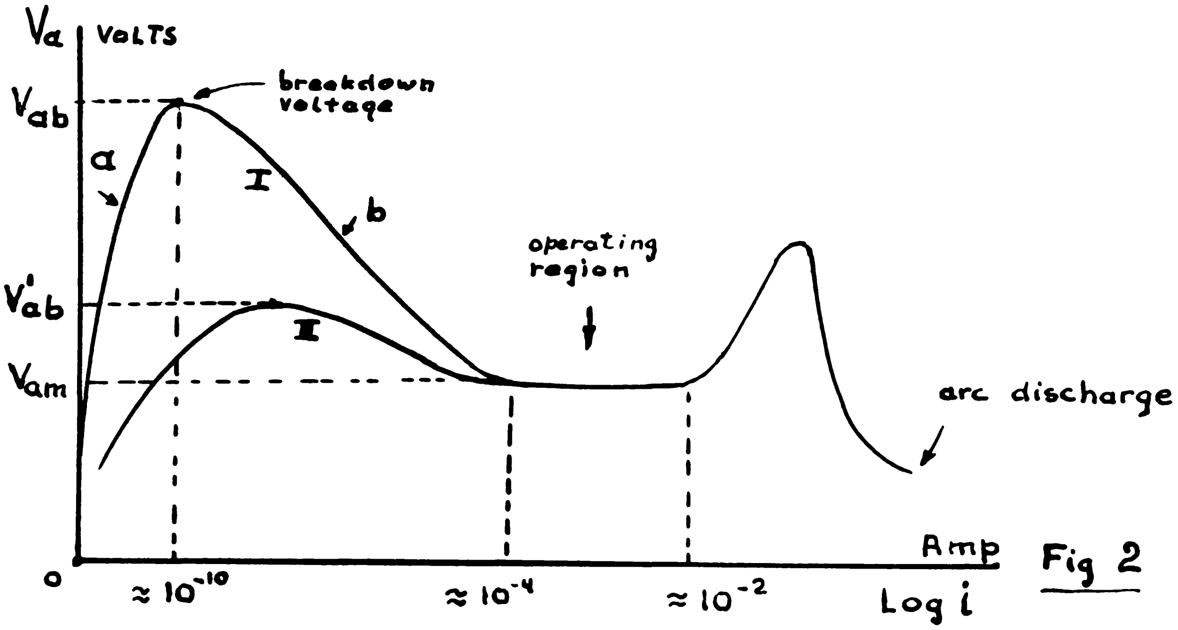
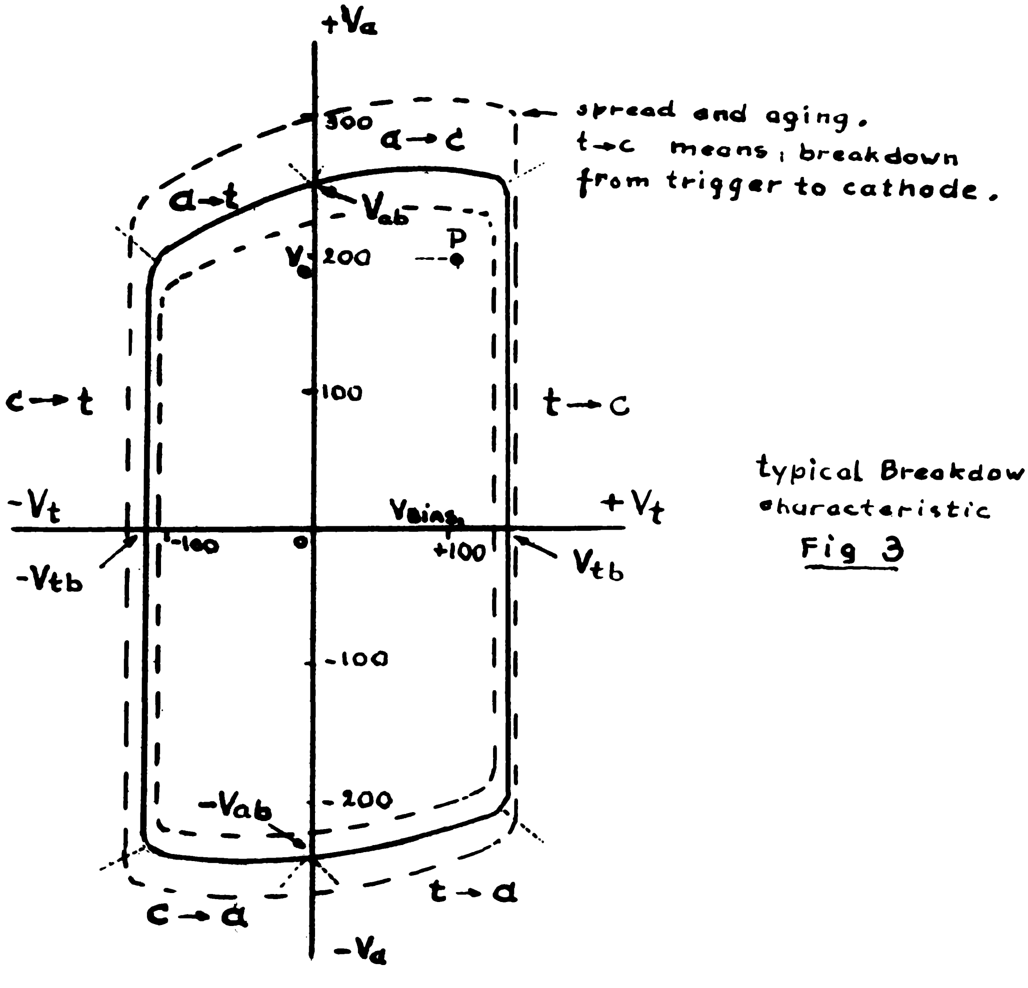
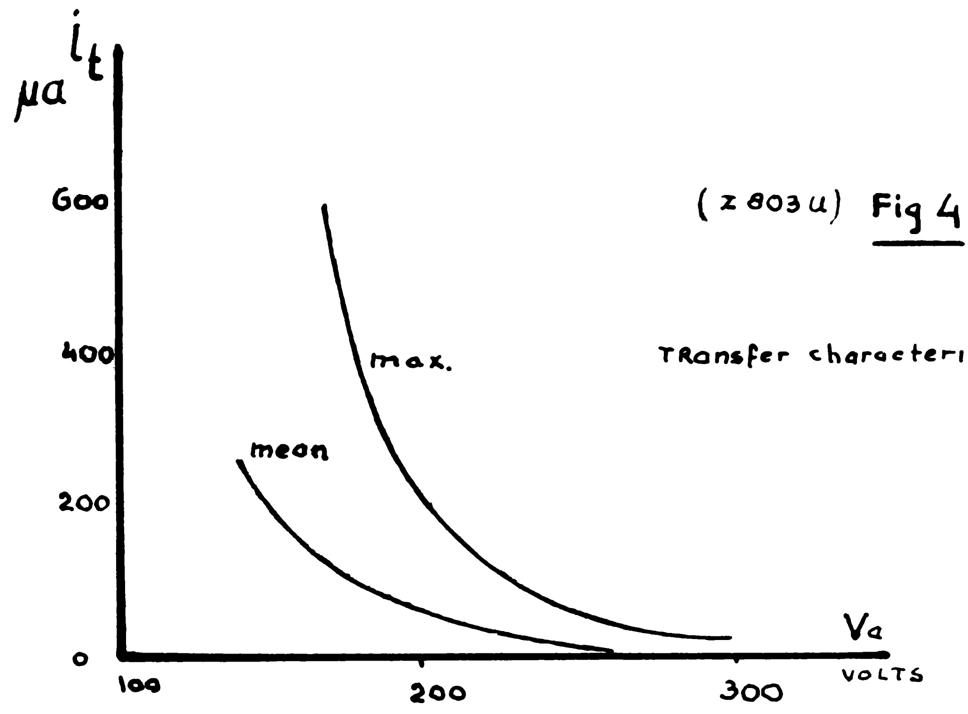


Fig 2



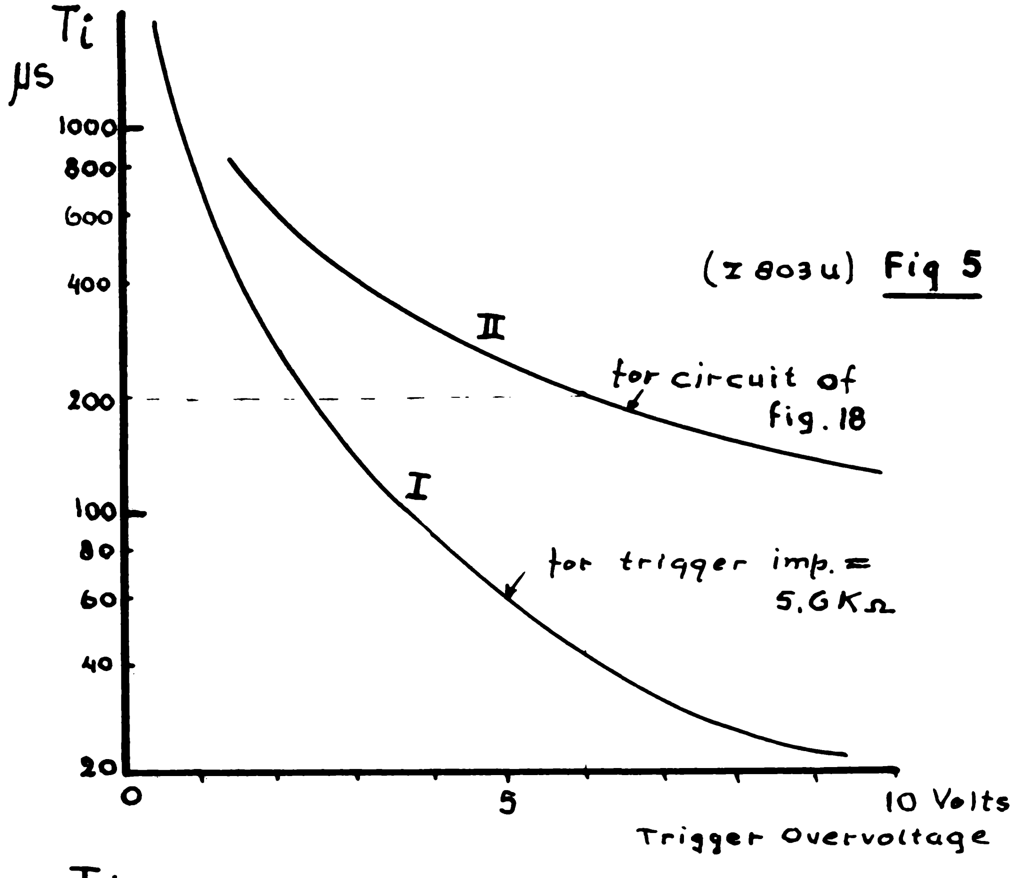
typical Breakdown characteristic

Fig 3

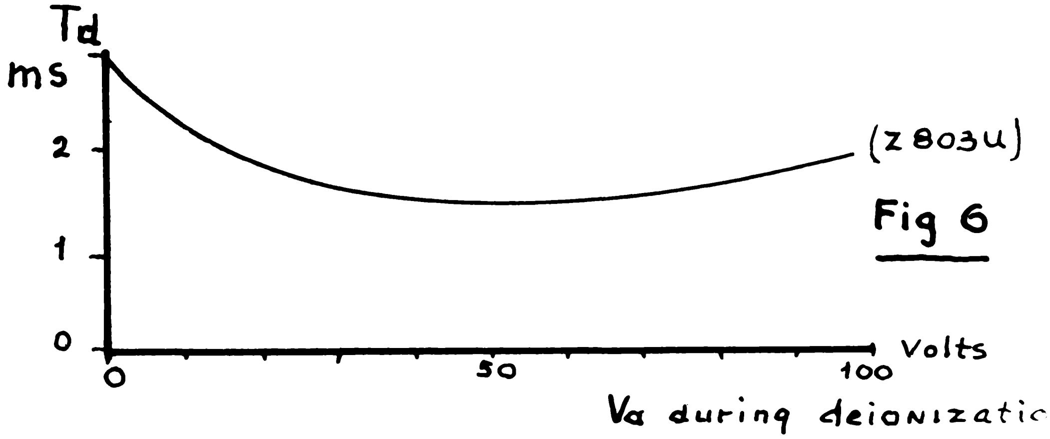


(Z803U) **Fig 4**

Transfer characteristic



(Z803U) **Fig 5**

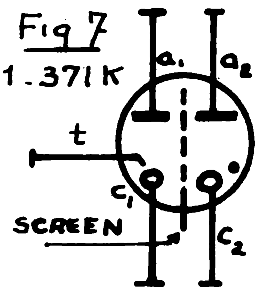


(Z803U)

Fig 6

Fig 7

G1-371K



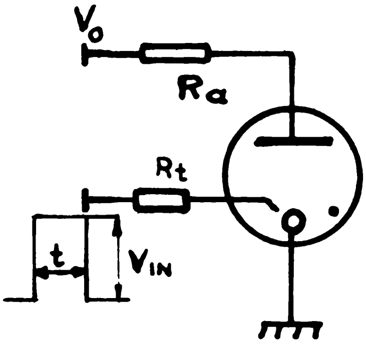


Fig 8

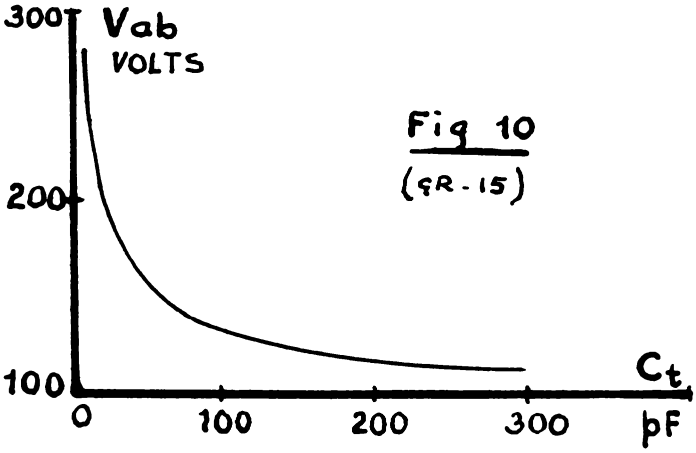
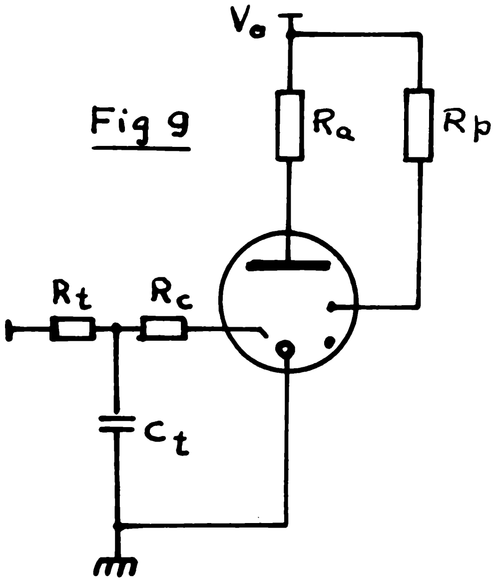


Fig 10

(GR-15)

Fig 9



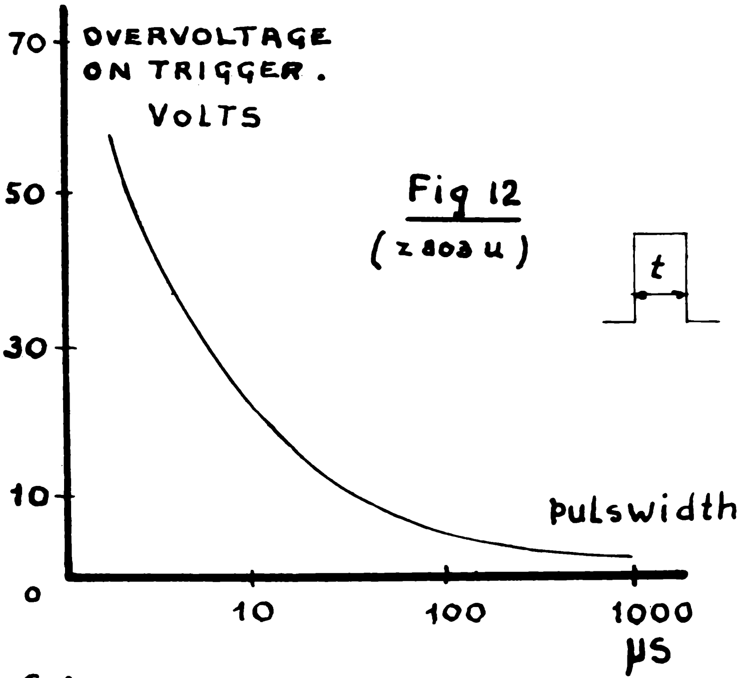
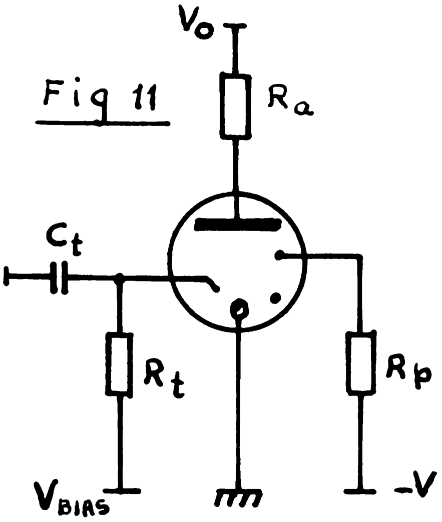


Fig 12

(Z 803 U)

Fig 11



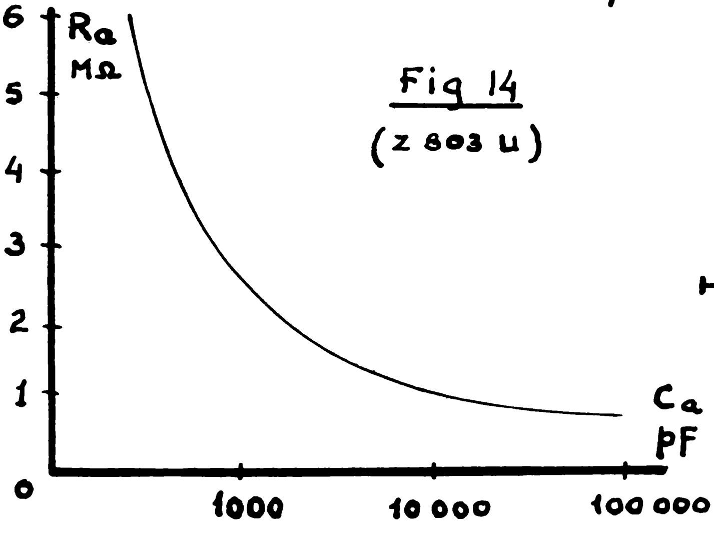
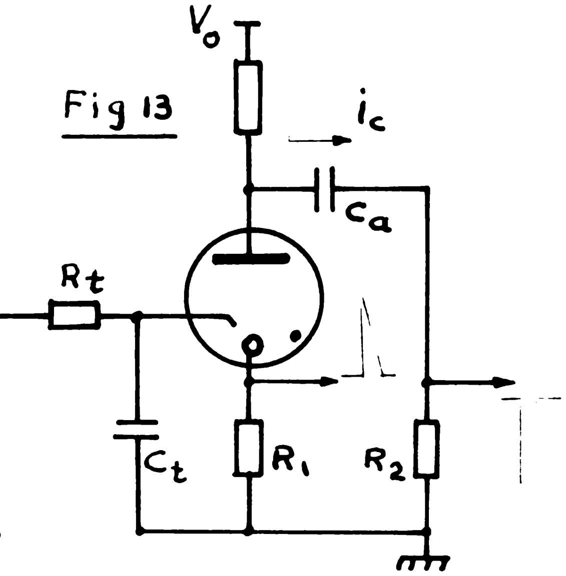


Fig 14

(Z 803 U)

Fig 13



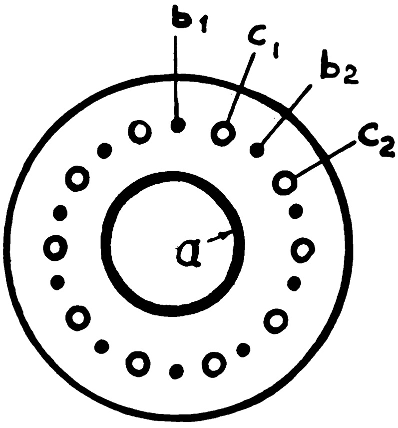


Fig 15

a = anode
b = transfer cathode
c = main cathode

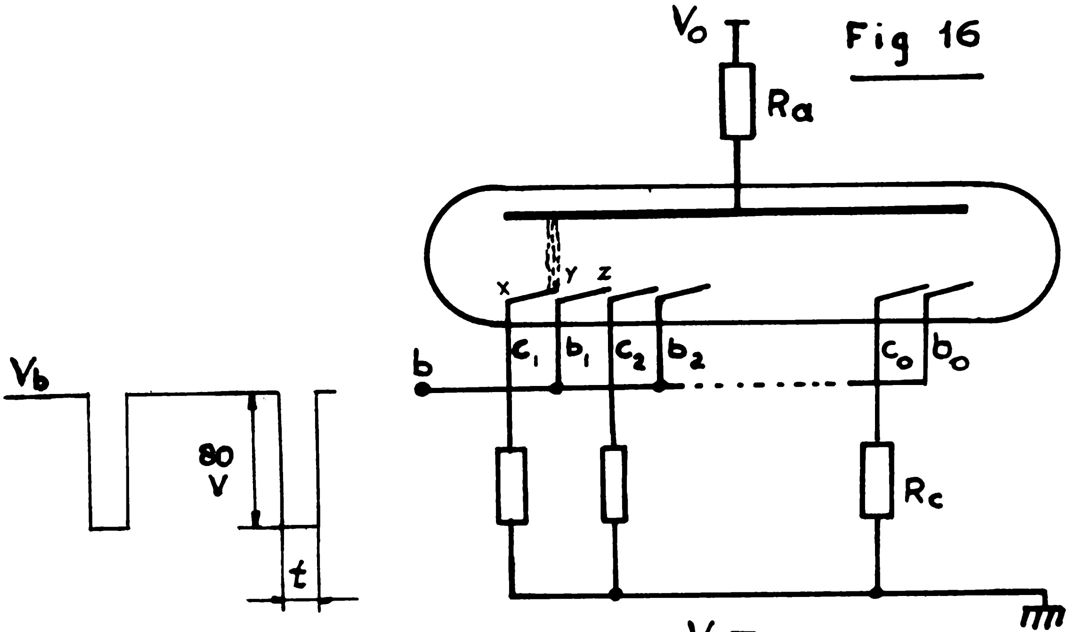


Fig 16

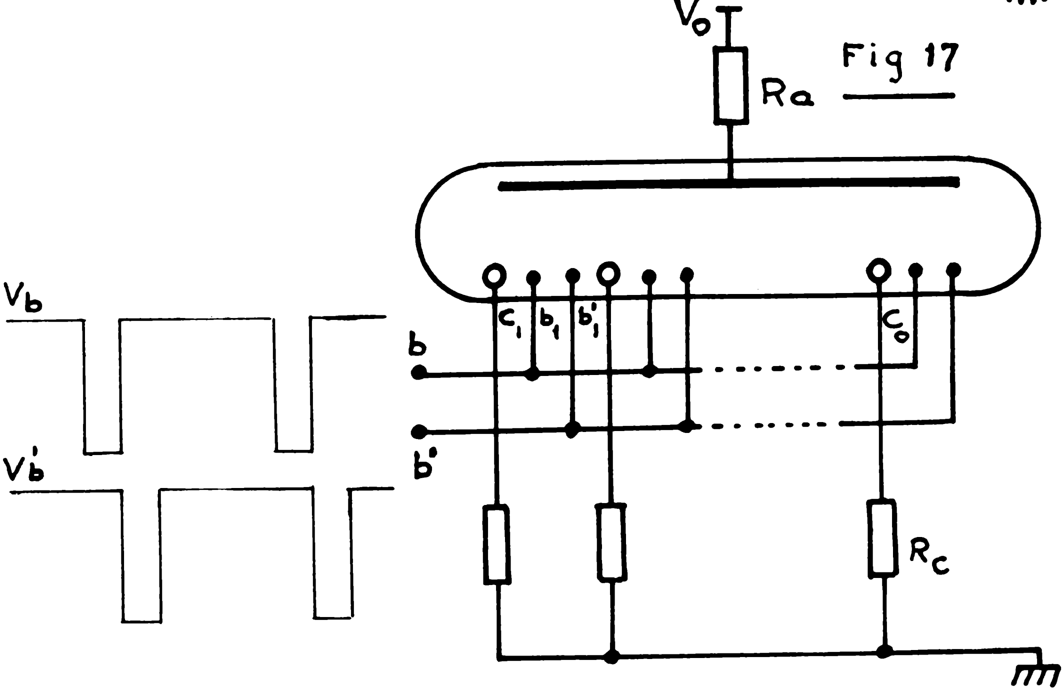
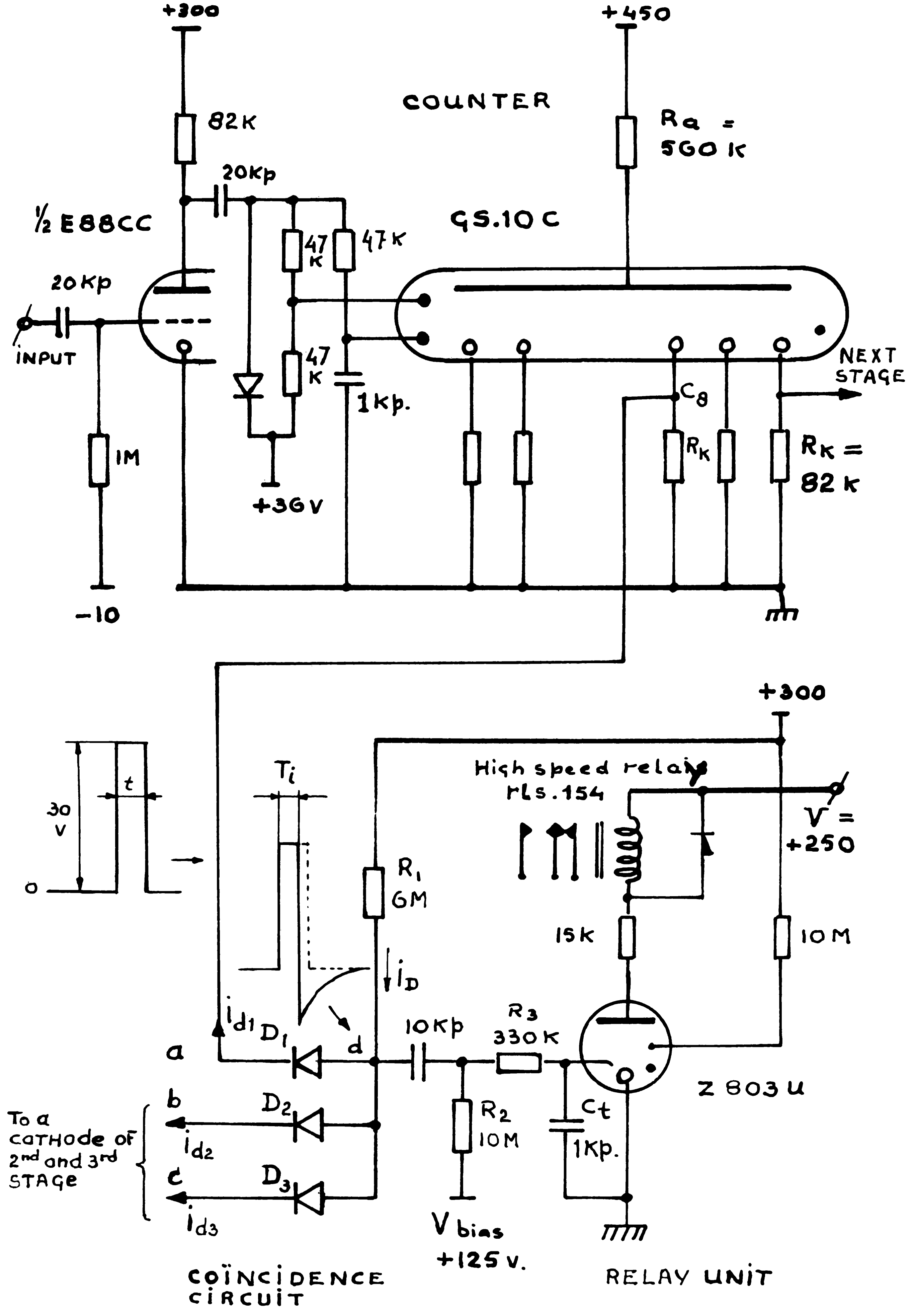


Fig 17

Fig - 18


+300
COUNTER
82K
20Kp
½ E88CC
47 K
47K
47 K
20Kp
INPUT
1M
-10
+36V
1Kp.
+450
R_a = 560 K
GS.10C
NEXT STAGE
C_8
R_K
R_K = 82 K
+300
High speed relay
rls.154
V = +250
30 V
0
t
T_i
R_1 6M
i_D
15K
10M
i_{d1}
D_1
d
a
10Kp
R_3 330K
Z 803 U
b
D_2
i_{d2}
c
D_3
i_{d3}
To a cathode of 2nd and 3rd STAGE
R_2 10M
C_t 1Kp.
V bias +125 v.
COINCIDENCE CIRCUIT
RELAY UNIT