BEAM SWITCHING TUBES

Electronic Tube Division

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CRITERIA FOR SELECTION OF THE MAGNETRON BEAM SWITCHING TUBE AS A CIRCUIT COMPONENT

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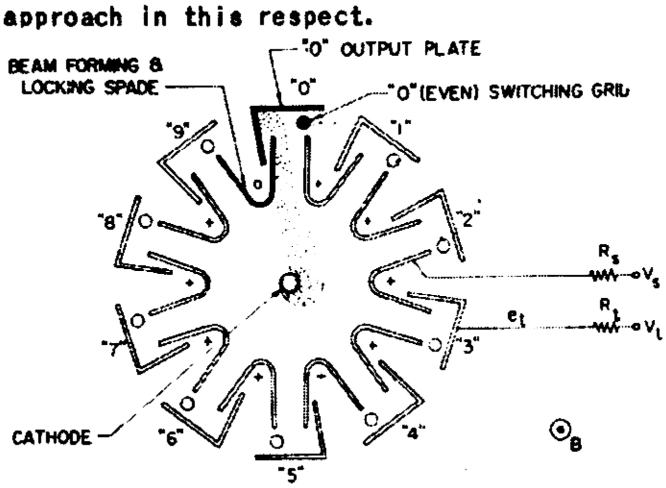
INTRODUCTION

Advances in applications of Beam Switching Tubes have been made throughout the electronic industry in loran, radar, guided missiles, coding, industrial electronic controls, communications systems, instrumentation and computers. This new component has been accepted primarily because it replaces the equivalent of many tubes or transistors and their associated circuitry, with added features of simplicity, reliability, versatility and performance. New information on tube characteristics, life, shock, vibration and temperature are noted, in reviewing the operation of the Beam Switching Tube. Circuit developments at the Burroughs Research Center and Electronic Tube Division are combined with application experience obtained generally throughout the industry. The result is compiled as a reference in determining the proper selection of the Magnetron Beam Switching Tube as an electronic component both individually and in conjunction with other devices such as vacuum tubes, gas tubes, transistors, and magnetic cores.

Beam Switching Tube Operation

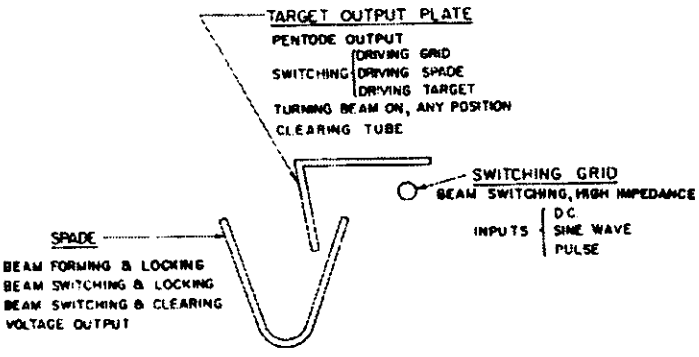
The function of electron distribution is present in almost every electronic application. This obvious factor has often been obscured by the devious methods and techniques required to accomplish this by other components. The Beam Switching Tube is a very simple, direct approach in this respect.



Cross-section of Beam Switching Tube
Figure I.

The Burroughs Beam Switching Tube is a high vacuum device consisting of ten identical positions mounted radially about a central oxide cathode, Fig. I. An axial magnetic field is provided by a small cylindrical magnet which is permanently attached to the glass envelope. Each individual position, Fig. 2, contains three electrodes which have characteristics capable of (1) forming an electron beam, (2) "automatically" locking the beam, (3) a constant current output, (4) switching the beam (in many ways), and (5) clearing the electron beam. Thus, the tube may be in a clear or cutoff condition, or an electron beam may be formed in any <u>one</u> of the ten positions and then switched sequentially or at random.

Impedances of the three elements are such that a building block versatility exists. Electrodes may be inter-connected in almost unlimited combinations, both between positions in the same envelope and between separate tubes.



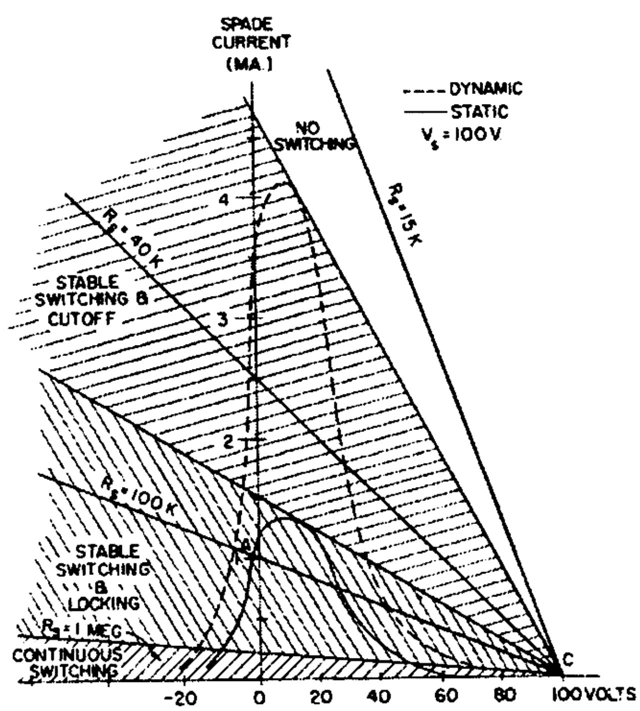
TYPICAL FUNCTIONS OF BASIC ELECTRODES

Figure 2.

Spade Characteristics

The spades are the only electrodes that directly affect the magnitude and shape of the electron beam in the area between the cathode and the spades. Operating voltages of the spades are typically 1/3 to 1/5 the theoretical "magnetron-diode" cutoff value (i.e. V_s= 100 volts: B=450 gauss). Therefore, the tube will always be in the cutoff state when power is first applied if there are no provisions for beam forming. The spades are commonly connected to their supply voltage, V_s, through individual series load resistors. Each spade has a negative resistance characteristic due to the crossed electric and magnetic fields. The resultant bistable states are shown in Fig. 3 by the solid "static" curve intersected by the series spade resistor load line. The beam may be formed in any one of its ten "on" positions by sufficiently lowering the potential of the respective spade (typical approx. 60% V_s) from point C to where the negative characteristics will take over and lock in at point "A" near zero, or cathode, potential. Thus the one spade which forms and locks the beam is near cathode potential, while the remaining ones are at a high positive level. Either a DC voltage or a high speed pulse may be used to trigger the beam formation.

When a beam has been formed on a spade, it can remain there indefinitely, or it can be advanced in many ways. One method is by lowering the switching grid voltage to a value where it will change the electric field in the outer area between spades so that enough of the beam is diverted to the leading spade to cause that spade to assume its locked-in stable state. The entire beam current is effective in quickly switching and lowering the potential of the leading spade. The lagging spade will remain at near zero potential for a longer time determined by its RC constant. An instantaneous condition results with two spades near zero potential. The resultant "dynamic" spade characteristic curve is indicated by the broken line shown in Figure 3. The increased peak is due to the broader electric field obtained by two spades being at near cathode potential during sequential switching. This difference is very valuable. It provides a means for switching the beam to a new position where an output may be obtained to perform a useful function, after which the beam will automatically clear or cut itself off as the lagging spade discharges according to its time constant. The wide range of reliability of the function of R_s whether used for beam forming and locking; beam switching and locking; or beam switching and clearing (using load line which intersects dynamic characteristic only) is indicated in Figure 3.



Beam Forming & Locking Spade Characteristic

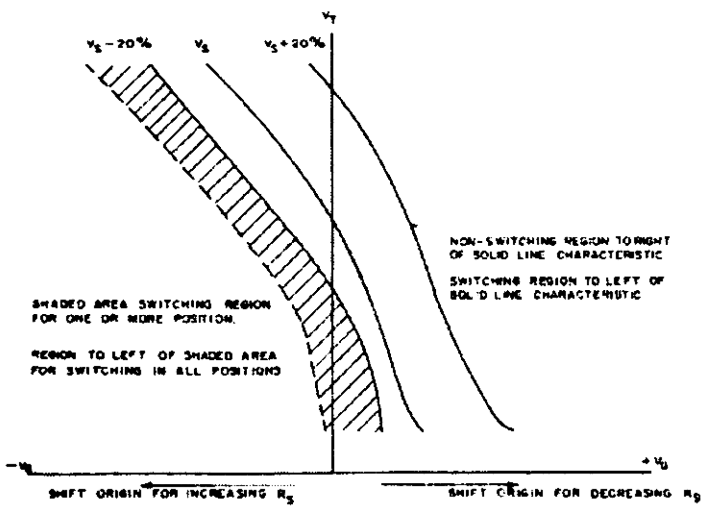
Figure 3.

The Switching Grid

The grid is normally the electrode used for sequential switching since it performs its function without drawing any appreciable current. Because of their shape and position, the grid electrodes effect a very uniform switching.

This dynamic action can be as fast as 0.1 micro second. The polarity of the magnetic field determines the direction of sequential switching which is clockwise as shown in Figure 1.

Figure 4 shows the relationship of operating parameters to the switching characteristic. In each case, biasing the grid voltage to the right of the characteristic will result in the beam remaining locked in. By obtaining a stable grid bias from a resistive bleeder across the spade supply voltage, proper relationship between these two elements will be maintained despite comparatively large variations of unregulated power sources.

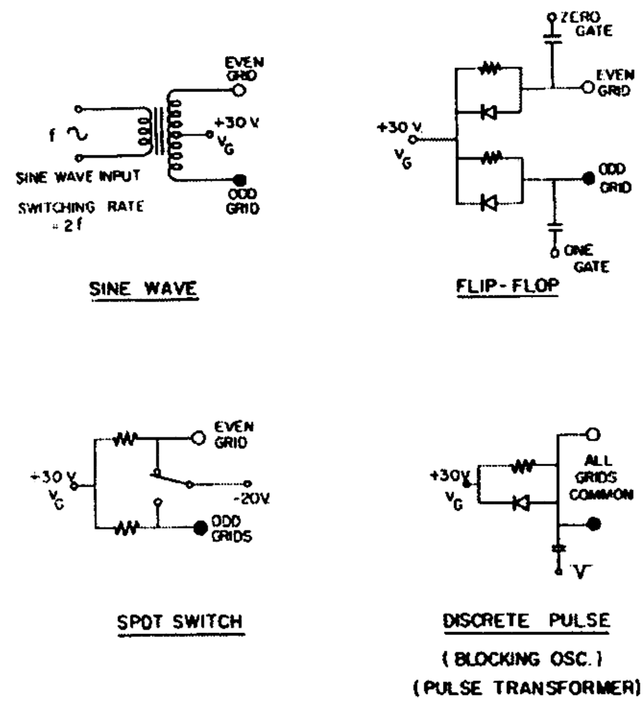


EFFECT OF OPERATING PARAMETERS ON GRID SWITCHING CHARACTERISTICS

Figure 4.

In each position, the beam is affected only by the individual grid with which it is associated. The grids are connected in two groups, the odd numbered grids in one group and the even numbered in the other. In this way it is possible to use a DC input in push-pull fashion and still secure single position stepping.

The adaptability of the grid to almost any type of switching input such as DC, (push-pull), sine wave, flip-flop or discrete pulse is illustrated in Figure 5, for $V_s = 100V$. Another important type of operation is one in which the DC level of all the grids is lowered to below the stable switching point. The beam will then continuously step around, or self-rotate at a rate determined by the RC time constant of the spade. This can be made very slow such as once a second; or very fast, in the megacycle range. In continuous operation type applications this self-oscillation type of operation can be synchronized very reliably to a grid drive frequency considerably higher than its natural frequency. Spade voltages and beam currents above those used in the discrete stepping type operation are permissible.

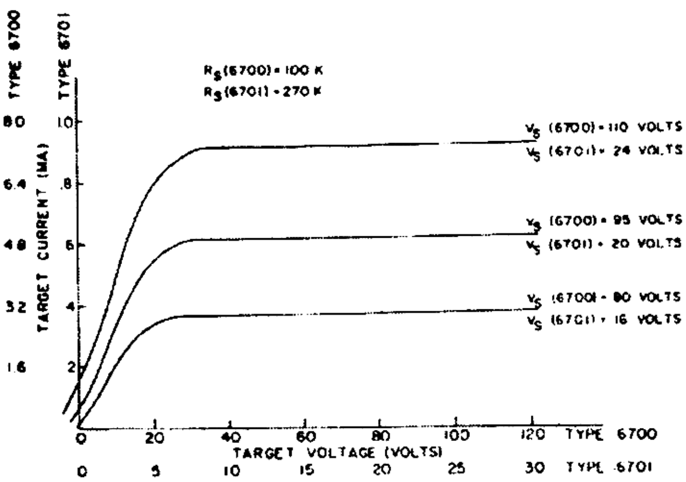


GRID INPUT CIRCUITS

Figure 5.

Grid Switching Limits

Typical limits for type 6700 recommend static biasing at +25 volts and flip-flop pulse inputs of 50V amplitude which will lower the switching grid to -25 volts for fast switching. Higher static bias voltages may be advisable under certain types of operation such as when obtaining very large target output voltages, or when inductive loads may cause its voltage to be instantaneously pulsed below the knee of its characteristic. This, of course, requires larger input voltages to still reach the same lower limit. It is interesting to note that the positive going excursion of flip-flop type input pulses do not appear to have any appreciable effect on the stability of the tube. When AC coupling to the switching grids, circuit techniques of differentiating or clamping to obtain the full negative going effect of the input pulse are recommended. Differentiating is sometimes necessary when the rising slope of the flip-flop input is slow enough to permit the beam to switch two or more positions for each change of state. For single input type of operation, the pulse width must be of discrete width, duration, and amplitude as indicated on Page 5 and Page 7 of the circuits appendix for types 6700 and 6701 respectively.



OUTPUT CHARACTERISTICS

Figure 6.

Target Output

From an output consideration alone the beam switching tube is without equal as a high current multi-position electronic distributor. Over 80-90% of the beam may be made available to an external load with the constant current characteristics of Figure 6. There is negligible cross-talk between outputs. Normally, the target output load line is made to intersect the straight portion of the curve approximately equal to the spade supply voltage. By operating closer to the knee of the curve, higher output currents may be obtained (using higher V_s) without exceeding its conservative one watt power rating. A wide variety of resistive load lines and target supply voltages can be used if the relationship $(V_T - (I_T R_T) = V_s$ is observed. For example, 500 volt outputs may be obtained from a type 6700 tube where V_s and R_s are selected for 5 MA target current (typically $V_s = 90V$ $R_s = 100K$) by using a 100K target load resistor and a 600 volt target supply. In applications requiring target output voltages of 100 volts or greater, it is usually advisable to use 20 uuf or greater spade by-pass capacitors to prevent the large target pulse from causing spade switching instability. By the same token by-pass condensers (.1 ufd) are used to prevent inductive overshoot when driving relays. Diode clamps could also be used to prevent the target voltage going below the knee of its characteristic.

The ability of the target to drive large capacities (and long leads) without affecting normal operation is desirable in many electromechanical operations. Concurrently, the leading and lagging edge slopes of the output are affected and undesirable in other applications.

The B+ efficiency of the beam switching tube as a ten position distributor compares very favorably with either vacuum tube or transistor flip-flop techniques. Substantially all of the B+ current drain of the beam switching tube circuit can be put to work in the one useful position. The type 6701 MBS tube with a 1 MA current drain at 22V B+ may be considered 20 - 30 times more efficient in this respect than equivalent transistor circuitry. This may be more than compensated for by the 6.3 volt 300 MA heater requirement depending on the degree of difficulty in obtaining this supply source.

Beam Switching Tube Types

The selection of the proper beam switching tube is generally straightforward. The mount structures are geometrically and mechanically exactly alike. Prime differences concern magnetic field strength, internal spade load resistors, external connections and the affects of these parameters on operating voltages, output currents, and switching speeds. These are tabulated below for convenience.

	Magnet	Switching Grid * Input Requirements Push-pull	Socket	External Connections	Maximum Frequency Single Input	Push Pull	V_s *	I_T *	Remarks
6700	450 Gauss	60	26 Pin	All Targets All Spades	2 MC	5 MC	100V	5.6 MA	General Purpose Application
MO-10R	450 Gauss	70	20 Pin	All Targets Zero Spade 1-9 Spade Common (All Spade Resistors internal 100 K	5MC	12 MC	100V	5.6 MA	Designed Specifically for Higher Frequencies than 6700
6701	160 Gauss	20	26 Pin	All Targets All Spades Zero Switching Grid Separate	1 MC	2.5MC	20V	0.6 MA	Designed Specifically for transistors and/or aircraft battery operation.

* = Typical

Beam Switching Tube Types – Selection Chart

<u>Relationship of Parameters</u>

Having selected a preferred tube type, the circuit designer may start out by selecting a value of V_s and R_s that will meet the desired frequency and result in a center value for target output current. The relationships of V_s, R_s, and frequency are shown in Figure 7.

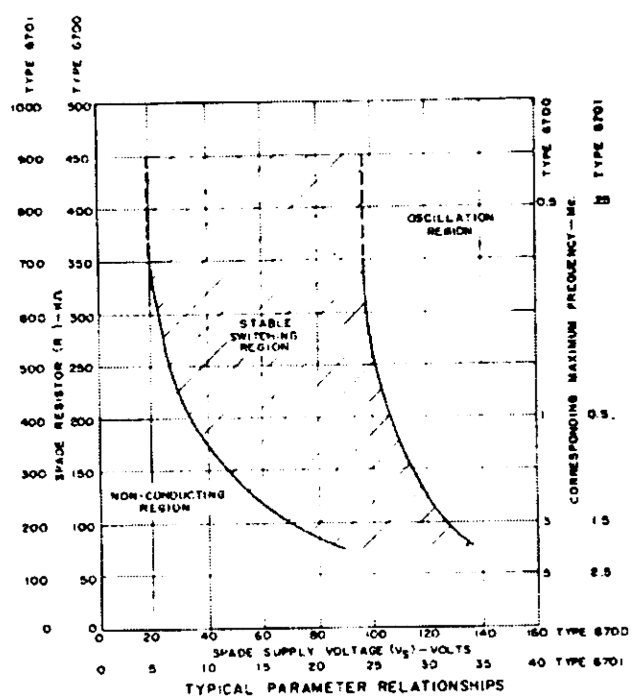


Figure 7.

The relationship of target current as a function of V_s is indicated in the constant current output Figure 6. Engineering data sheets or MIL-E-IC Specifications, where available, should be referred to for exact values. It should be noted that when the spade voltages of the types 6700 and 6701 are scaled in accordance with the magnetic field strength relationship $\frac{V_s}{B^2}$ (which is typically true), the cathode current relationship $I_k : V_s^{3/2}$ applies. However, in determining the magnitude of current change in any one tube type for a given variation in V_s, $I_k : V_s^2$ since the magnet field strength is a constant. Thus, a considerable gain in output current is obtained for a comparatively small increase in spade voltage.

Target load line values may be selected in accordance with circuit requirements and precautions outlined in the selection entitled Target Outputs.

Static Grid bias requirements are indicated in Figure 4.

The order of magnitude and direction of

variations are indicated as a function of other parameters. It is recommended that exact values and curves are taken or obtained for conditions other than shown on engineering data sheets. By obtaining the grid bias source from a voltage divider directly between the Cathode and V_s, the proper relationship may be maintained despite wide variation of V_s supply voltage.

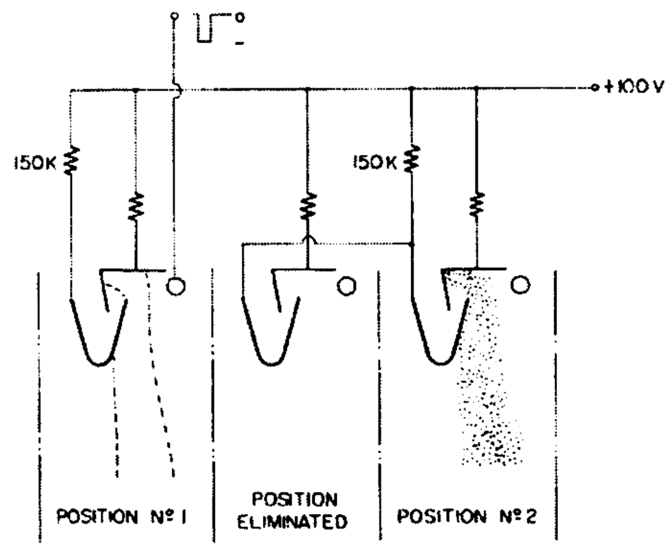
The basic circuit, Page 2 Circuits Appendix, is one example of proper relationship of parameters for tube type 6700 with features of cathode degeneration and zero setting added.

Zero Setting

The beam may be formed to any position from the cutoff condition by either a pulse or DC voltage as explained under Spade Characteristics. Once the beam is formed, it is usually advisable to clear and reset the beam as explained under Spade Switching. The basic circuit, Page 2 Circuits Appendix, illustrates a simple one switch method whereby a simultaneous clear and zero set action takes place. Closing the switch lowers the common V_s to below cutoff, clearing the tube. When the switch is opened, the common V_s recovers to B+ at a faster rate than the zero spade and its associated capacity, causing the beam to form to this position. Recommended design centers for type 6700 call for the common bus to approach 85V when the zero spade is approaching zero volts. The switch can be replaced by a high speed electronic pulse source such as a vacuum tube, Page 3 Circuits Appendix. In either case, the negative pulse amplitude should be limited to not much greater than V_s (depending on duration) or the beam may reset in the adjacent "one" position. Other time constants can be chosen for this reset circuit, typically 10K paralleled by .01 mfd in series with 3.3K. (Page 4 Circuits Appendix, relay type automatic reset.) This latter acts on the closing of the zero set switch or relay rather than the opening and thus is less sensitive to contact bounce.

Automatic Zero-Setting

It is often necessary to have the tube turn itself on at zero automatically, either when the power is first turned on or in the event of power failure. Either relays, tubes, or transistors can be used for this purpose by sensing the presence or absence of beam current as indicated in the Circuits Appendix, Page 4.



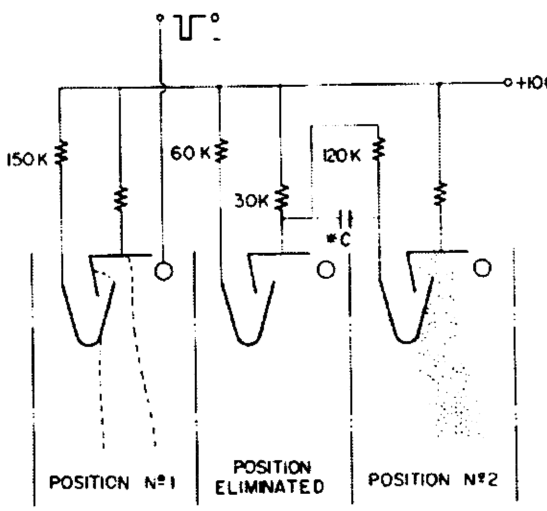
COMMON SPADES SWITCHING

Figure 8.

Spade Switching

The spades are normally used to perform beam forming, locking and clearing functions, or switching functions indirectly from current received by the action of switching grids or target outputs. This permits a simple uniform spade circuit of high reliability. Once the beam is formed, a study of its shape will indicate the limitations of random spade switching. It is apparent that any controlling electric field such as a pulse introduced on a nearby leading spade may be effective in switching and forming the beam to this new position. However, the same field introduced on a lagging spade, behind the electric path, may not effect switching the beam position. These different conditions generally hold true for half a beam revolution respectively. For this reason, random switching to any alternative position generally involves the equivalent of simultaneously obtaining switch and cutoff conditions.

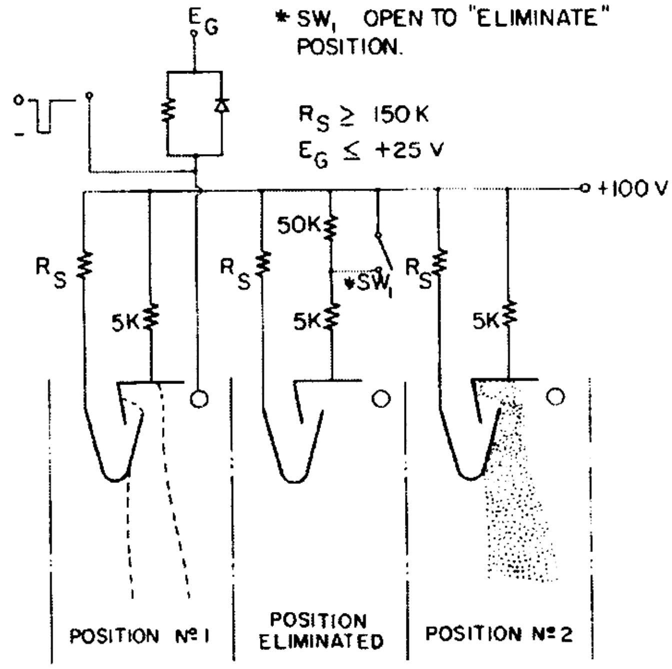
If adjacent spades are tied together, the beam will always lock in on the leading spade as shown in Figure 8. Since two spades are always common, the dynamic spade characteristic of Figure 3 would become the static characteristic for this type of operation. Compensation of spade resistance might be advisable at the upper frequency limit.



TARGET CONTROLLED SPADE SWITCHING

Figure 9.

(or applying a negative voltage) lowers the target voltage below the knee of its characteristic towards zero voltage, causing the beam to switch by that position at very high rates of speed. This type of switching could be present or absent at each position to obtain a variable count output.



TARGET SWITCHING WITH HIGH IMPEDANCE (OR LOW VOLTAGE)

Figure 10.

Target Switching

A preferred method for eliminating any number of consecutive positions up to five, uses target controlled spade switching and is shown in Figure 9 for type 6700. Here the target current is used to lower the spade voltage of the new positions to which the beam will form directly without transient output at the bypassed position. The target may also switch the beam directly in the individual position with which it is associated by both operating below the knee of its characteristic and by setting up a condition of associated grid and leading spade load resistor such that the current thus diverted performs the switching operation. This is shown in Figure 10 with typical values for type 6700. Opening switch, SW 1,

Eliminating more than five positions may be accomplished by using switch and cutoff conditions, (Figure 3 where R_s = 40K ohms) while simultaneously providing a target output to directly lower the spade voltage of the new position. This is necessary as explained under spade switching and shown in Figure 11. This condition may require that the target operate below the knee of its characteristic towards zero voltage to enhance the control of a particular spade. This same technique is useful in forming or turning on the beam of any other tube at any position from cutoff. To permit this, a different condition of associated grid and leading spade load resistor may be nec- to prevent target switching or cutoff before the proper spade was lowered sufficiently to perform its function.

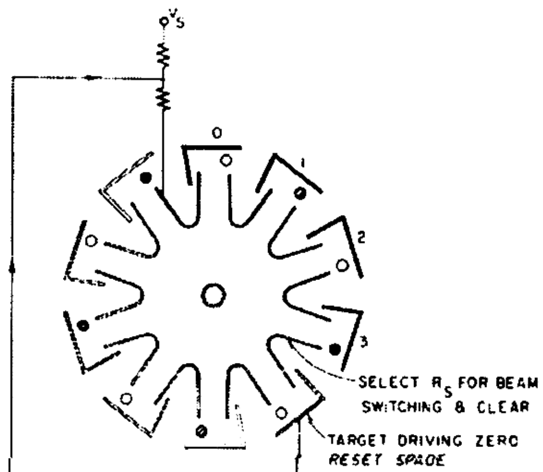
Speeds involved in direct types of target switching may be very fast because of the high current pentode output, generally in the order of tenths of a microsecond. Where switch and clear spade RC constants are involved, speeds are considerably slower.

Distributor of Less than 10 Positions

In many applications, it is desired to obtain a distributor of a given number of positions less than 10. The MBS tube offers many methods of achieving this. By use of the spade and target switching techniques previously described, we can simulate the equivalent of a tube containing only the required number of positions to be used. Figure 11 illustrates another method of using a switch and clear inter-connection for four positions. The beam may be made to switch from the last output, Number 3, directly back to zero in the same length of time as normally required to switch between adjacent positions. Switch and clear time constants for positions 1, 2, and 3 should be proportionally greater than the other positions. This method is adaptable to a variable scale counter controlled by a multi position switch. Speed and range may be increased by adding tubes as shown on page 4 of the Circuit Appendix.

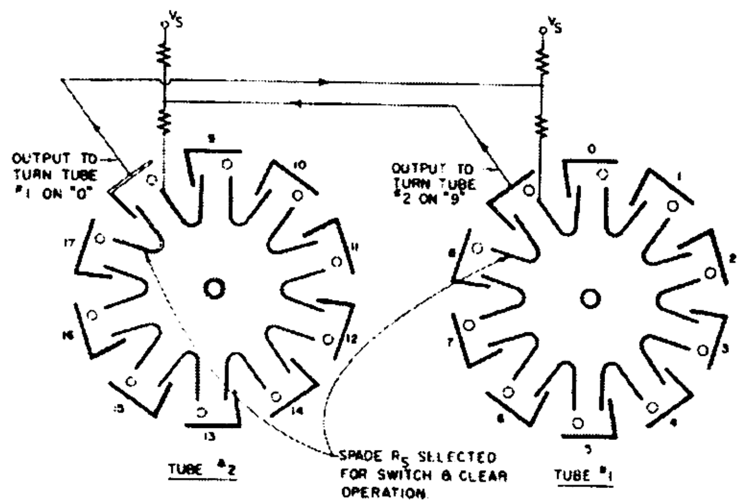
Distributor of More than 10 Positions

The equivalent of one distributor tube of any number of positions more than 10 may also be obtained, by proper interconnection of tubes. This is illustrated in Figure 12 where two tubes are used to obtain an 18 position distributor with switching grid inputs common. Here tube #1 is used for the first nine positions, 0 through 8, while tube #2 is in "clear" position. The next grid switching input pulse will switch tube #1 to its final "unshaded" position where this target's output will turn on the beam in tube #2 at "9" and then turn itself (tube #1) off. Tube #2 will provide output positions 9 through 17. Similarly the next grid switching input pulse will turn the beam in tube #1 on at "0" after which tube #2 turns itself off. In this unique manner one tube may be used for any multiple of nine outputs or less. Since each tube can directly turn on the next tube in tenths of a microsecond, and then turn itself off, a thousand position distributor using only the equivalent plate supply power of one tube and capable of operating at a megacycle is quite feasible.



TYPICAL TUBE INTERCONNECTION
(LESS THAN 10 POSITIONS)
"4"

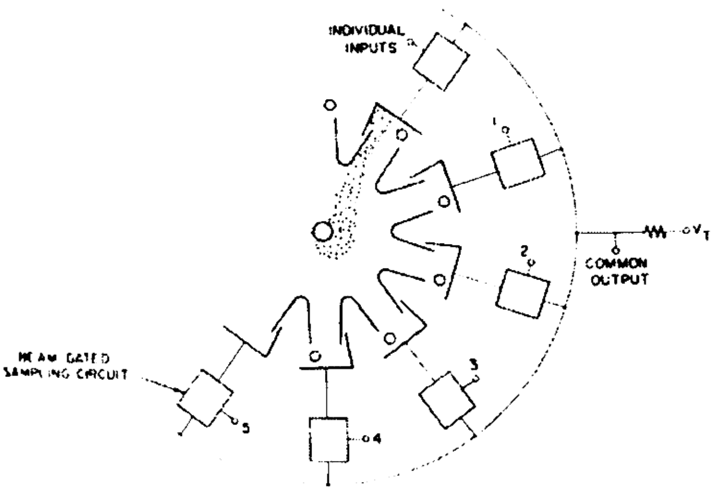
Figure 11.



TYPICAL TUBE INTERCONNECTION
(MORE THAN 10 POSITIONS)
"18"

Figure 12.

The Circuit Appendix page 7 shows an exact circuit of such a multi-position distributor, which has demonstrated a high degree of reliability with random interchangeability of production tubes. The proper grid bias is obtained from the power supply bleeder to extend the range of operation. This grid bias is designed higher than normal to prevent target switching in the cascading positions where the target voltage goes below the knee of its characteristic.

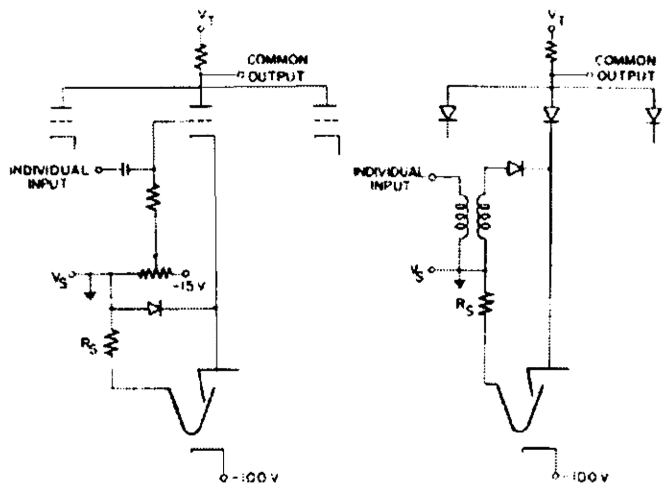


SAMPLING, MULTIPLEXING, PARALLEL TO SERIAL CONVERSION

Figure 13.

The Beam Switching Tube in Multiplexing

Figure 13 shows a schematic of sampling or multiplexing where the beam current gates on each individual sampling circuit to a common output. Typical beam gates sampling circuits are shown in Figure 14. The cathode gated triode, 14a, is normally cut off. The beam clamps the target to ground turning the triode on with exactly the same voltage across it each time. The input at that position is the only one effective at the common output. This positive clamping to ground also conveniently permits individual grid bias position control as shown.



(a) "CATHODE-GATED" TRIODE (b) LOW IMPEDANCE CRYSTAL GATE

TYPICAL BEAM GATED SAMPLING CIRCUITS

Figure 14.

When the inputs to be sampled are of low impedence, a simple crystal diode gate circuit, 14b, may be used. Here again the input is not effective at the common output until the beam clamps the target. Isolation crystal diodes between circuits as shown are necessary.

Methods of Obtaining Fixed Counts Less Than Ten

Count	One Preferred Method	Remarks
2	Tie all odd and even targets common	"Doubling odd count makes flip-flop input possible even for odd counts
3	Tie targets common in two sets of three (1-6, 2-7, 3-8) "Eliminate" 2 positions	
4	Tie targets common in two sets of four (1-5, 2-6, 3-7, 4-8) "Eliminate" 2 positions	
5 (a)	Tie targets common in two sets of 5 for push-pull operation	
(b)	Tie adjacent spades and targets common for single input. Design parameters around dynamic spade characteristic (Fig. 3)	Single input
6	"Eliminate" 2 positions in each half of tube	
7 (a)	"Eliminate" 3 positions by target controlled spade	Single input
(b)	Targets 7 and 8 common with feedback to trigger flip-flop – then "eliminate" 2 positions	
8	"Eliminate" 2 position	
9 (a)	"Eliminate" 1 position	
(b)	Targets 9 and 10 common with feedback to trigger flip-flop	Single input

"Eliminating" two positions accomplished by either target controlled spade switching, Figure 9; or common spade switching, Figure 8.

Reliability

There have been few tube types that have been tested as thoroughly as the beam switching tube by so many individual Government and commercial agencies. Limits have been established on almost all possible mechanical and operational parameters to obtain reproducibility and dependability, despite the wide variety of applications.

Specifications of special interest are tabulated for reference:

Specification	Test Conditions	Remarks
Magnet Secureness	30 pound thrust	Typically 60 pounds
Vibration	10 G 0-2000 cycles	20 G 0-2000 cycles obtained with individual tubes - Design program pending for all tubes.
Shock	375 G	
Temperature	-55^0 $+85^0$ C	Operation at 200° C obtained
Altitude	60,000 ft.	Conservative considering low B+ required
Noise	500 MV R M S	Random magnetron noise. Negligible effect in most applications.
Light Sensitivity	.1 MA max. cathode current change	May be eliminated by coating exposed bulb.

Life

From experience and the considerations that follow, it appears that the beam switching tube may be one of the most reliable of vacuum devices, with a life potential of 50,000 hours. The lack of a close-spaced control grid has unquestionably contributed to this factor. The currents and voltages used are many times less than those for which the cathode is rated. The particular beam shape and the inherent tube characteristic which locks the receiving spade at near cathode potential both tend to minimize the effects of ion bombardment. The beam formation has the property of using a different portion of the cathode for each beam position in a manner which results in time sharing and minimizes the effects of hot spots or poor emission.

A rather unique proof of the reliability of the Beam Switching Tube with respect to emission and life can be made quickly with any production tube. It will be found that while the tube is in operation the filament potential may be lowered to as little as 3 1/2 volts or raised to as much as 9 volts without appreciably affecting emission. Therefore, it appears that a circuit may be designed more reliably around Beam Switching Tubes with an end point emission of 75% than previously possible on standard tubes with a comparative end point of 50%.

Temperature

Vacuum tubes are noteworthy as being one of the electron devices least sensitive to either high or low temperatures. Operation in computers with ambient temperatures of 100°C have been common. Tubes with special processing schedules have been successfully made for continuous operation at 200°C and higher.

The beam switching tube design and production techniques take full advantage of these properties. The structure uses simple standard components, well fired and cleaned. A special multi-position automatic exhaust provides 16 positions with double, triple, and longer processing schedules to insure the high vacuum, even at elevated temperatures. The curie point of the Alnico 6 permanent magnet is well over 500°C. Every completed tube and magnetized magnet assembly goes through a 5 minute cycle at 150°C to permanently fix the silicon cement which obtains the precise magnetic field alignment. Random tests made with repeated cycling at these temperatures have shown negligible affects. Ambient temperature test ratings from -55 to +85 have been established. Laboratory tests indicate satisfactory tube operation at 200°C is possible although appropriate manufacturing processing schedules should be incorporated if this is a normal requirement.

Shock and Vibration

With the increased interest in using beam switching tubes in aircraft and guided missiles for such applications as coding, radar, loran, and telemetering, many laboratories have made individual shock and vibration tests with gratifying results. As a result of these tests the vibration rating of the present tube has been established somewhat conservatively at 10 G, 0-2000 cycles. Factors are being studied which permitted sample tubes to go the limit of existing equipment, 20 G, 0-2000 cycles without failure.

Rugged Structure

The rugged box-like symmetrical structure is balanced and supported evenly at all points, both within the mica and to the glass envelope. It is firmly held through many tie points to the multi-lead stem. Finally, the tube floats within the "rubberized" silicon cement that attaches the glass envelope to the permanent magnet to obtain an additional protective effect.

Mount Assembly by Automation

The beam switching tube introduces the first use of a multi-electrode assembly jig using principles of automation to a production vacuum tube. The 20 spade and target parts are precisely fixed and simultaneously inserted in both the top and bottom mica around the central cathode. The 10 switching grid wires are inserted in a similar manner. This automation in the assembly of so many parts could not be approached by even the most skilled hand assembler and it results in a premium ruggedness as borne out by shock and vibration tests.

Magnetic Field Precautions

The Alnico 6 magnet has been saturated to 550 gauss and then de-magnetized to its rated strength of 450 and 160 gauss for the 6700 and 6701 types respectively. This results in a permanent field strength that can not normally be changed. However, the close presences of strong magnetic fields or large ferrous objects may temporarily modify its shape and magnitude and thus affect operating characteristics. The following typical precautions are normally recommended:

1. Mount on non-magnetic chassis
2. Center to center mounting of MBS tubes not less than 3 1/2 - 4"
3. Distance to power and filament transformers, not less than 1 1/2 - 2"
4. Distance to other vacuum and gas-filled tubes, not less than 1/2"
5. Unshielded magnetic cores, not less than 2" - 6"
6. Large ferrous plates or covers, not less than 1" - 2"

These spacings can sometimes be reduced as much as 50% with reliable circuits having wide ranges of operation (typical basic circuit, page 2, Circuit Appendix).

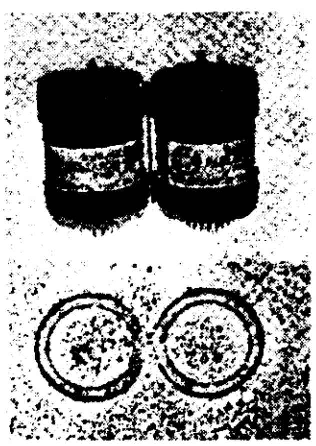


Figure 15.

A technique of Magnetic Equalizing is in development which enables MBS tubes to be stacked directly adjacent to each other without any appreciable change in characteristics. For example, a cold-rolled steel equalizer bar, 1/16" x 1/2" and equal in length to the magnet, placed directly at the point of contact as shown in Figure 15, compensates almost exactly for the closer spacing.

Deficiencies in this technique are (1) an approximately 10% shift in characteristics; (2) necessity for maintaining adjacent magnet heights equal to within $\pm$ 1/16"; and (3) less reliable for single input switching operation as opposed to push-pull. A modification of this magnetic equalizing technique which will minimize these deficiencies and result in a simplified package appears imminent.

Packaging

Beam switching tube circuitry lends itself to turret type socket assembly. Printed circuit sockets will unquestionably contribute to simplified packaging. Accessories in various stages of development and production are:

1. Printed Circuit resistor disc - Sprague
   - (a) 10 - 100K, or 150K spade resistors for basic circuit
   - (b) same with each spade resistor paralleled by 7 1/2 uuf capacitor
2. Printed Circuit Socket
3. Printed Circuit board with provisions for mounting beam switching tube and and numerical indicator ("Nixie").
4. Turret Socket Assembly
5. Magnet Clamps
6. Pulse Transformers designed specifically for beam switching tube circuitry
   - (a) 1 MC blocking oscillator
   - (b) one-shot multi-vibrator (mechanical to electrical converter)
   - (c) direct coupling

Beam Switching Tube Applications and Circuitry

It has been established that the beam switching tube can perform the equivalent functions of 20 and more vacuum tubes or transistors. Careful analysis may make it preferable even when the ratio is as low as two or four to one. Criteria for evaluation in determining such selection include life, temperature, shock, vibration, B+ power, B+ efficiency, heater power, reduction in components, size, switching speed, reproducibility, versatility, simplicity, packaging, and compatibility with overall equipment requirements.

The most important conclusion resulting from application experience obtained by the industry is that the best circuit techniques developed around other components can be combined with beam switching tube characteristics to better accomplish almost unlimited complex circuitry requirements. The beam switching tube will rarely be the limiting factor in such combinations, as is indicated in the following table:

Limits of Electron Devices or Components Used in Conjunction with the MBS Tube

Electron Device or Component	Limiting Factors Freq.	Life	Power	Temp.	Remarks
Mechanical Switch	X	X			Push pull input. Eliminates contact bounce problem.
Push pull transformer					Sine wave input, any frequency.
Pulse transformer	X				Quantized pulse coupling, single input directly between MBS tubes.
Vacuum Tubes:					
a. Flip flop	X	X			Most commonly used as input below 1mc.
b. Blocking Osc.	X	X			1mc input reliable with proper design.
c. Mono-stable Multi-vibrator	X	X			Single input or mechanical to electrical converter.
d. Schmitt Trigger	X	X			Develop pulse from "DC" varying source for input to MBS tube.
Transistors	X		X	X	Input and output circuits similar to vacuum tubes for Type 6701.
Diodes	X			X	For matrixing, voltage limitations.
Thyratrons	X	X			Input, output, or presetting circuits
Gas Counters	X	X	X	X	MBS Tube output and storage.
Numerical Indicators	X	X		X	MBS Tube output and storage.
Position Indicators	X	X		X	MBS Tube output and storage.
Neon Lamps	X	X		X	MBS Tube output and storage.
Relays	X	X			Typical 5 ma. 5K ohm used in target output.

The variety of circuits that can be designed in combination with the MBS tube appears to be limited only by imagination and creativity. Several unique applications are listed for reference.

	Remarks
High speed (100 KC) bi-directional distributor	2 MBS tubes inversely interconnected controlled by high speed flip-flop
High speed analog to digital conversion	10 Positions (± 5% accuracy)
Beacon transponder coders	Timing accuracy exceeding delay lines
Flat Picture Tube Horizontal Drive	Sequentially driving ten deflection plates with 1000 volt pulses obtained directly from target, special mica insulator used.
All electronic multi-position flash tube programmer	Driving thyratrons directly in dual pre-set application
Teletype decoding	Relay sequencing
Transfer Storage	Directly driving numerical indicator or recorder *(Circuits Appendix, page 6)*
Color TV	Single gun color tube. Varying ratio of color sampling to obtain 6 times brightness.
Conveyor belt programmer	Photo cell reading of marked boxes for sorting.

CONCLUSION

The purpose of this paper is not to claim advantages over other components. It is rather to provide the vacuum tube, transistor, and magnetic core specialist with information necessary to determine when to use the beam switching tube in place of, or in conjunction with, these components to better accomplish their complex circuit requirements.

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