RYG10 - Trochotron Decade Counter

RGY 10 was the first commercial trochotron, introduced by Ericsson in 1954. Its design was directly derived from the experiments conducted by the Swedish physicist Hannes Alfvén who, along with Harald Romanus, had described in Nature, November 1, 1947 linear counting structures based upon trochoidal trajectories of electrons moving in combined electric and magnetic fields.

Its basic sleeve-anode two-electrode structure was a crude design, yet it operated as divide-by-ten counter characterized by stable states. No grid was available and negative counting pulses were directly applied to the common anode, forcing it to zero in order to release the beam from the current spade. Provided that the conting pulse was short enough to let the anode voltage return fast enough positive, the beam jumped then in a stable state to the next spade. Its operation was critical, being necessary to balance voltages and time constants of the spades as well as the intensity of the magnetic field so that the electrons could follow circular trajectories at a given speed along equipotential paths. At the same time, the shape and duration of negative pulses had to be compatible with the flight time, the time necessary for the beam to be released from the current spade and approach the zone of influence of the next one. Once the proper parameters were selected for a given frequency, pulses had to be shorter than 0.8 CV/I, whereas C and V were the spade capacitance and voltage and I was the cathode current, otherwise one or more spades were skipped.

Principles of operation, data and application circuits are given in the pages below from original Ericsson documentation.

THE PRINCIPLES OF THE TROCHOTRON RYG 10

During the development stage the trochotron RYG 10 was called AD 3. It is a high vacuum electron tube with an oxide-coated cathode /fig. 1/, designed to operate in a magnetic field as a ring counter with ten /or less/ positions. The ten symmetrically arranged electrodes are called spades and the round electrode outside these is called the plate.

The strength of the magnetic field has to be so large that, when all spades are at the working potential, no current flows to them. If from this condition the potential of one of the spades is lowered, a current - potential diagram similar to fig. 2 is obtained. It follows that three operating points /A, B and C/ are possible if a resistance is connected to the spade. Of these three points, however, only A and C are stable. The appearance of the electron beam when one spade is "locked down" /i.e. at the operating point A of fig.2/ is shown in fig.3. The reason for this behaviour is that electrones moving in crossed electric and magnetic fields mainly follow an equipotential line. The direction of the rotation of the beam may be reversed by rotating the direction of the magnetic field 180 degrees.

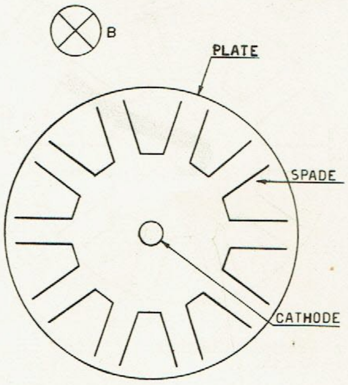


FIG 1 TROCHOTRON RYG 10, SHOWN IN A PLANE PERPENDICULAR TO THE CATHODE.

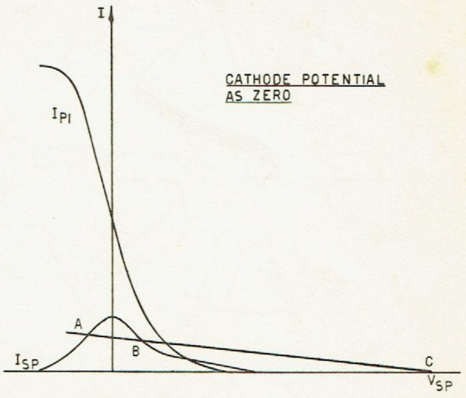


FIG 2 CURRENT TO ONE SPADE AND TO THE PLATE AS A FUNCTION OF THE POTENTIAL OF THE PERTINENT SPADE. PLATE POTENTIAL HAS ABOUT THE SAME VALUE AS THAT FOR OTHER SPADES.

It is now possible to make a simple stepping device. To each spade is connected an RC circuit as in Fig. 4. Assume at first that spade n in fig. 4 is "locked down". Most of the electron current from the cathode thus goes to the plate /confer Fig. 2/ If the plate potential is abruptly decreased to almost cathode potential most of the current will then go to the next spade /n + 1/ instead of to the plate. This current quickly charges the capacitor connected to this spade and the spade potential decreases. When this potential approaches the cathode potential, the whole beam will switch over to the next box and it is then necessary to restore the plate potential to its normal value in order to avoid that the beam steps further. At this moment the beam is locked to spade /n + 1/ and is divided between the plate and one spade in the same manner as before, but it is advanced one step. There it will stay until the next negative pulse is applied to the plate. The spade n now receives no current and its capacitor is consequently discharged by the corresponding resistor.

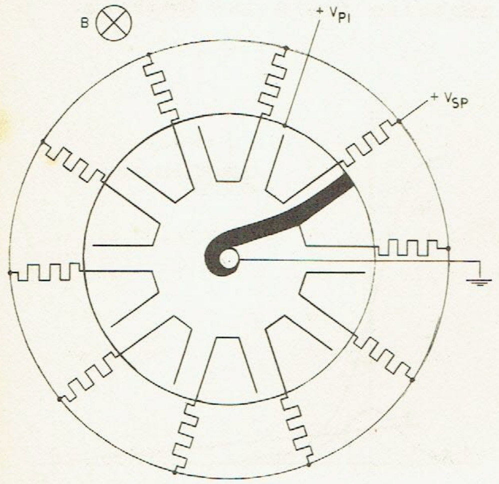


FIG 3 THE BEAM FORMATION WHEN ONE SPADE IS IN WORKING POINT A.

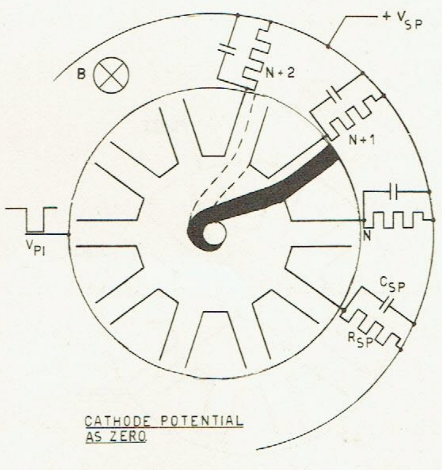


FIG 4 A SIMPLE STEPPING DEVICE USING THE TROCHOTRON RYG 10.

The speed of stepping is increased by decreasing the spade resistors and capacitors. Minimum values are expected to be of the order of 100.000 ohms and 10 pF. A suitable length of the stepping pulse applied to the plate is approximately

$$T_p = 0{,}8 \frac{C_{sp} \cdot V_{sp}}{I_{pl}}$$

provided that the plate pulse goes down to cathode potential. Because it takes a longer time to discharge the spade capacitor than to charge it with the current available in the trochotron, the time for one complete rotation of the beam /ten steps/ should not be less than $4 \cdot R_{sp} \cdot C_{sp}$.

Increased beam current /increased voltage and magnetic field strength/ contributes to the stability at lower spade resistor values. The use of a cathode resistor is recommended as this minimizes the influence of voltage variations. A variable cathode resistor is also conveniant for compensating for possible differences in the circuits or of the magnetic field.

The max. counting speed of the tube itself is of the order of 1.000.000 counts/sec. while reasonable simple driver circuits permit counting speeds up to 400.000 counts per sec.

The position of the beam in the tube can be read electrically from the spade voltage or visually from the fluorescent screen.

Resetting to any of the ten positions may be accomplished by momentarily removing all spade potentials and then reapplying them whilst delaying the voltage rise at the relevant spade. This can easily be achieved by an RC combination or by means of mechanical contacts.

The magnetic field needed can be produced by a cylindrical Alnico magnet 45 mms long and with a wall thickness of more than 5 mms

DESIGNATIONS

V_{sp} = Spade Voltage

R_{sp} = Spade Resistor

V_{pl} = Plate Voltage

B = Magnetic Induction

I_k = Cathode Current

All voltages refer to the cathode potential as 0.

RECOMMENDED WORKING CONDITIONS

Heater Voltage	6.3	volts
Heater Current	0.3	amps
Plate Dissipation maximum	1.0	watt
Spade Dissipation, each spade	0.5	watt

$\frac{V_{sp}}{B^2}$ = approx. 10^5 / volts resp. volt · sec/m^2 /

V_{pl} approx. = V_{sp}

For sufficient visual indication the plate voltage should not be lower than 80 volts.

Keeping $\frac{V_{sp}}{B^2}$ constant, I_k varies as $V_{sp}^{3/2}$.

NORMAL WORKING POINT

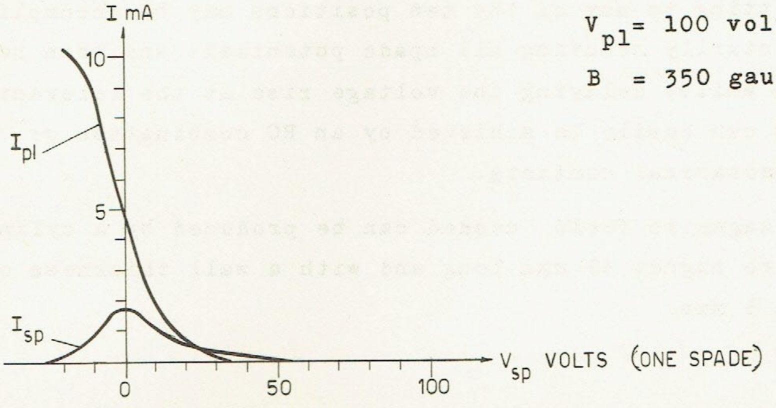
Spade Voltage	100	volts
Plate Voltage	100	volts
Magnetic Induction, approx.	350	gauss
Cathode Current, approx.	10	mA
Spade Resistor	0.2	megohm

EXAMPLE FOR THE CURRENT - VOLTAGE CHARACTERISTICS

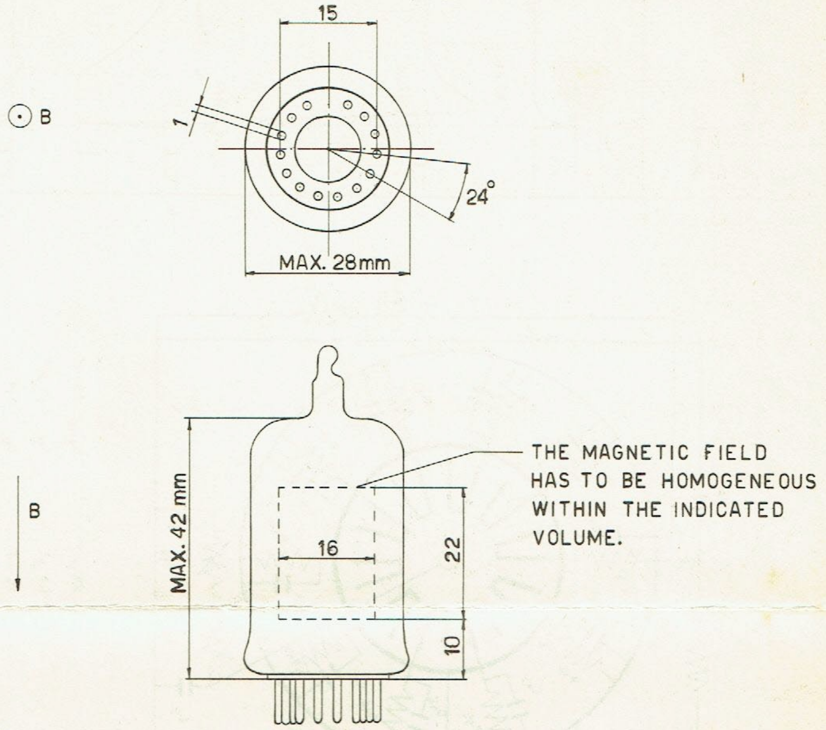
Other spades: V_{sp} = 100 volts

V_{pl} = 100 volts

B = 350 gauss

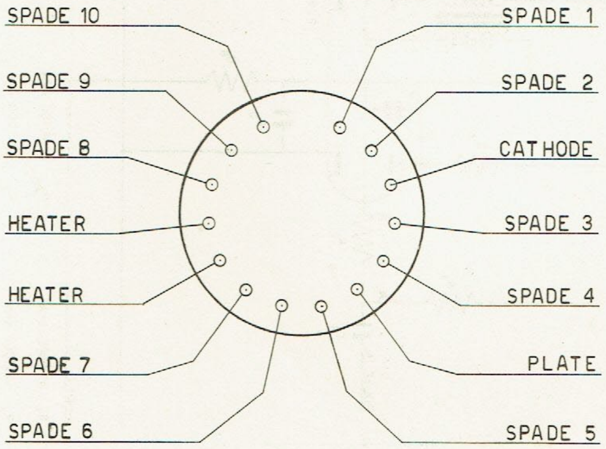


BOTTOM AND SIDE VIEW OF THE TUBE



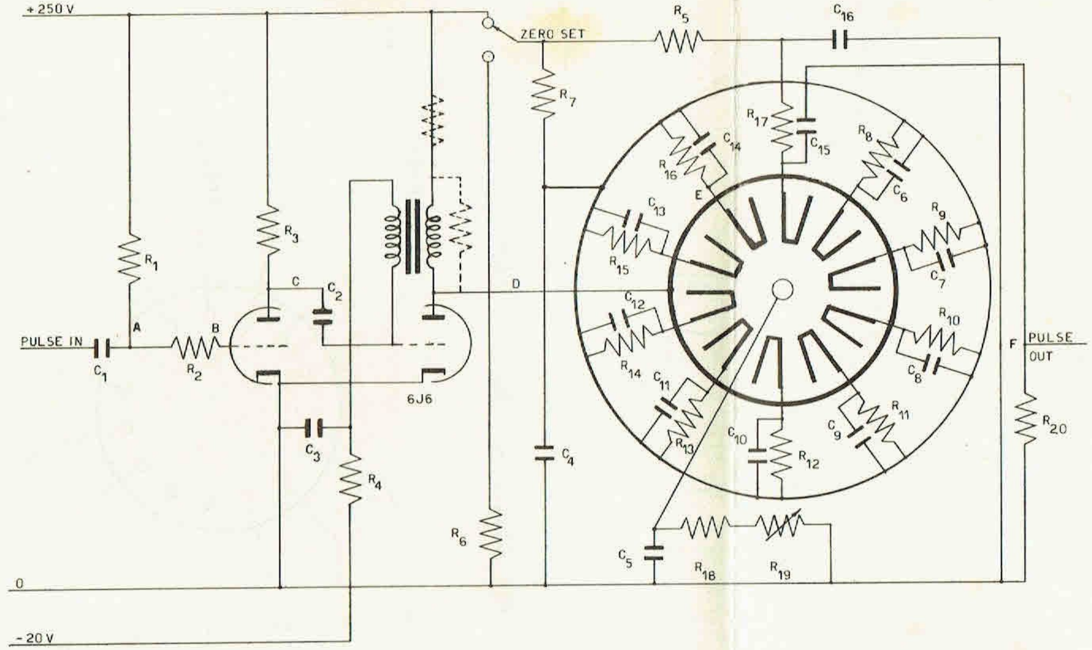
THE MAGNETIC FIELD HAS TO BE HOMOGENEOUS WITHIN THE INDICATED VOLUME.

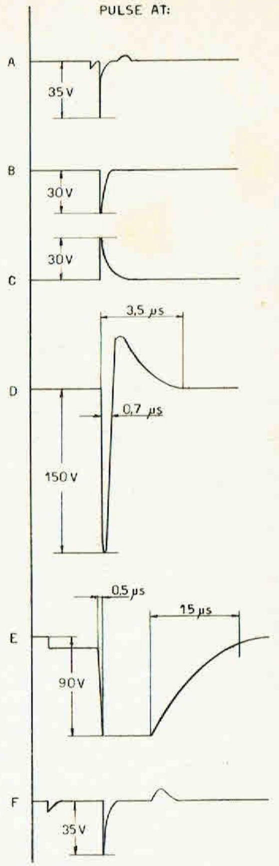
SOCKET CONNECTION. BOTTOM VIEW.



DECADE COUNTER, USING THE TROCHOTRON RYG 10

Counting speed max. 300.000 pulses/sec.





R_1	470,000 ohm	$R_{4\text{-}6}$	4,700 ohm	R_{18}	4,700 ohm (1W)	$C_{1\text{-}3}$	100 µµF	$C_{6\text{-}14}$	30 µµF
R_2	22,000 ohm	R_7	500 ohm	R_{19}	15,000 ohm (2W)	C_4	0,1 µF	C_{15}	35 µµF
R_3	18,000 ohm	$R_{8\text{-}17}$	180,000 ohm	R_{20}	15,000 ohm	C_5	25 µµF	C_{16}	1 µF

Coaxial Trochotron for Pulse Counting

O STERNBECK, TELEFONAKTIEBOLAGET L M ERICSSON, STOCKHOLM

U.D.C. 621.385.832:621.218.572

The action of the trochotron is based on the characteristics of an electron beam in a magnetic field that is crossed by an electric field. An electron beam, which moves in a trochoidal path perpendicular to the directions both of the magnetic and electric fields, is characterized primarily by its easy deflectability and its capacity to maintain its width even at high currents and low voltages.

The principle of the trochotron originates in an invention of H. Alfvén and H. Romanus.[1] *A number of types of electron tubes have been developed by Telefonaktiebolaget L M Ericsson on the trochotron principle. One of them, designated RYG 10, manufactured by AB Svenska Elektronrör, is described below.*

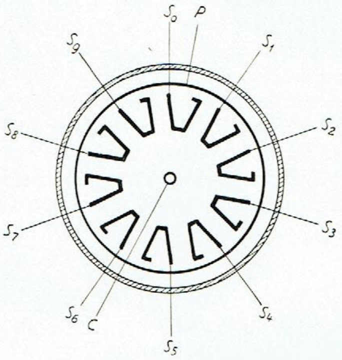


Fig. 1 X 4928

Schematic cross-section of coaxial trochotron, type RYG 10

S_0-S_9 control electrodes
P receiving electrode
C cathode

Method of Operation

The coaxial trochotron *RYG 10* (previously called AD-3) is a high-vacuum tube, in which the electron beam can be guided into ten different positions or "boxes" and which, when suitably connected, can retain the electron beam in one box until it is moved on to another. A cross-section of the tube is shown in fig. 1. Round an oxide-coated cathode forming the axis are ten V-shaped control electrodes (called spades) so arranged as to form boxes with parallel sides between them. The control electrodes are surrounded by a cylindrical receiving electrode which encloses the control electrodes forming the bottom of the boxes. For the correct functioning of the tube the space enclosed within the receiving electrode must be permeated by a magnetic field with its lines of force parallel to the longitudinal axis of the cathode (perpendicular to the plane of the paper in fig. 1).

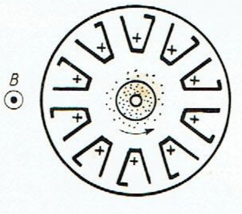


Fig. 2 X 4929

The coaxial trochotron with all control electrodes positive

If all control electrodes are made positive in relation to the cathode and the strength of the magnetic field is properly balanced, the magnetic field repels the electrons emitted from the cathode before they reach the control electrodes and compels them to return to the cathode. The returning electrons form a negative space charge around the cathode which further suppresses the emission of electrons, fig. 2. In that condition no current flows in the tube, but around the cathode there circles a swarm of electrons, the direction of movement of which is determined by the direction of the magnetic field. When the potential of one of the control electrodes is now lowered to, for example, that of the cathode, the swarm of electrons can no longer circle around the cathode, but is deflected in the direction of the negative control electrode and into the box between the negative control electrode and the positive control electrode immediately preceding it, finally striking the receiving electrode, fig. 3. An electron current is thus obtained in the tube, the strength of which is determined by the geometry of the tube, the voltage of the control electrodes and the strength of the magnetic field. The transition from dead to live condition due to lowering of the potential of a control electrode is continuous, as will be seen from fig. 4, which shows the current-voltage conditions in the tube. It is observed that the characteristic of the control electrode is negative, i.e. that the current increases if the voltage of the control electrode is decreased. The negative characteristic of the control

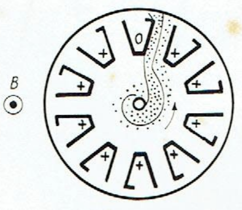


Fig. 3 X 4930

The coaxial trochotron with 1 control electrode on cathode voltage and the remainder positive

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[1] ALFVÉN, H. & ROMANUS H.: *Valve with trochoidal electronic motion.* Nature 160 (1947) p. 614.

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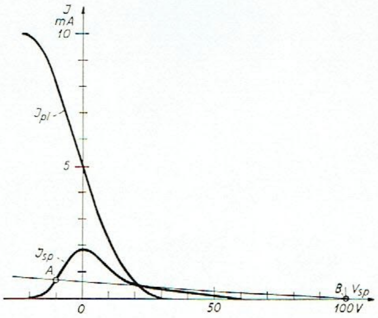
Fig. 4 X 4931

Control electrode current (I_{sp}) and receiving electrode current (I_{pl}) as function of the control electrode voltage (V_{sp}). The voltage of the remaining control electrodes is 100 V.



electrodes permits automatic locking of the beam if every control electrode is connected in series with a sufficiently high resistance. In fig. 4 a load line is drawn, and it is manifest that there will be two stable points of operation for the control electrode in series with such a resistance, viz., point A in the neighbourhood of the cathode potential and point B at the feed potential. Thus in a trochotron with control electrodes connected in series with high resistances, if the potential of a control electrode is momentarily lowered to the neighbourhood of the cathode potential, the voltage drop in the series resistance takes over the task of holding the potential of the control electrode at a sufficiently low level, and so-called locking is obtained. To ensure locking with a 100 V control electrode feed voltage, a resistance of about 200,000 Ω will be required.

As is seen from fig. 4, only part of the current in the tube is received by the control electrode, the major portion passing on to the receiving electrode. If the potential of the receiving electrode is reduced below the cathode potential, the electrons are unable to reach the receiving electrode but go to the immediately preceding control electrode. If a resistance of sufficient magnitude is connected in series to the control electrode, the latter undergoes a drop in voltage and takes over the locking of the beam. If the potential of the receiving electrode is still below that of the cathode, the beam continues to the previous control electrode, and so on. Thus the beam itself advances from control electrode to control electrode in the opposite direction to the electrons. On the other hand if the potential of the receiving electrode is again made positive after the beam has moved one step, the beam is retained in the position it last assumed. The normal use of the coaxial trochotron RYG 10 as pulse counter is mainly based on its ability to compel the beam to move one step at a time by means of short negative pulses on the receiving electrode. The condition necessary for stable stepping is that the time during which the receiving electrode is negative coincides with the time required by the beam to lower the voltage of the control electrode from feed voltage to cathode voltage.

Design

The aim has been to make the design of the tube as simple as possible. The number of components has therefore been kept low. The possibility exists of offering an inexpensive product in the event of large scale manufacture.

The tube is in the form of an all-glass bulb with 14-pole button stem with lead-in wires of the same type as in miniature tubes. The tube is 25 mm in diameter and 52 mm long. The electrode-system, which forms a composite unit kept together by the receiving electrode, is spot-welded direct to the lead-in wires. The material used in control and receiving electrodes is a non-magnetic nickel-chromium alloy. The cathode is of the oxide-coated type and is heated by a 6.3 V, 0.3 A coiled filament. The magnetic field required for operation is generated by a separate cylindrical, axially magnetized permanent

Fig. 5 X 4932

Perspective drawing of RYG 10

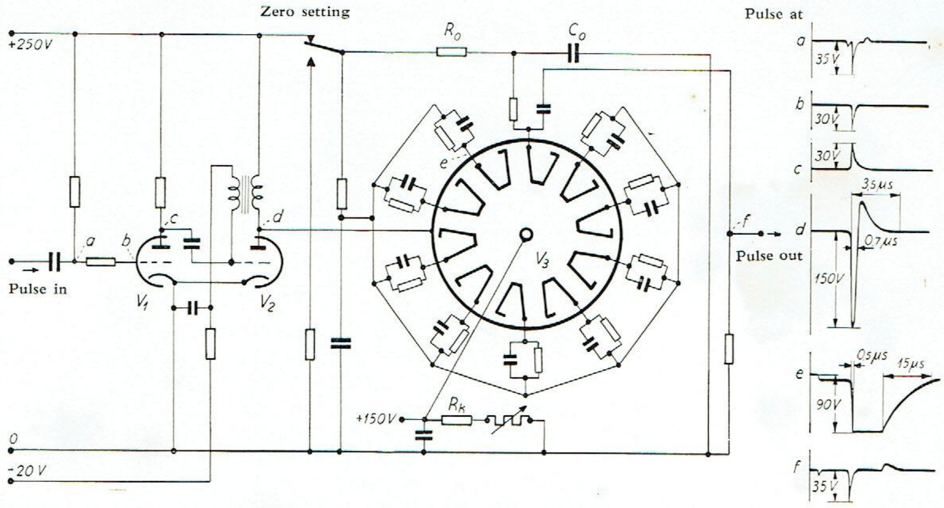


Fig. 6 X 7658

Wiring diagram for decade counter using RYG 10

magnet surrounding the tube. At a control electrode voltage of 100 V the requisite magnetic field is about 345 gauss.

The position of the beam in the tube is indicated by the voltage drop on the control electrode which locks the beam. A visual indication is often sufficient and, in order to save the roundabout method involved in using separate glow-lamp indicators, the tube has been provided with a fluorescent screen. The fluorescent screen is formed integral with the receiving electrode in such a way that 10 boxes, open at the top, are formed between screen and receiving electrode. Each of these boxes is connected to the corresponding box between the control electrodes by means of holes in the receiving electrode. A voltage of about 100 V is required for clear indication.

Decade Counter

Simultaneously with the tube, a basic circuit suitable for pulse counting has been developed (fig. 6). The stepping principle employed is that described above, involving the movement of the beam one step by means of a short negative pulse on the receiving electrode. To make the required pulsing time comparatively independent of tube and coupling capacitances, all control electrode resistors are coupled in parallel to 25 µµF capacitors. A drop in voltage of 100 V for a locked control electrode at a total control electrode capacitance of 40 µµF corresponds to a charge of

$$CV = -100 \cdot 40 \cdot 10^{-12} = -4 \cdot 10^{-9}[\mathrm{As}]$$

At a control electrode voltage of 100 V the beam current is about 10 mA and, if the current in the resistance is disregarded, the requisite pulsing time will be

$$t = \frac{CV}{I} = \frac{-4 \cdot 10^{-9}}{-10^{-2}} = 4 \cdot 10^{-7}[\mathrm{s}]$$

The above-mentioned pulsing time will determine the capacity of the counter to distinguish between two successive pulses. For counting longer trains of pulses the speed is limited also by the time constant of the control electrode circuit. The time taken by one revolution (10 steps) must not be less than four times the time constant of the control electrode circuit if the tube is to count irregular trains of pulses.

The pulse is generated by a blocking oscillator V_2 which is started by the phase changer and the amplifier V_1. The pulses to be counted enter V_1 in the form of negative voltage pulses. If the counter forms part of a larger counting unit, the pulse arrives from the preceding counter. The grid circuit of V_1 has been made insensitive to negative pulses below a given amplitude, and also to all positive pulses. The blocking oscillator is a stable and simple pulse generator of sufficiently low impedance. Unfortunately it limits the speed of the counter to about 400,000 pulses per second, while RYG 10 with a more complex pulse generator comes up to 10^6 pulses per second.

In order that an outgoing pulse shall be obtained on every tenth incoming pulse, the shunt capacitor of control electrode no. 0 is connected in series with a resistance. Every time the beam enters box 0, a sharp negative outgoing pulse is received.

At zero-setting the feed to all control electrodes is first broken and no current flows in the tube. Thereafter feed voltage is again applied to all control electrodes. Control electrode No. 0 does not reach full voltage until rather later due to the delay in its combined resistance and capacitance R_0C_0. Since the potential on control electrode 0 is at first lower than on the remaining control electrodes, the beam to control electrode 0 is locked.

Thanks to the complete symmetry of the tube, zeroing can be performed in any of the ten positions. Reading and zeroing arrangements may be considerably varied to meet different requirements of speed and amplitude.

The counter is extremely reliable in operation. Despite the absence of precision components it functions at variations in feed voltage of from 200 to 300 V. No adjustment is necessary on replacement of tubes, nor trimming of individual units. On the other hand the magnet must from the start be magnetized to the proper field strength and the magnetic field must be parallel to the axis of the tube.

Summary

RYG 10 is up to this time the only commercial decade pulse counter tube which permits direct setting to a desired position, indication of the beam position in the form of an electric potential from all positions, and a high counting speed. Its simplicity, small dimensions and clear indication, and its applicability in simple coupling arrangements, give promise of its finding wide use within the fields of mathematical machines and other instruments.

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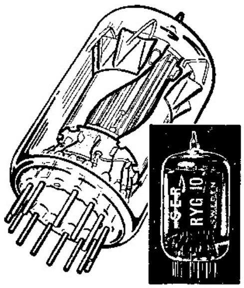
BEAM SWITCHING TUBE
TROCHOTRON

RYG 10

The RYG 10 is a pulse counting tube in which a beam is formed with the help of a magnetic field. The beam position is indicated on a fluorescent screen in the tube, and also as a voltage on each of the ten control electrodes. Switching rates up to 1 mc can be obtained. The tube is used as a decade counter in Geiger-Müller apparatus, in industrial counting equipment, electronic computers, frequency dividers and the like.



MECHANICAL DATA

Basing designation

Pin No	Connected to
1	Spade 1
2	Spade 2
3	Cathode
4	Spade 3
5	Spade 4
6	Plate
7	Spade 5
8	Spade 6
9	Spade 7
10	Heater
11	Heater
12	Spade 8
13	Spade 9
14	Spade 10

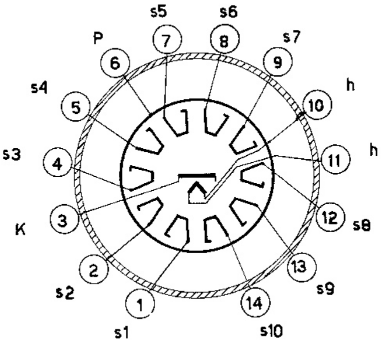


FIG. 1

BOTTOM VIEW

Dimensions

Overall Length, max. . . .	55 mms
Diameter, max.	28 mms
Diameter of pin circle . .	15 mms
Diameter of pins	1 mm

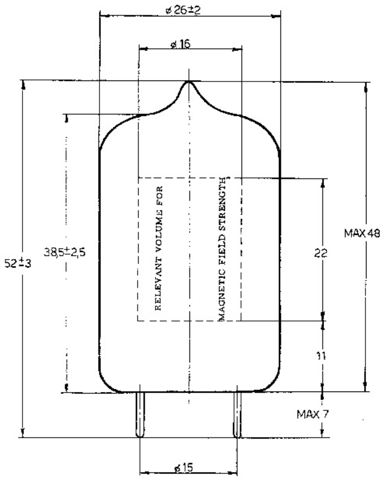


FIG. 2

Magnetic Field

A cylindrical magnet (see fig. 3) is recommended to provide the magnetic field. The magnet should be made of homogeneous material, and should give a field in the direction of the axis of the cathode with maximum variation of the order of a few percent within the relevant volume in fig. 2.

The field strength is defined as the mean value over the relevant volume, measured with a fluxmeter and a coil of the same size as the electrode structure of the tube.

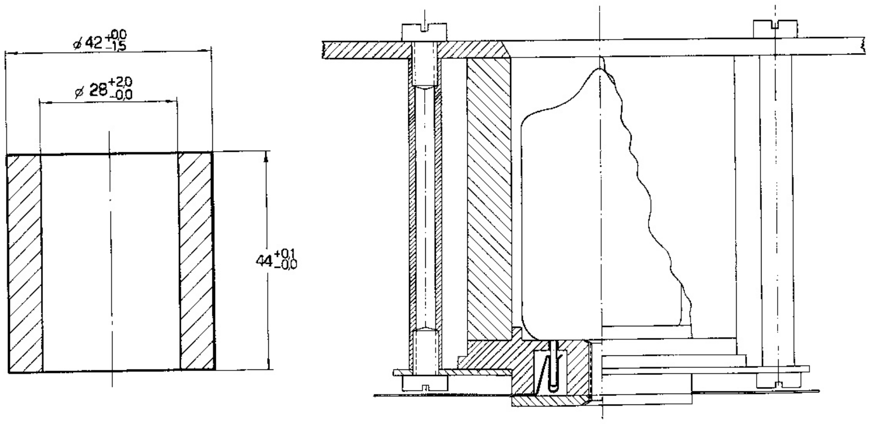


FIG. 3

ELECTRICAL CHARACTERISTICS

Heater Voltage	6.3	volts
Heater Current	0.3	amp
Plate Dissipation, max.	2.0	watts
Spade Dissipation, each spade, max.	0.5	watt
Heater-Cathode Voltage, max.	100	volts

Interelectrode Capacitances

Spade to other electrodes, approx.	2	uuF
Plate to other electrodes, approx. *	22	uuF

* Measured with the tube inside a magnet, connected to the spades and cathode, having an inside diameter of 29 mms.

Typical operation I (for max. recurrence frequencies 400 kc/s)

Supply Voltage (ref. to ground)	250	volts
Magnetic Field Strength	325	gauss
Spade Capacitance (incl. internal cap.)	33.5	uuF
Spade Resistance	180,000	ohms
Cathode Resistance (adjust to specified cathode current)	20,000	ohms
Cathode Current **	7.5	milliamps
Rise & Falltime of Drive-pulse, approx.	0.05	microsec.
Width of pulse at cathode potential	0.5	microsec.

Typical operation II (for max. recurrence frequencies 1 mc/s)

Supply Voltage (ref. to ground)	350	volts
Magnetic Field Strength	375	gauss
Spade Capacitance (incl. internal cap.)	13	uuF
Spade Resistance	150,000	ohms
Cathode Resistance (adjust to specified cathode current)	20,000	ohms
Cathode current **	11.5	milliamps
Rise & Falltime of Drive-pulse, approx.	0.05	microsec.
Width of pulse at cathode potential	0.3	microsec.

** At pulse recurrence frequencies above 100 kc/s, the cathode current decreases somewhat.

Note. If visual indication of the beam position is desired, the plate should be operated at not less than 80 volts.

TECHNICAL INFORMATION

CONSTRUCTION AND OPERATION

The RYG 10 is a high-vacuum tube in which the electron beam can be guided to 10 positions, or boxes, arranged around the cathode, and can be set direct to any position desired.
External circuit components hold the beam in a given position until it is required in another.
Ten V-shaped electrodes, called spades, form a circle of ten boxes with parallell sides around the oxide-coated cathode. The plate is a cylinder outside the spades (see fig. 4).

CLEAR CONDITION

If all the spades are positive with respect to the cathode, the magnetic field will deflect the emitted electrons before they reach the spades, and they will be driven back towards the cathode. This establishes a negative space charge around the cathode, which suppresses further emission. Under these conditions, the tube passes no current. A cloud of electrons circle around the cathode, their direction of rotation beeing determined by the polarity of the magnetic field (see fig. 5).

ONE SPADE AT CATHODE POTENTIAL

If one of the spades is at cathode potential, the electrons can no longer circle around the cathode, but are deflected towards the spade. They pass into the box formed by the negative spade and its preceding neighbour, and then strike the plate (see fig. 6).
The strength of the electron flow thus established depends on the geometry of the tube, the spade voltage, and the intensity of the magnetic field. The variation of the plate and spade currents with the spade voltage appears in fig. 7, which also shows that a part of the spade characteristic has a negative slope. It is this property upon which the locking operation of the tube is based.

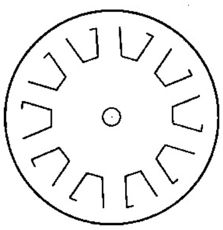


FIG. 4

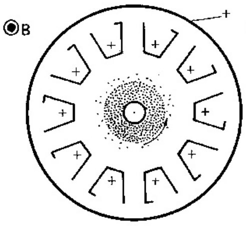


FIG. 5

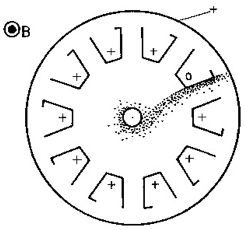


FIG. 6

LOCKING THE BEAM

If a sufficiently high resistance is placed in series with each spade, the negative spade characteristic allows automatic locking of the beam; when the voltage on a spade falls momentarily to cathode level, the voltage drop across the resistance holds the spade voltage low enough to lock the beam in position.

A spade with such a series resistance has two stable operating points (see fig. 7):

A. Near the cathode voltage, where the beam is automatically locked and current flows in the spade circuit.

B. At the supply voltage, where no spade current flows.

ADVANCING THE BEAM

Fig. 8 shows how the beam can be advanced in the RYG 10.

There is an RC circuit in series with each spade. Assume that the beam is locked by spade N, a larger part of the electron flow going to the plate. If the plate voltage is now lowered to the cathode level or below it, the electrons will flow to spade N + 1, following the path indicated by the dashed lines in the drawing. The resultant current charges the capacitor in the spade circuit, and the spade voltage drops. When the voltage has dropped to a certain value, the beam is locked to spade N + 1 and the entire beam advances to the next box. The plate voltage must now resume its positive value, as otherwise the beam will continue to rotate.

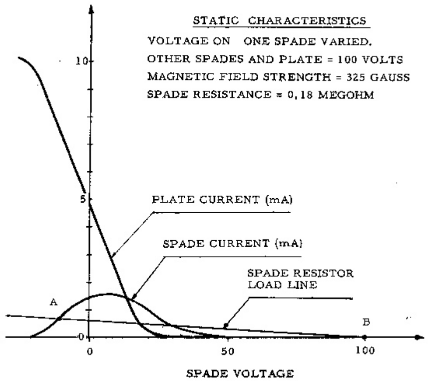


FIG. 7

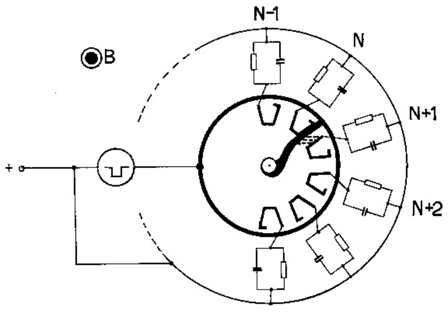


FIG. 8

CONDITIONS FOR OPERATION

Two conditions must be met for the tube to function as a counter:

1. The values of the spade voltage, the magnetic field strength and the spade circuit resistance must be such that the beam can be held in every box.
2. The duration of the drive pulse must be such that the beam advances one position only, for each pulse.

SUPPLY VOLTAGE LIMITS

For most applications, the two characteristics shown in fig. 9 are of importance.

> Characteristic I is obtained by varying the voltage on spade N, with the other spades and the plate at the supply voltage. (Compare fig. 7, where the same curve is shown).
>
> Characteristic II is obtained by varying the voltage on spade N with the spade N - 1 at locking voltage E_L, and the plate and other spades at the supply voltage.

The lowest supply voltage which can be used is that at which the loadline just cuts the peak of characteristic curve I (see fig. 10). At lower supply voltages, the spade current characteristic drops so that the loadline does not cut the curve, and the spades do not lock the beam.

The highest supply voltage which can be used is that at which the tail of curve II just touches the loadline (see fig. 11). At higher voltages, selfrotation occurs.

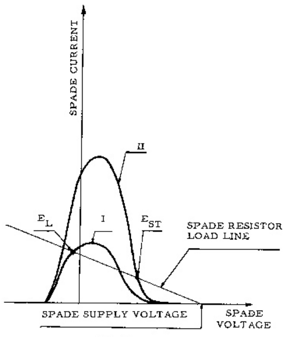


FIG. 9

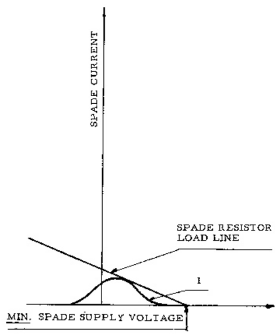


FIG. 10

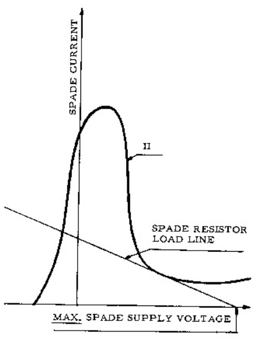


FIG. 11

SHAPE OF DRIVE PULSE

The pulse duration must be sufficient to allow the voltage on spade N + 1 to drop below the beam advance value (E_{ST} in fig. 9); otherwise, the beam will not advance.
The pulse must not last long enough, however, to allow the voltage on spade N + 2 to drop below E_{ST}, as the beam will then advance more than one position.

The amplitude of the pulse must be great enough to hold the plate voltage down to the cathode level or below it during the stepping interval.
For the following discussion the effective pulse width is defined as the time the plate voltage is equal to or below cathode level.

To prevent the tube capacitances and stray capacitances from seriously affecting the stepping we recommend a value of not less than 10 uuF for the spade capacitor.

STEPPING SPEED

As the spade voltage has to obtain its initial value before the beam returns, the time for a complete rotation (10 positions) is determined by the time required for the spade capacitor to discharge.

The time that should be allowed for one rotation is:

$$4 \cdot R_{sp} \cdot C_{sp} \qquad (1)$$

R_{sp} should be at least 100, 000 ohms. At values lower than 170, 000 ohms, it is necessary to use high voltages and strong magnetic fields so as to increase the cathode current. Reference is made to "Selecting operating conditions" on page 7.

CATHODE RESISTOR

To counteract variations in cathode current caused by variations in the supply voltage or input pulse rate or by aging of the magnet, it is advisable to use a resistor in series with the tube, usually a cathode resistor.

INDICATION OF BEAM POSITION

The fluorescent screen in the tube provides visual indication of the beam position. Since the potential of the spade to which the beam is locked is at cathode level, electrical indication can also be obtained. Load resistors down to 3 megohms may be used in the spade circuits without endangering beam advance.

ZEROING

Since the tube is symmetrical in construction, it can be zeroed to any of its ten positions. The simplest procedure is to open the voltage supply to all spades, which clears the tube; then the supply voltage is applied again, but the voltage rise at the "0" spade is delayed by an RC circuit or by means of manual switching.

SELECTING OPERATING CONDITIONS

Notation:

E_{sp}	spade supply voltage with respect to cathode
E_p	plate voltage with respect to cathode
B	magnetic field strength, defined as in fig. 2
I_k	cathode current
R_{sp}	spade circuit resistance
C_{sp}	spade capacitance, including external capacitances
t	duration of drive pulse

A suitable operating point can be determined with the equations below.

To find the relationship between the spade supply voltage and the magnetic field strength:

$$\frac{E_{sp}}{B^2} = 0.96 \cdot 10^{-3} \qquad \text{volt/(gauss)}^2 \qquad (2)$$

To find the spade circuit resistance:

$$R_{sp} \cdot \sqrt{E_{sp}} = 1.80 \cdot 10^{3} \qquad \text{kohm} \cdot (\text{volt})^{1/2} \qquad (3)$$

To find the pulse duration:

$$\frac{t}{C_{sp}} \cdot \frac{I_k}{E_{sp}} = 1.10 \cdot 10^{-3} \qquad \frac{\text{us} \cdot \text{mA}}{\text{uuF} \cdot \text{V}} \qquad (4)$$

Normally, E_p should be equal to E_{sp}

An operating point chosen from the above equations gives a favourable operation range. A view of permitted variations is given in fig. 12 to 14, where:

> Fig. 12 shows the static characteristics for cathode current as a function of the supply voltage at different magnetic fields and with one spade locked by a resistor of 180,000 ohms.
>
> Fig. 13 shows permitted voltagechanges when all other parameters are kept at the values indicated on the diagrams. The working ranges should be considered as average values.
>
> Fig. 14 shows that the working range decreases at higher counting speeds.
>
> Figs. 15 and 16, finally, show the construction of driving circuits for different counting speeds.

AVERAGE CHARACTERISTICS

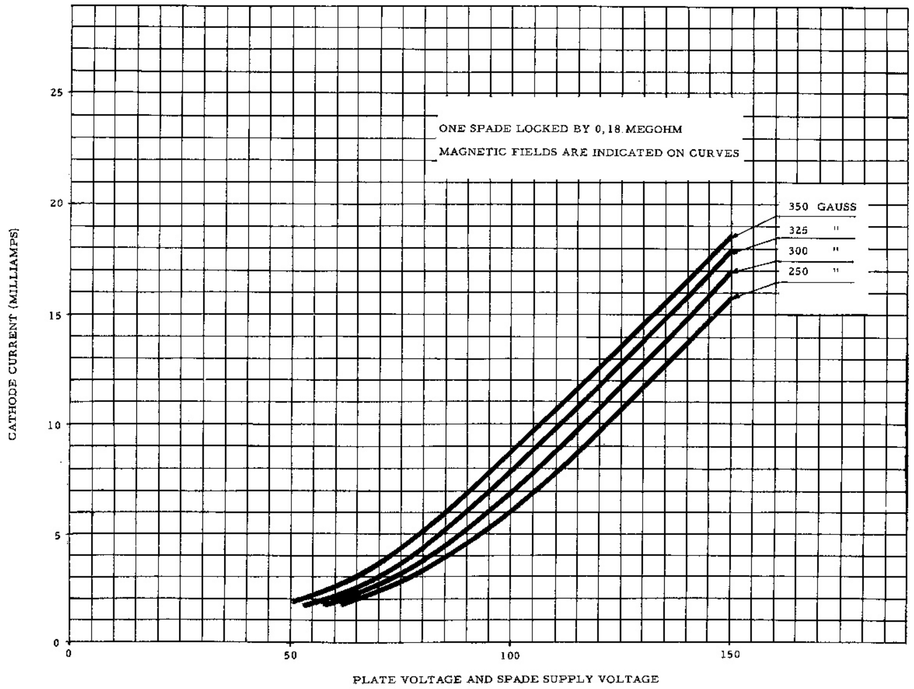


FIG. 12

AVERAGE CHARACTERISTICS

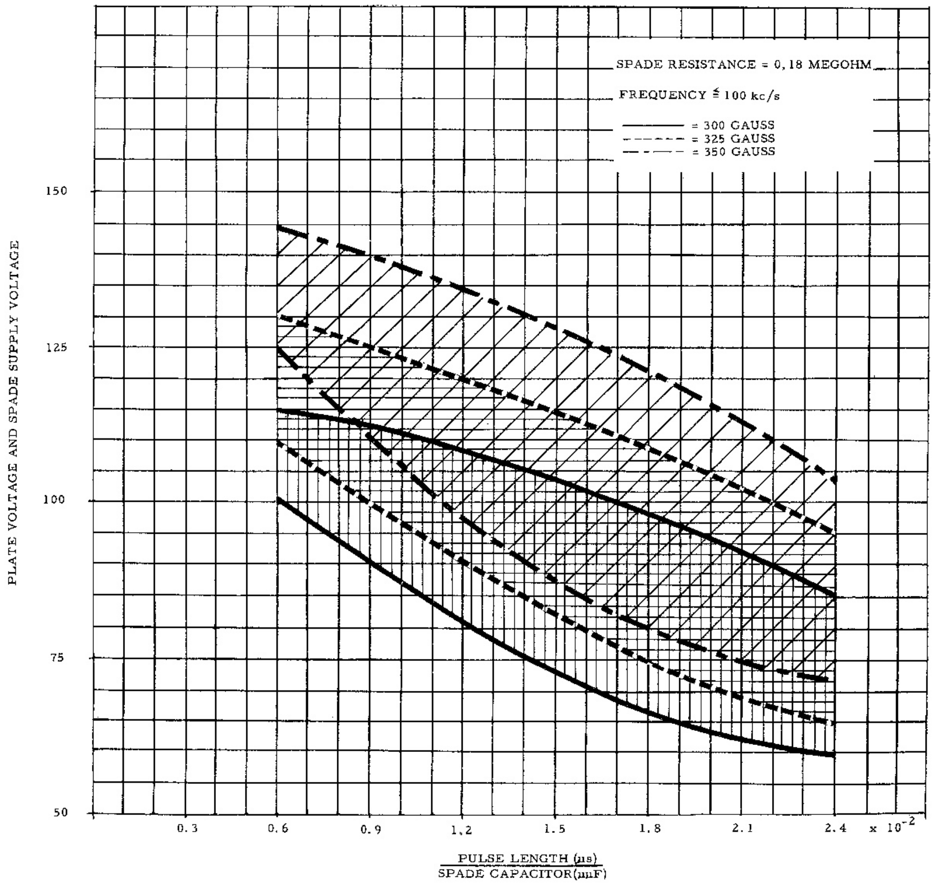


FIG. 13

AVERAGE CHARACTERISTICS

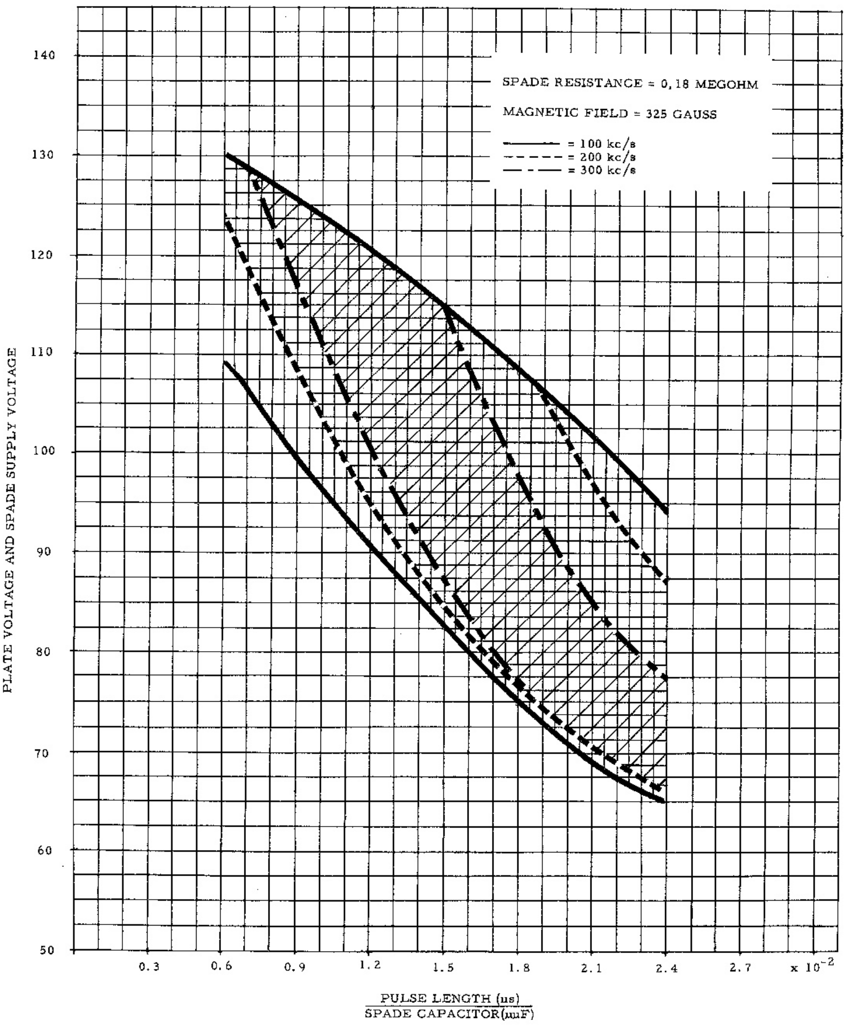


FIG. 14

TROCHOTRON DRIVING CIRCUIT FOR FREQUENCIES UP TO 1 Mc/s

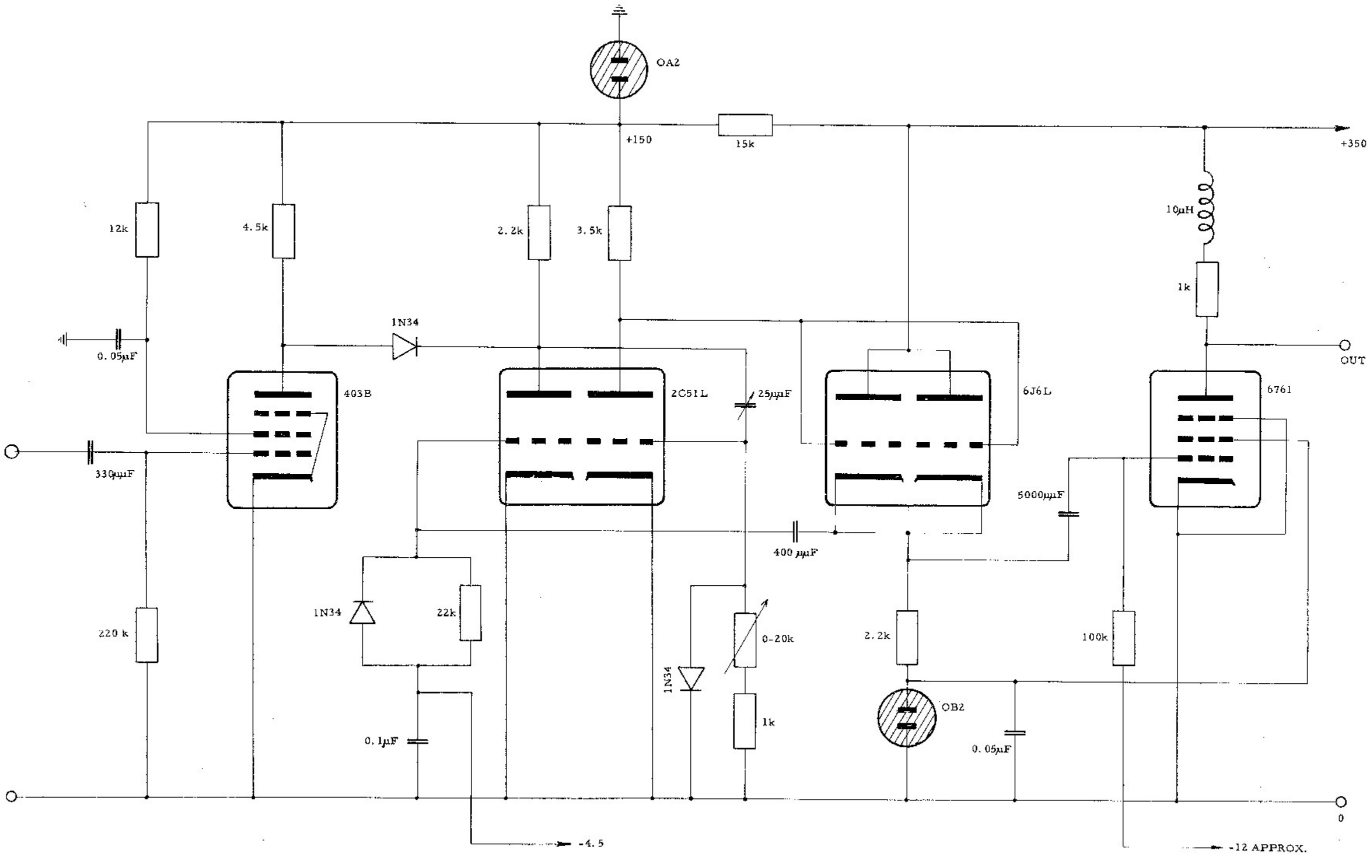
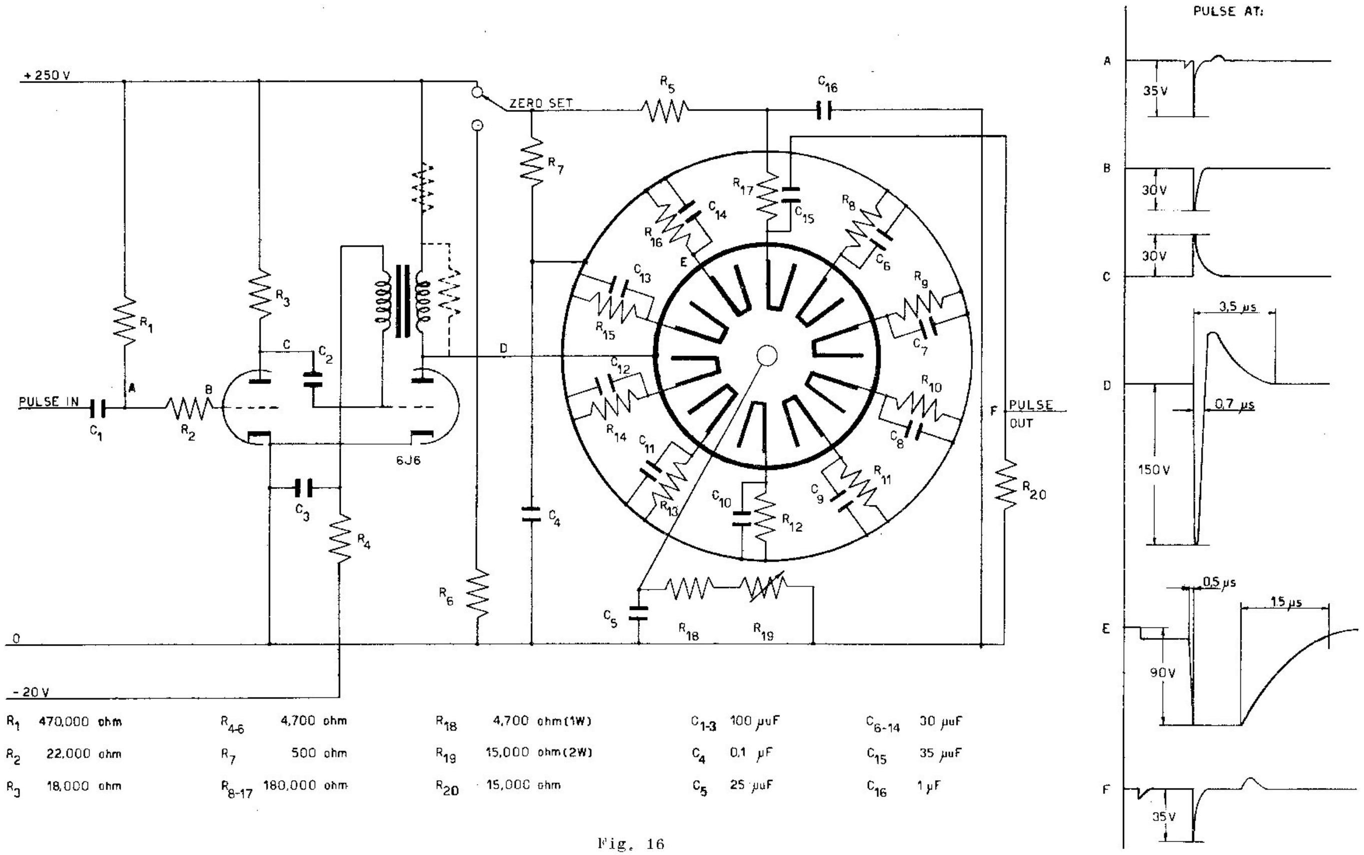


FIG. 15

DECADE COUNTER, USING THE TROCHOTRON RYG 10
Counting speed max. 300.000 pulses/sec.



R_1	470.000 ohm	R_{4-6}	4.700 ohm	R_{18}	4.700 ohm (1W)	C_{1-3}	100 μuF	C_{6-14}	30 μuF
R_2	22.000 ohm	R_7	500 ohm	R_{19}	15.000 ohm (2W)	C_4	0,1 μF	C_{15}	35 μuF
R_3	18.000 ohm	R_{8-17}	180.000 ohm	R_{20}	15.000 ohm	C_5	25 μuF	C_{16}	1 μF

Fig. 16