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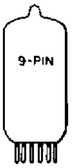
engineering data for CBS®

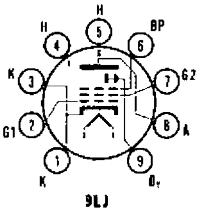
BULLETIN E393B
4-61

SECONDARY EMISSION HEXODE

7548



Miniature hexode for fast pulse generator and pulse amplifier service. High fast pulse wavefronts are obtainable from this tube because of the secondary emission current multiplication.



ELECTRICAL DATA

HEATER CHARACTERISTICS

Heater voltage	6.3	volts
Heater current	700	ma

DIRECT INTERELECTRODE CAPACITANCES

Input	8.0	pf
Output, anode	3.1	pf
Output, dynode	4.4	pf
Grid 1 to plate	.027	pf
Grid 1 to dynode	.110	pf

MAXIMUM RATINGS (Design maximum values)

Anode Voltage (Ebb)	1000	volts
Dynode Voltage (Edy)	400	volts
Grid 2 Voltage (Ec2)	300	volts
Anode — Dynode Gradient (Ebb-Edy)	600	volts
Beam Rod Voltage (E_{BR})ϕ	500	volts
Anode Dissipation (Eb-Edy) Ib	3.5	watts
Dynode Dissipation(Edy Idy)	4.0	watts
Grid 2 Dissipation (Ec2 Ic2)	1.5	watts
Grid 1 Dissipation	1	watt

CHARACTERISTICS AND TYPICAL OPERATING CONDITIONS

Class A Voltage Amplifier

Anode Voltage	300	volts
Dynode Voltage	150	volts
Grid 2 Voltage	250	volts
Anode Current	23	ma
Dynode Current	−15*	ma
Grid 2 Current	2.5	ma
Transconductance (Ecl =-1.5)	26,000	µmhos

PULSE AMPLIFIER SERVICE

Anode Voltage	350	500	900	volts
Dynode Voltage	150	200	400	volts
Screen Voltage	250	250	250	volts
Pulse Anode Current	.6	.9	>1	amp
Max. instantaneous anode power	—	—	1	kw

*The dynode current is negative relative to the plate current. Since it draws "negative" current from the positive terminal of the power supply, a bleeder resistor must be used to prevent supply instability.

ϕIn certain applications, it is permissible to operate the beam forming rods at positive potentials. Normally beam forming rods are grounded or tied to cathode.

ENGINEERING DATA

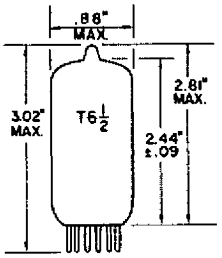
7548

SECONDARY EMISSION HEXODE

MECHANICAL DATA

Cathode, coated unipotential

Bulb	T-6 1/2
Outline	6-4
Base, 9-pin miniature	JEDEC E9-1
Basing	9LJ
Mounting position	Any



PIN CONNECTIONS

Pin 1	Cathode
Pin 2	Grid 1
Pin 3	Cathode
Pin 4	Heater
Pin 5	Heater
Pin 6	Beam Forming Rods
Pin 7	Grid 2
Pin 8	Anode
Pin 9	Dynode (Secondary Emission Electrode)

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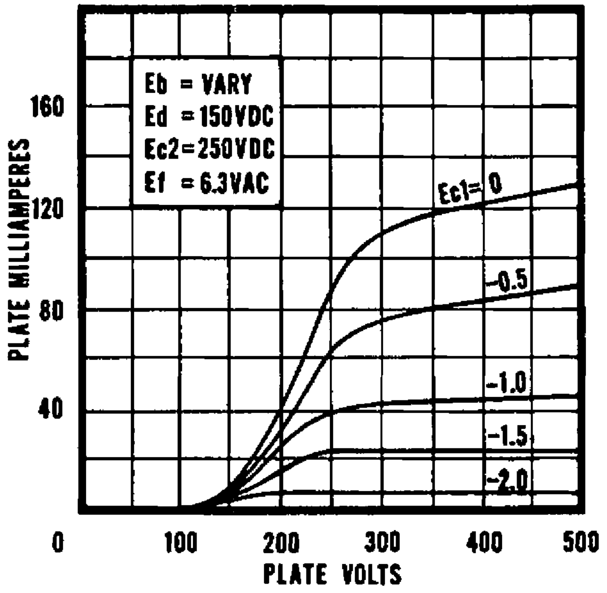
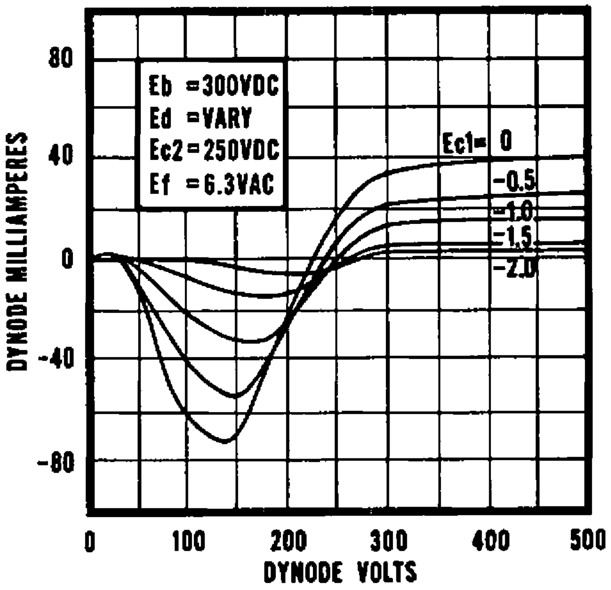
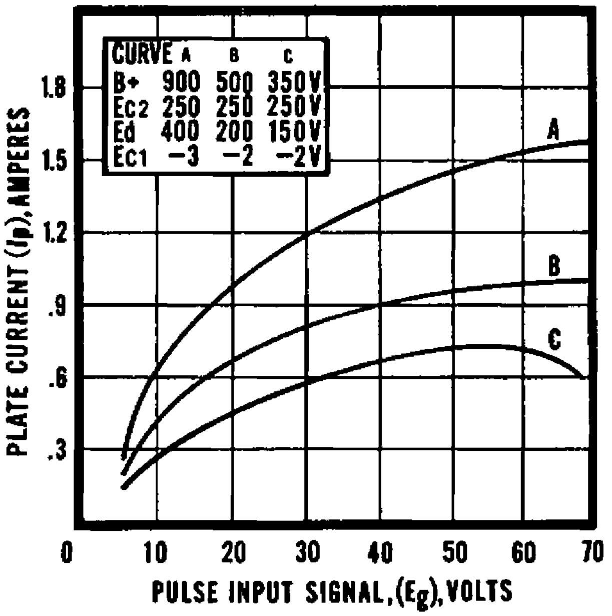
AVERAGE PLATE CHARACTERISTICS



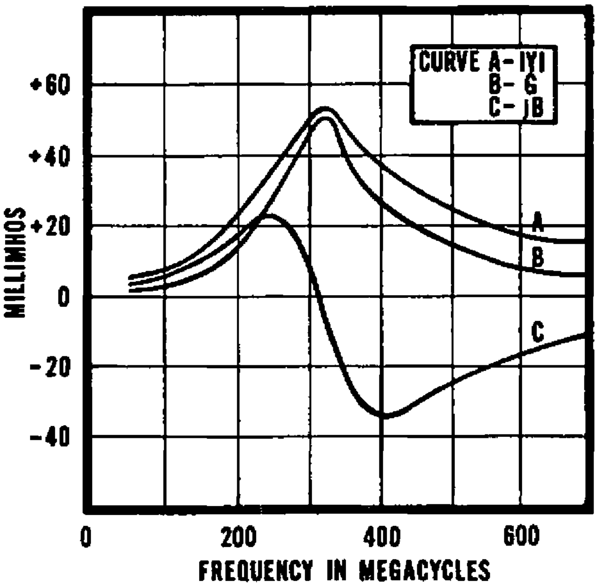
AVERAGE DYNODE CHARACTERISTICS



POSITIVE GRID CHARACTERISTICS



HOT INPUT ADMITTANCE CHARACTERISTICS



ELECTRO MITE®
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YORK RESEARCH CORP
ONE RESEARCH DRIVE
STAMFORD, CONNECTICUT

Technical Information

SECONDARY EMISSION HEXODE

7548

The EM 7548* is an important new secondary emission vacuum tube. Featuring high-current, fast rise-time pulse generation characteristics, a wideband performance capability, and a stable life-expectancy of over 2000 hours, the 7548 surpasses other secondary emission tubes in performance and reliability. Its reliability features include standardized outline and basing dimensions, coiled heater, cathodes free from interface impedance and refractory dynode surfaces. The EM 7548 is designed for volume production and exhibits a uniformity of electrical and mechanical parameters required by todays' critical military and commercial markets.

PRINCIPLES OF OPERATION

The EM 7548 follows conventional vacuum tube design concepts in developing, controlling, accelerating and shaping the primary electron stream. Departure from conventional design occurs in the 7548 in its dynode-anode region. Here a secondary-emission dynode structure is located in relation to the anode, for the efficient development of high secondary-to-primary electron ratios. Secondary electrons emitted from the dynode surface as a result of primary electron impingement are collected by the anode. The result in the EM 7548 is a primary electron multiplication factor of 3.

The use of secondary emission in the EM 7548 design provides several advantages unavailable with conventional high gain or pulse application tubes. These are:

(1) Dynode output currents which produce dynode resistive load signals that remain in phase with the grid input signals. Regenerative circuits can thus be developed by applying feedback from the dynode to the control grid.

(2) Anode currents greater than cathode currents (occurring as the result of secondary emission electron multiplication) allow the application of positive feedback from the anode to the cathode.

(3) Two amplified outputs are developed by the tube, one of which is in phase with and the other out of phase with the input signal.

(4) Faster recovery times at higher pulse currents than conventional gas filled or solid state pulse devices. (In the 7548, pulse recovery times are limited only by low values of interelectrode capacitances.

(5) Noncritical electrode spacings which effectively reduce the probability of intermittent short circuits and other defects. The EM 7548 obtains high g_m values with secondary emission electron multiplication rather than with closely spaced tube elements.

(6) Low output impedance characteristics. The plate resistance of the 7548 is determined by the plate current and plate to dynode voltage parameters. As the plate voltage approaches dynode potential, plate resistance decreases to values as low as 50 ohms.

* REDESIGNATED AS EM7548 AND NOW MANUFACTURED EXCLUSIVELY BY: ELECTRO-MITE DIVISION OF YORK RESEARCH CORP., STAMFORD, CONN.

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Application Notes

SECONDARY EMISSION HEXODE

7548

1. In operation, the tube may exhibit a pale blue glow. This is a normal phenomenon in the tube and does not indicate a gaseous condition.

2. Efficient secondary electron collection is achieved when the potential difference between dynode and anode is greater than 150 volts.

3. Recommended maximum anode to dynode voltage is 600 volts. Field emission may produce arcing if these two electrodes are operated at voltage differences greater than this value. At voltage differentials greater than 600 volts secondary electron collection may decrease.

4. Since the dynode is an electron emitter, it is possible for the instantaneous dynode voltage to be greater than the dynode supply voltage. A bleeder resistor shunting the supply must be used to maintain a proper net positive current from the power supply and prevent supply instability.

5. In order to extend tube life, it is recommended that a B+ voltage delay be utilized. This recommended delay is mandatory if anode-dynode voltage differentials exceed 400 volts.

6. Recommended heater supply voltage regulation is ± 5%.

7. Since dynode transconductance is approximately 2/3 the value of anode transconductance, equal voltage outputs may be obtained when the dynode load resistance is made 1 1/2 times the anode load resistance.

8. In fast pulse circuits with low load resistance, output coupling capacitances must be selected to produce time constants with a value at least 10 times greater than pulse width to prevent pulse degradation.

9. To achieve maximum performance with the EM 7548, stray circuit capacitances and inductances must be minimized.

10. The recommended maximum grid resistance is 100 K ohms.

11. In certain high current pulse applications, internal primary electron beam defocusing may occur due to the presence of large electron space currents. This effect may be neutralized by operating the beam forming rods at d-c potentials similar to those appearing on the screen and dynode. The beam rods should always be operated at a-c ground.

EM 7548 APPLICATIONS

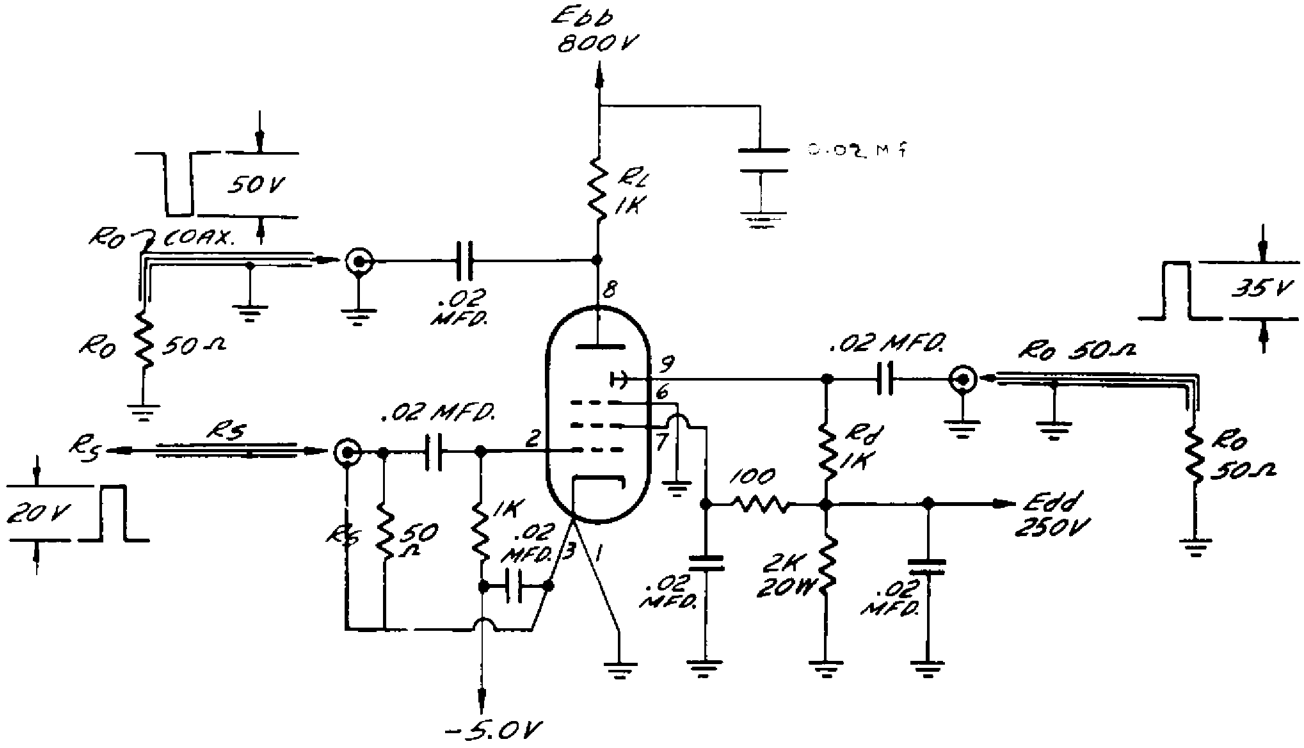
The 7548 operates efficiently in pulse circuits with switching times below 5 nanoseconds. It will furnish pulse-rise times of less than 3 nanoseconds for peak currents of over 1 ampere into low impedance loads (e.g. 50-ohm load) at high repetition frequencies. Life tests under high current pulse conditions are in operation using the EM 7548 and have logged over 2000 hours.

Examples of single stage pulse circuits employing the 7548 appear on following pages. These circuits illustrate the capabilities of the tube in fast rise-time free-running or driven pulse generators. In the univibrator (free-running) circuit the rise time is less than 3 ns and in driven circuits pulse rise times of less than 2 ns have been measured. These performance characteristics suggest the use of the EM 7548 in advanced flip-flop, trigger sweep and switching circuits.

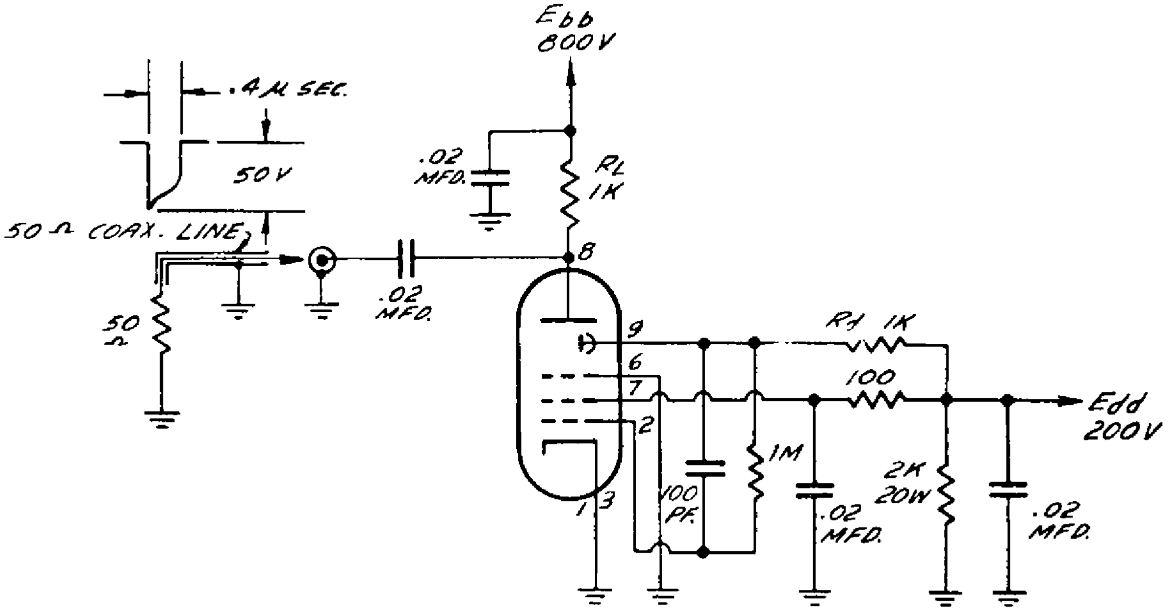
The enclosed bibliography lists literature discussing the application of secondary emission tubes, similar to the EM 7548, in many technical areas such as nuclear particle counting, Kerr cell studies, fast oscillography, and image tube studies.

The EM 7548 design has a class A transconductance of 26,000 micromhos and a gain-bandwidth figure of merit of 350 mc/s. High conductivity gold-plated base pins and double cathode connections minimize inductive effects. These characteristics offer a flexibility in wideband circuit design unobtainable with conventional tubes. With a gm/I_b ratio of 1500: this tube delivers class A amplifier gains of 1.4 into low impedance loads. Circuit economies can be realized since the high transconductance of the EM 7548 can effectively reduce the number of stages required in high gain amplifiers. These features indicate the important advantages accruing from the use of this tube in such applications as wideband distributed amplifiers, video amplifiers and wide band-pass amplifiers. A single stage Class A amplifier circuit is illustrated on a following page, while the bibliography suggests other wideband circuit application literature.

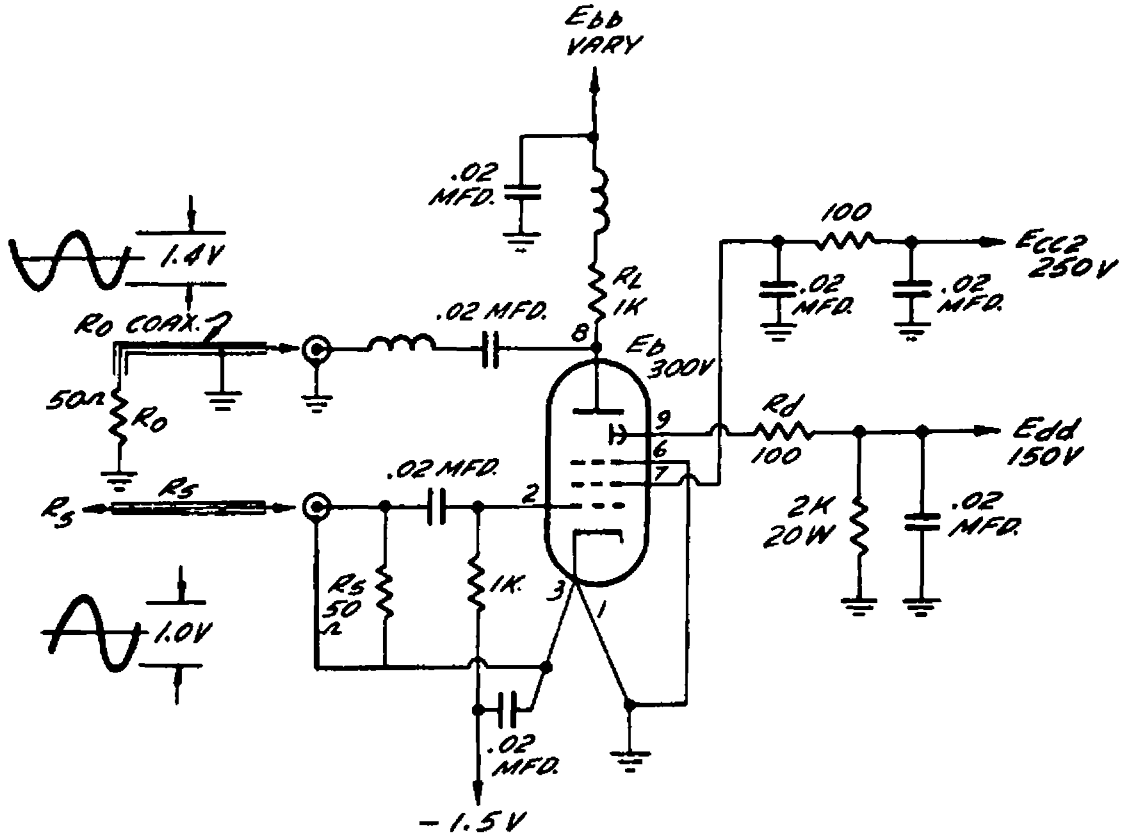
The enclosed data sheet describes important mechanical and electrical parameters of the EM 7548. Anode and dynode dynamic characteristics are shown on the attached curve sheets.



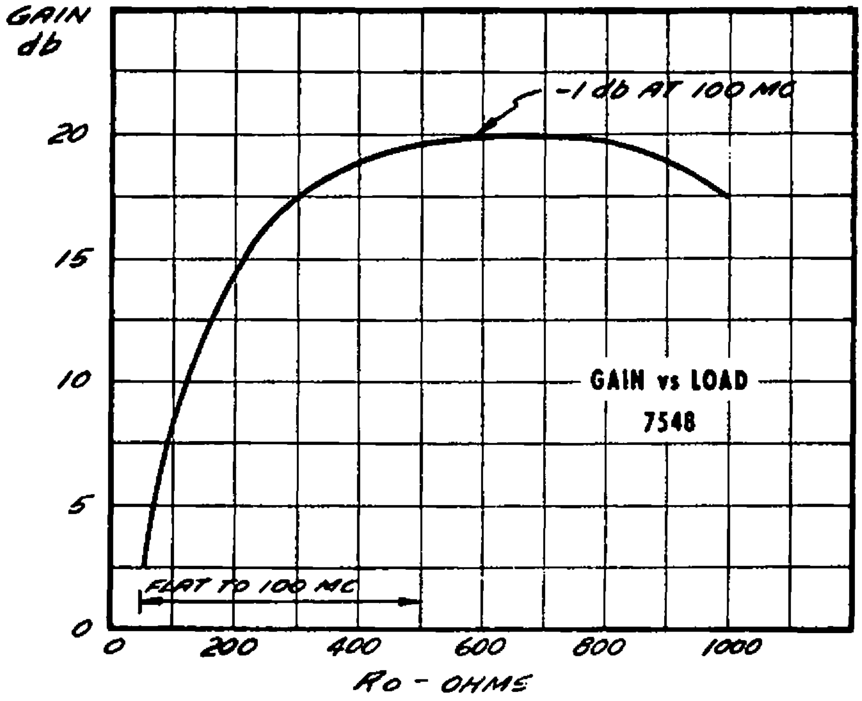
PULSE AMPLIFIER CIRCUIT (POSITIVE OUTPUT FROM DYNODE) - (NEGATIVE OUTPUT FROM ANODE)



UNIVIBRATOR CIRCUIT



WIDEBAND CLASS "A" AMPLIFIER



WIDEBAND CLASS "A" AMPLIFIER

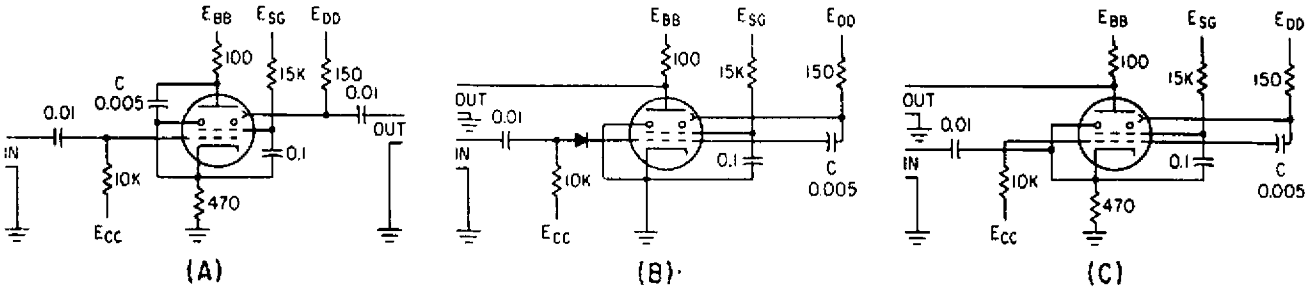


FIG. 1—Secondary-emission pentode trigger circuits: with positive feedback from plate to cathode (A); with positive feedback from dynode to grid (B); and for triggering with negative pulses (C)

How to Use the Secondary-Emission Pentode

Unique properties of the secondary-emission pentode, important in high-speed, short-duration pulse work, make this tube potentially useful in solving vacuum tube circuit problems

By E. J. MARTIN, JR., Midwest Research Institute, Kansas City, Missouri

SECONDARY-EMISSION pentodes represent an important contribution to nanosecond pulse techniques.[1]

Although many persons who have a working knowledge of millimicrosecond pulse circuits might find it difficult to justify the designation of this or any other device as the most important, the secondary-emission pentode has done much to advance the state-of-the-art in high-speed, short-duration pulse work. The tube has made possible triggering circuits that have shorter starting delays, better repeatibility and shorter recovery times than gas-discharge tube circuits used for similar purposes. In addition, the secondary-emission pentode makes it convenient to use regenerative feedback for generating fast-rise pulses at extremely fast repetition rates. Finally, the secondary-emission pentode can produce signal amplification without phase inversion, and thus can be used in some unique, balanced, distributed amplifier circuits.

Three types of secondary-emission pentodes are avaliable commercially—the Philips EFP-60; the E.M.I. Z-319; and the recently announced EM type 7548.

We do not discuss or compare specific characteristics of these different tube types here, but deal with the general properties of the secondary-emission pentode class of vacuum tubes and demonstrate some unique properties by considering a few circuits which are frequently used for pulse generation, triggering and pulse amplification.

Engineers not engaged in the development and/or application of millimicrosecond pulse techniques should become acquainted with the secondary-emission pentode. Its general capabilities make it a potentially useful tool in the solution of some specific electronic circuits problems.

The secondary-emission pentode comprises a high-vacuum, r-f pentode modified by a secondary-emission cathode, or dynode, situated between the suppressor and the plate. This dynode is operated at a potential intermediate between cathode and plate potentials. Its location is such that primary electrons which traverse the first part of the pentode structure (from cathode through suppressor) impinge upon the dynode rather than traveling directly to the plate.[2] The dynode is made of, or sensitized with, a material that has a high secondary-emission ratio,[3] usually in the range between four and seven. Since the plate is at a higher potential than the dynode while the suppressor is at cathode potential, the secondary electrons from the dynode are collected by the plate.

This arrangement greatly increases the overall transconductance of the tube without introducing relatively large interelectrode capacitances. The secondary-emission pentode may show an effective transconductance in excess of 20,000 micromhos with input and output capacitances of only 10 pf and

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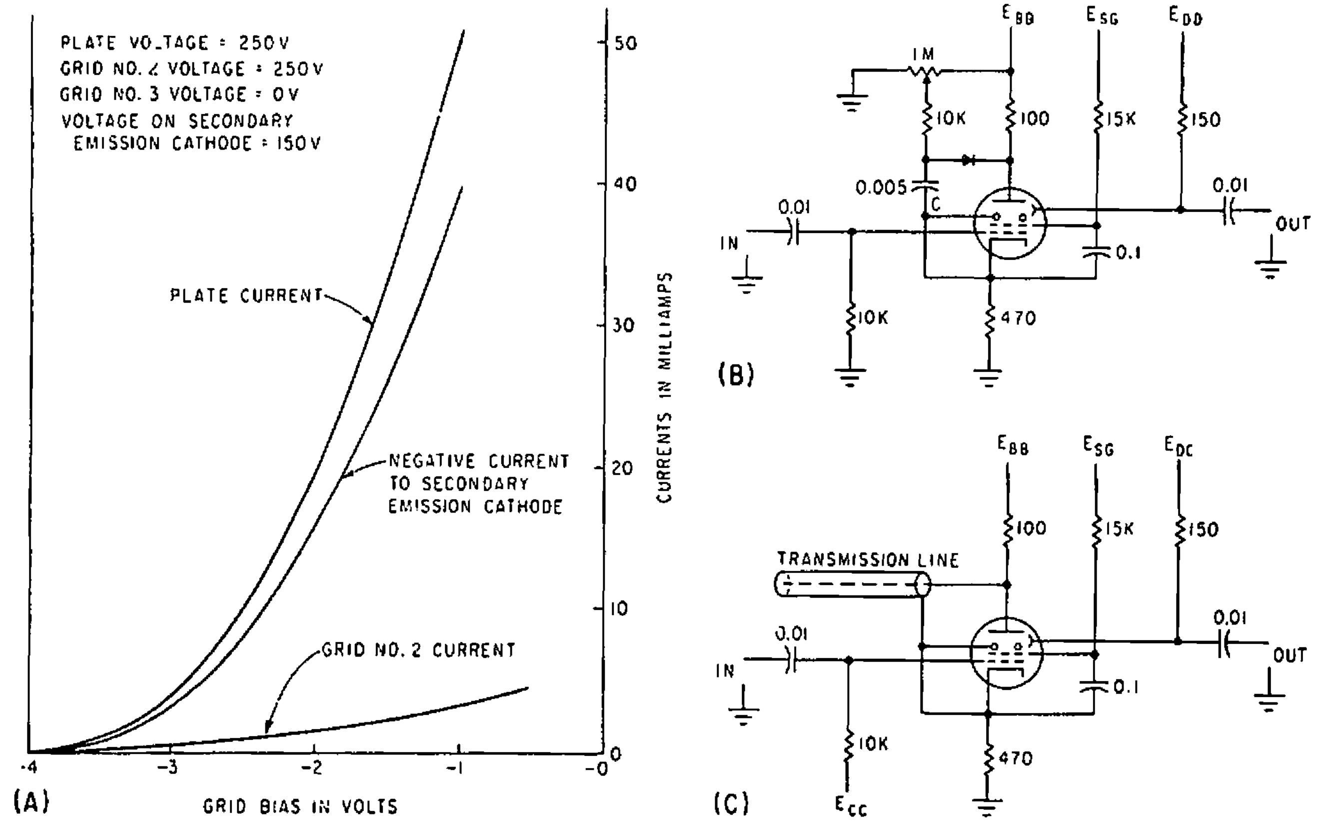

FIG. 2—Transfer characteristics of the EFP-60 (A); trigger circuit or pulse height discriminator (B); and a variation of the feedback circuit in a secondary-emission pentode trigger (C)

5 pf, and a grid-to-plate capacitance approximately three orders of magnitude smaller. Thus, in the design of cascaded, class-A amplifier stages, the secondary-emission pentode is of interest since it has a gain-risetime factor that compares favorably with those of other high-frequency pentodes.

Another feature arising from the novel arrangement is that since the dynode emits electrons at a greater rate than it receives them, there is an effective positive current flow out of the dynode. Except for the slight delay due to electron transit time, this dynode current is in phase with the grid signal. Consequently, an amplified, in-phase voltage will appear across a load impedance in the external dynode circuit. Besides amplification without phase inversion, this positive dynode current, along with the fact that both the dynode and plate currents are several times larger than the cathode current, leads to the possibility of using positive feedback to generate fast-rise pulses.

The ways in which the properties of the secondary-emission pentode can be employed to advantage are most easily explained by considering a few typical secondary-emission pentode circuits.

Consider triggering and pulse generating circuits.[4,5,6] A regenerative, secondary-emission pentode trigger circuit is shown in Fig. 1A on p 60.

In the quiescent state, the control grid potential is adjusted to a value that is sufficiently negative to just maintain the tube cutoff. The cathode is at ground potential, the plate is at some potential E_{BB} volts above ground and the dynode is at an intermediate potential E_{DD}. Since the tube is just cutoff, even a small positive-going signal on the grid will liberate some cathode electrons. When these electrons impinge on the dynode, secondary emission occurs and the plate collects an electron current several times larger than that which originally left the cathode. Because it is emitting electrons, the dynode rises slightly above E_{DD}; the plate potential drops slightly below E_{BB} when it collects the electrons. The drop in plate potential is fed back to the cathode through coupling capacitor *C*. Since the plate current is several times larger than the cathode current, the signal fed back to the cathode can be made of sufficient magnitude to overcome the cathode rise resulting from the flow of cathode current and to drive the cathode negative. This lowering of the cathode potential corresponds to an increase in grid potential. Consequently, more electrons are released from the cathode. Thus, even if the initiating pulse on the control grid should end during the cycle, feedback will keep repeating until the conduction of the tube has built up to a saturation level. Saturation is reached when the plate and dynode potentials have become substantially equal so that the plate can no longer collect all of the secondary

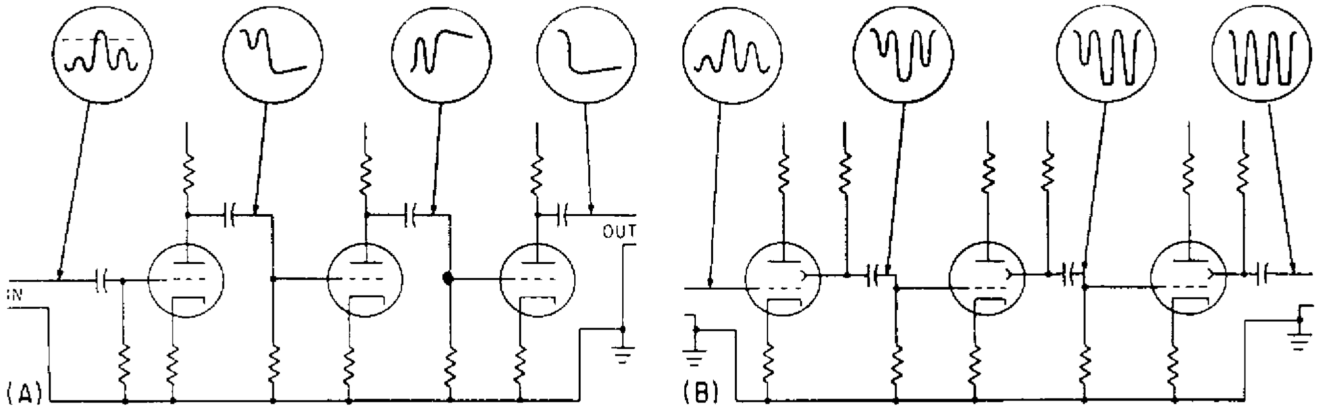

FIG. 3—Amplification by conventional cascade (A) and by cascaded secondary-emission pentodes (B)

electrons from the dynode.

With the tube in the heavily conducting state, the cathode begins to rise from its highly negative potential as the charge on the feedback capacitor is equalized through the cathode resistor to ground. This relatively slow rise of cathode potential has little effect on either the dynode or plate potentials so long as the supply of primary electrons from the cathode is large enough to maintain a rate of secondary emission at the dynode equal to or greater than the rate at which electrons can be collected by the plate. However, once the cathode potential rises to where liberation of primary electrons becomes small enough to result in a rate of production of secondary electrons at the dynode less than the rate at which the plate can collect electrons, the plate current will decrease slightly. The rise in plate potential is fed back to the cathode to further decrease the supply of primary and consequently secondary electrons. The tube is driven rapidly into cutoff and remains cutoff until another positive grid pulse is applied.

The circuit shown in Fig. 1A produces a positive output pulse across the dynode load each time it is triggered by a positive grid pulse. In Fig. 1B, a similar arrangement is shown for the production of a negative output pulse across the plate load. Feedback is from dynode to control grid, rather than from plate to cathode. The diode in the grid circuit in Fig. 1B insures that the feedback pulse is not impressed on any other circuit that might be connected to the input terminals and also to make the feedback nearly independent of the impedance of the input generator. This second consideration is important when the positive trigger input is derived from a relatively low-impedance source that might make the development of the feedback signal difficult. An alternate form of this circuit, which can be used when a negative trigger pulse is available, is shown in Fig. 1C. The diode is not necessary in the input circuit since feedback is from dynode to control grid while the negative trigger pulse is impressed on the cathode.

In the trigger circuits of Fig 1A through 1C, it is necessary that the grid be biased beyond cutoff because whenever cathode current flows in any of these circuits, regeneration takes place. With a grid that is not biased to cutoff, any of these circuits will free-run. That is, another cycle of regeneration will begin each time the circuit recovers from the previous cycle. Then the circuit is no longer a trigger circuit, but rather a pulse train generator.

The EFP-60 transfer characteristics shown in Fig. 2A are typical of secondary-emission pentode transfer characteristics. They show there is a disadvantage to the operation associated with the circuits of Figs. 1A through 1C. Each regeneration cycle must begin from cutoff where the tube transconductance, and consequently the circuit gain, is relatively low. The circuit shown in Fig. 2B obviates operating the tube at or beyond cutoff in the quiescent state, and makes it possible to obtain an output pulse with a somewhat shorter overall rise time. In the circuit of Fig. 2B, regeneration is prevented by the biased diode in the feedback circuit. No feedback can occur until a negative-going pulse, which has an amplitude greater than the bias on the diode, appears at the plate. Adjustment of the diode bias allows the sensitivity of this circuit to be varied; the circuit may therefore be used as a pulse-height discriminator as well as a trigger circuit.

A variation of the trigger circuits can be obtained by replacing the feedback capacitor with an open-circuited section of transmission line. Figure 2C shows such an adaptation applied to the regenerative circuit in Fig. 1A. Upon application of a positive grid pulse to this circuit, the progress of the tube into the metastable, saturation-conduction state proceeds as described. The negative-going voltage step on the plate is transmitted down the length of transmission line in the feedback path. In-phase reflection of this voltage step at the open-circuited end of the line causes the potential difference between the two conductors to double as the reflected step is transmitted back up the line. Since the plate is drawing saturation current, its potential with respect to ground cannot change when the reflected step reaches the tube end of the line. Consequently, the reflected step voltage is developed as a positive-going voltage on the cathode. The result is a sharp decrease in primary electron flow that causes a sharp decrease in secondary electron flow to the plate and the tube is driven rapidly into cutoff. Since the duration of the high-conduction state is dependent upon the length of the section of transmission line in the feedback path, the duration of the output pulse taken across the dynode load is adjusted by varying the length of this transmission line.

The secondary-emission pentode can be used for voltage amplification without phase inversion of the signal[1,3,9].

This feature leads to the possibility of applications that would be difficult or impossible using more conventional tubes. One application is the trigger amplifier, shown in Fig. 3A. This amplifier might be used with one of the trigger circuits.

Suppose that it is desired to trigger a regenerative circuit similar to the one discussed in Fig. 2B, with each one of the pulses in the pulse train pictured at the input of Fig. 3A. Suppose, further, that the lowest diode bias level at which the trigger circuit can be operated with insured stability corresponds to an input pulse height indicated by the dashed line. The pulse train must be amplified if each one of the pulses is to produce triggering. However, the use of a conventional cascaded amplifier (Fig. 3A) may be precluded because the larger pulses will be amplified to the point where they cause grid current to be drawn in the latter stages of the amplifier string before the smaller pulses have amplified sufficiently to result in triggering of the regenerative circuit. The amplifier circuit shown in Fig. 3B presents a solution. The positive pulses in the train are amplified and converted to negative pulses by the first stage in the conventional manner. In subsequent stages, the negative pulses are amplified without phase inversion by taking the outputs of the second and successive stages from the dynodes rather than the plates. As the amplification proceeds stage by stage, there is no possibility of any stage being made temporarily insensitive by grid conduction. On the contrary, as amplification proceeds down the cascaded stages, the amplitudes of the larger pulses are limited to a value determined by the grid biasing on the stages. Thus the output of the amplifier string can be a train of pulses, all of which have the same amplitude. The requirement that the pulses be positive to trigger the regenerative stage is satisfied by taking the output of the final stage from the plate rather than from the dynode. Amplitude is limited without clipper stages.

Another example of how the secondary-emission pentode can be applied to advantage is shown in Fig. 4—a distributed amplifier from which balanced push-pull outputs can be obtained. With conventional pentodes, two separate amplifier strings would be required to achieve comparable results.

Up to this point, the discussion has been concerned with a representative coverage of what might be called conventional secondary-emission pentode circuit applications, although here the conventional is somewhat unconventional when compared with ordinary vacuum-tube circuits.

As a final example of the uses that can be made of secondary-emission pentode properties, consider the cathode-follower circuit shown in Fig. 5[10].

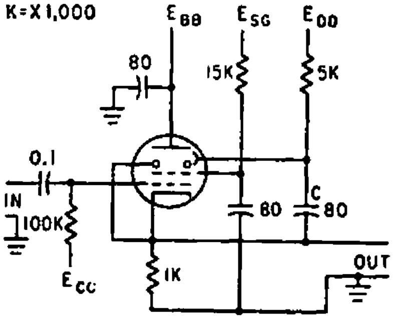

FIG. 5—This cathode follower circuit is useful for matching high-impedance sources with low-impedance loads

Figure 5 shows that the circuit is an ordinary cathode-follower enhanced by the connection of the dynode back to the cathode. This circuit uses degenerative feedback, in much the same way that the trigger circuits use regenerative feedback, to achieve high-performance impedance transformation. This takes advantage of the high effective transconductance of the secondary-emission pentode in the cathode-follower circuit, even though the cathode current is only a small fraction of the plate or dynode current. This circuit can be applied when it is necessary to match a high-impedance source and a low-impedance load.[11]

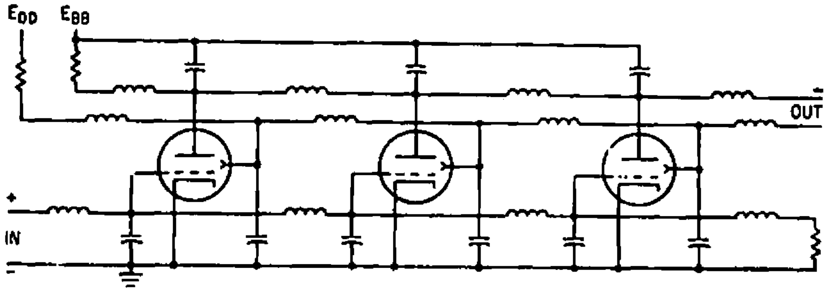

FIG. 4—Secondary-emission pentodes in a distributed amplifier from which balanced push-pull outputs can be obtained

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