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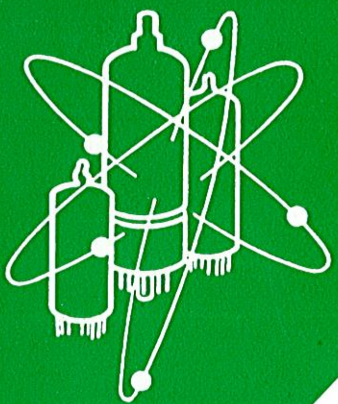
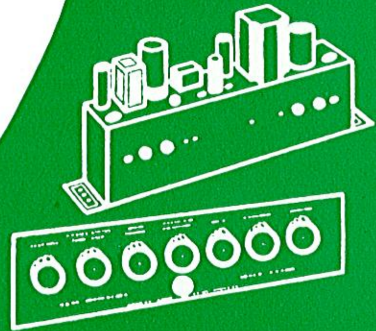


ELECTRONIC VALVES

AUDIO



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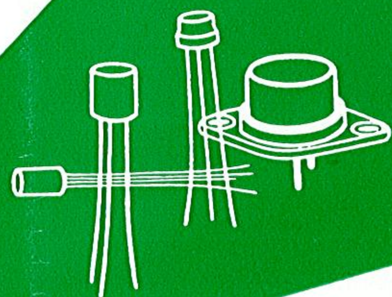
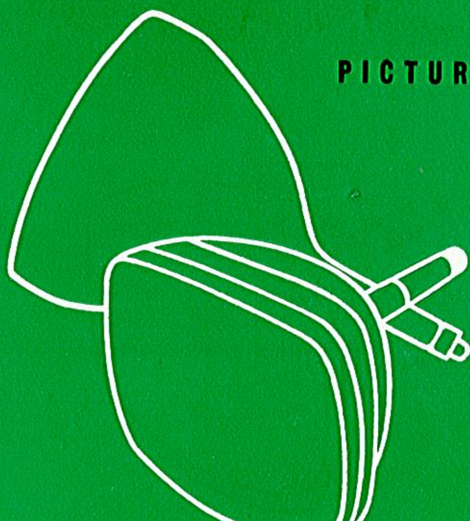
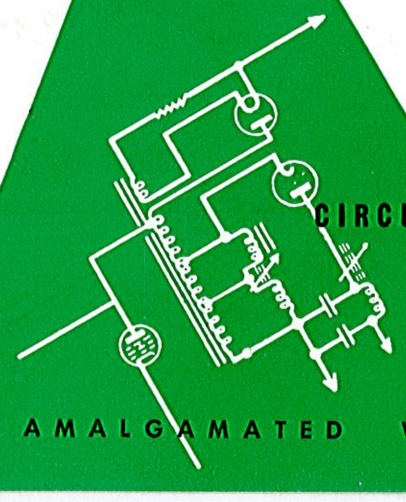


TRANSISTORS

RADIOTRONICS

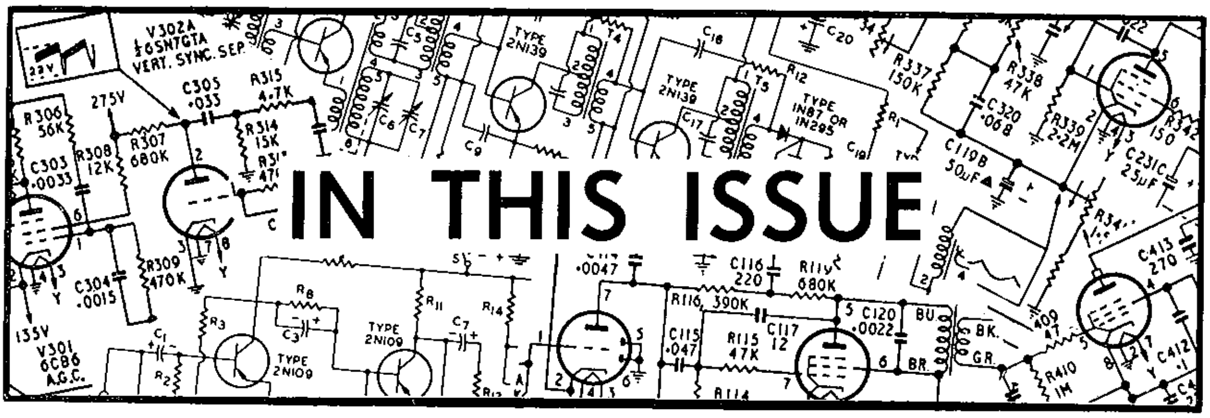
PICTURE TUBES





CIRCUITRY

AMALGAMATED WIRELESS VALVE COMPANY PTY. LTD.



EDITOR ...... BERNARD J. SIMPSON

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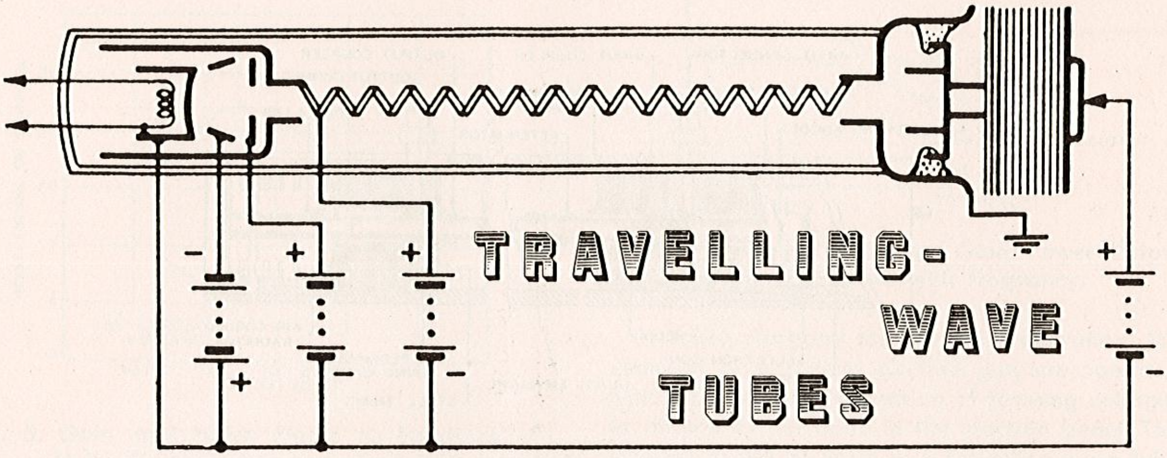


TRAVELLING-WAVE TUBES

PART 1

DESCRIPTION OF OPERATION

Travelling-wave tubes are best known for their ability to amplify microwave signals simultaneously over a wide band of frequencies. This amplification feature is obtained by the use of an interaction circuit which is essentially a transmission line and does not usually contain any resonant elements. The product of the gain and the bandwidth of a travelling-wave tube may be as high as 10^{13}. Travelling-wave tubes have been constructed to operate in frequency bands from at least 100 to 50,000 Mc/s.

Recent developments have demonstrated that travelling-wave tubes, like more conventional tubes, can be designed for a variety of applications. Typical applications for these tubes include their use as CW power amplifiers, high-power pulse amplifiers, low-noise amplifiers, frequency multipliers, mixers, electronically-tunable amplifiers and oscillators, and in amplitude — phase —, and pulse modulation service.

All travelling-wave tube amplifiers incorporate the basic components shown in the schematic diagram of Fig. 1. These components include an electron gun which produces an electron beam, a transmission line (slow-wave structure) which propagates a microwave signal in a manner that permits interaction between the beam and the signal, a collector which removes the unused beam energy, transducers which introduce and remove the signal, and an attenuator which isolates the input and output sections of the slow-wave structure to prevent oscillations. A cross section of a developmental travelling-wave tube is shown in Fig. 2. Although travelling-wave tubes may differ widely in size and construction depending on their application, the basic theory of operation is the same for all types.

The interaction which provides amplification in a travelling-wave tube may be explained by consideration of the slow-wave structure, which is generally a helix. The velocity of the electron beam introduced at the left end of the helix is determined by the helix voltage, i.e., the dc voltage between the helix and the cathode of the electron gun. A strong magnetic field (supplied by an electromagnet or a permanent magnet) parallel to the axis of the helix confines the electrons to a cylindrical beam whose diameter approaches the inside diameter of the helix. An electromagnetic wave introduced at the left end of the helix travels circumferentially along the helix wire at approximately the velocity of light, although its velocity in the axial (beam) direction is reduced by the pitch-to-circumference ratio of the helix. When the helix voltage is properly adjusted, the velocity of the beam electrons is made slightly greater than the velocity of the rf electromagnetic wave. The rf electric field then influences the electron velocity, decelerating the electrons in the rf retarding field, and accelerating, to a smaller degree, those in the rf accelerating regions. As the beam travels through the helix, the decelerating action becomes predominant and dc beam energy is transferred to the rf electric field, causing amplification.

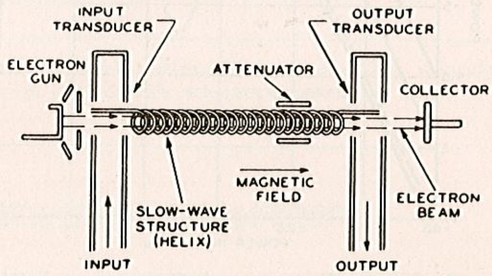


Fig. 1. Schematic Diagram Showing Basic Components of a T-W Tube Amplifier.

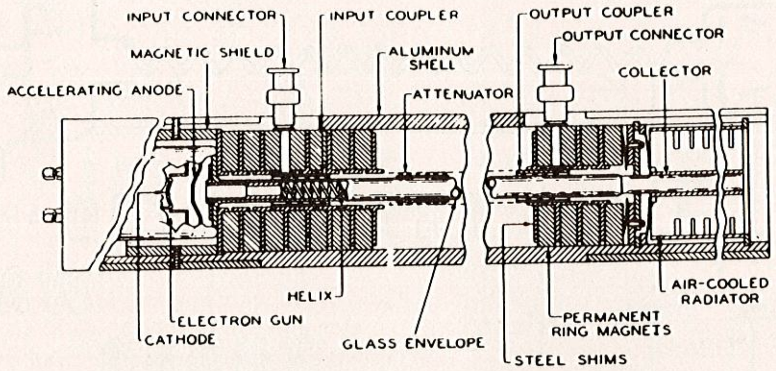


Fig. 2. Cross Section of a Developmental T-W Tube.

TUBE CHARACTERISTICS

For a given beam current, the power output of a travelling-wave amplifier is a function of the input power, as shown in Fig. 3. The gain is essentially constant for low input levels, but decreases at higher levels. When the rf electric field becomes too strong, as a result of either amplification or input signal, the amount of energy which the beam can deliver to the wave reaches a maximum limit. This condition, known as the saturation point of the tube, represents the maximum power which can be delivered for a given condition of beam current. If the input power is increased beyond the value which causes saturation, an actual decrease in power output results. (An increase in the beam current, of course, produces a corresponding increase in saturation power and gain).

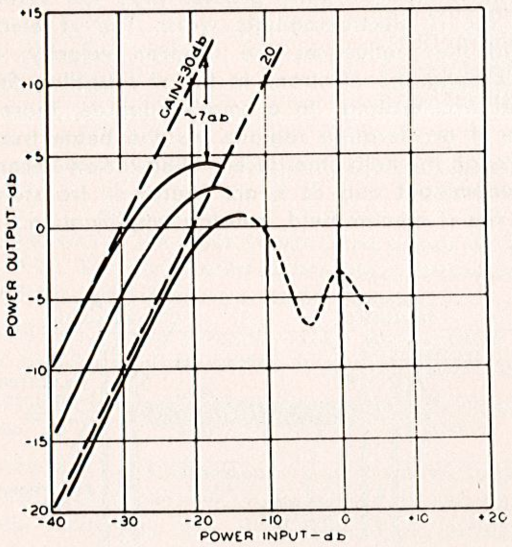


Fig. 3. Power Output and Gain of a T-W Amplifier as a Function of Input Power for three values of Beam Current.

The maximum gain is determined by the stability limit (i.e., the beam-current value at which the tube begins to oscillate), the safe emission limit of the cathode, and the maximum current which can be focused through the helix without causing excessive current to be intercepted by the helix or other tube elements and thereby producing over-heating. For high-power operation, the tube must employ elements which can dissipate the heat created by the rf wave and the intercepted beam current. In high-power travelling-wave amplifiers, therefore, a maximum value is often specified for helix and collector power dissipation. Travelling-wave amplifiers designed for very high power output often use special disc-loaded structures which can dissipate large amounts of heat. These structures, however, have a relatively narrow frequency band compared with that of helix-type structures. This type of structure is closely analogous to a filter network.

The helix-type of slow-wave structure shown in Fig. 1 is especially suitable for wide-band operation. In the design and application of wide-band tubes, however, some sacrifice of power output and gain must usually be made to extend the useful bandwidth and flatten the power-output curve, as illustrated in Fig. 4. A typical

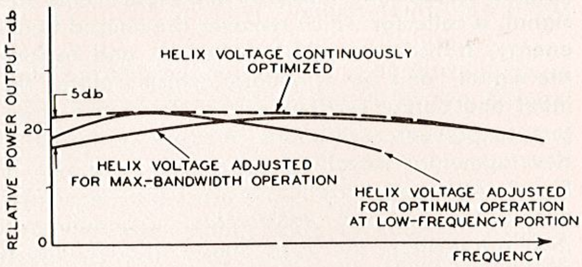


Fig. 4. Power Output as a Function of Frequency for different Helix Voltage Adjustments.

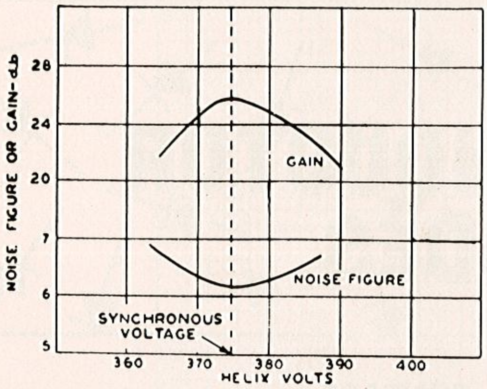


Fig. 5. Gain and Noise Figure as Functions of Helix Voltage for a typical T-W tube; dashed line indicates "synchronous voltage".

value of low-level gain for broad-band operation is in the order of 30 db. However, values of 50 db can be realised. The variation of gain with helix voltage is shown in Fig. 5. For highest gain, the helix voltage must be adjusted so that the electron beam and the rf electromagnetic wave have almost equal axial velocities. The value of helix voltage, called the "synchronous voltage", is indicated by the dashed line in Fig. 5.

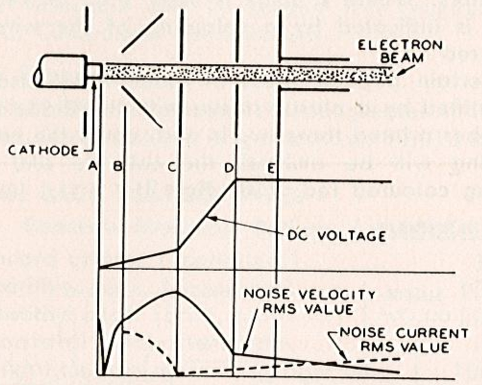


Fig. 6. Schematic Diagram showing Construction of "Three-region" type of Electron Gun used in Low-noise tubes. Curves of relative dc voltage and noise for the gun are also shown.

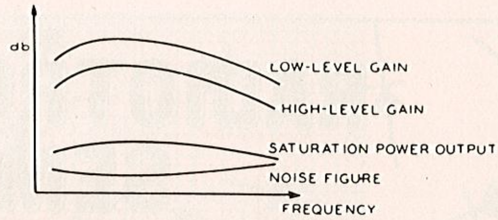


Fig. 7. General Variation of Gain, Power Output and Noise Figure with Frequency.

In tubes designed for low-noise operation, the elements of a special electron gun are operated with a particular combination of focusing voltages to deamplify the noise in the electron beam. The primary source of noise in a travelling-wave tube is shot noise. This noise appears in the beam as power which varies as a standing wave having alternate maxima and minima along the beam length. The noise power may be reduced by operation of the cathode so that the space charge limits its emission at the lowest possible temperature and by the use of a "three-region" type of electron gun, such as that shown in Fig. 6, to deamplify the noise power. After the noise power is reduced, the helix is positioned so that the input signal is initially amplified in a region of the noise standing-wave minimum.

In low-noise tubes, beam interception must be kept extremely low. Tubes can be designed to have low noise over relatively large bandwidths. When constant electrode voltages are used, however, the noise figure can be expected to increase slightly above the optimised value as the frequency deviates from mid-band. Somewhat better performance as a function of frequency can be obtained by optimising the electrode voltages for each specific frequency band. Fig. 7 shows the general variation of gain, power output, and noise figure of a travelling-wave tube as a function of frequency. A critical microscopic examination of these parameters over a narrow band of frequencies generally reveals further "fine-grain" variations caused by minute discontinuities in the slow-wave structure, at the attenuator, and/or in the coupling circuits.

This four-part article, which will be continued in succeeding months, is printed with acknowledgements to RCA.

RADIOTRON SEMICONDUCTOR DIODES

GERMANIUM POINT CONTACT DIODES

Germanium diodes consist of a small piece of germanium and a point contact or catwhisker, the whole being sealed into a glass capsule.

The advantages of this type of diode include very small size, robustness, low capacitance and ability to be soldered directly into the circuit. In addition, since a heater is not required, no hum is introduced.

Compared with other non-thermionic diodes, germanium diodes are outstanding in their h-f performance and ability to handle relatively high voltages.

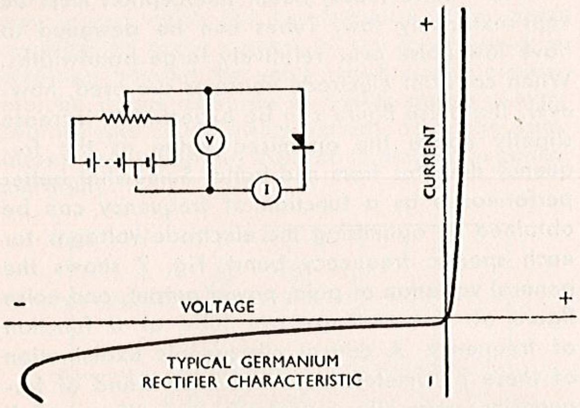


Fig. 1.

A typical characteristic curve is shown in Fig. 1. It will be noticed that when the reverse voltage exceeds a certain figure the reverse resistance suddenly decreases and then becomes negative. The potential at which this occurs is known as the "turnover" voltage. The curves in Figs. 3 and 4 show variations between different types, and a derating temperature curve.

Germanium diodes are divided into two general categories, the first being the high back voltage types made from germanium of great purity, and the other being the special low resistance types using germanium containing deliberately introduced impurities. The high back voltage types are differentiated mainly by their turnover voltage and back resistance figures which are the most important factors when considering their applications.

COLOUR CODE

In the colour coding system, red is an indication of the negative end of the diode. Thus, when compared with a thermionic diode, the red end of the germanium diode corresponds to the cathode.

The second and third colours give the type number according to the standard code used for resistors. Where a suffix is used, e.g., GEX45/1, this is indicated by a colouring of the wire at the red end.

Certain popular types of diodes may also be identified by a plastic sleeve with the diode type number printed there on. In such cases the colour coding will be omitted, the cathode end still being coloured red. (See Fig. 2).

DIMENSIONS

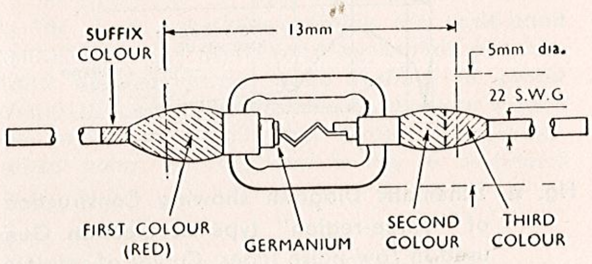


Fig. 2.

GENERAL

Temperature Range

Germanium diodes will function satisfactorily in the range −40° to +70°C, and may be stored in the range −40° to +85°C.

Humidity

Germanium diodes are hermetically sealed and it is impossible for moisture to penetrate to the working surfaces.

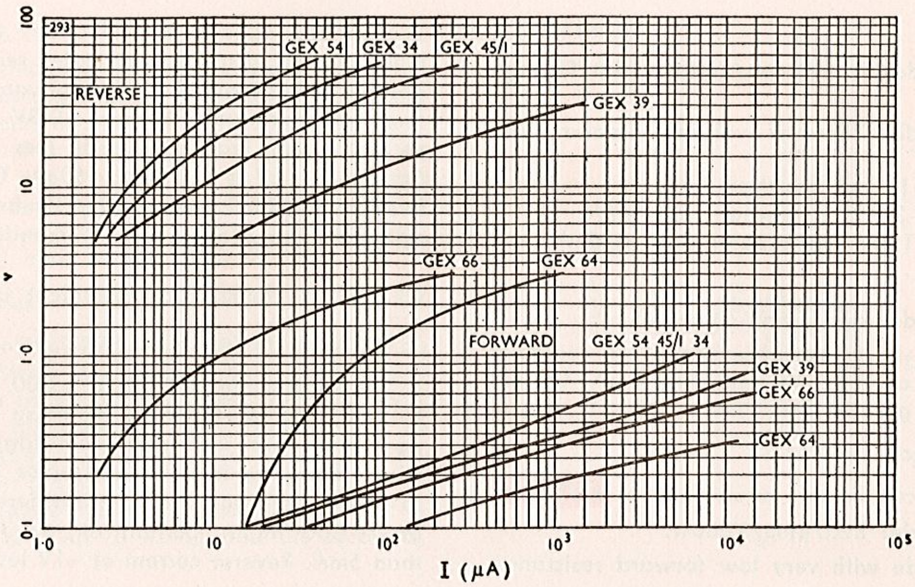


Fig. 3. Typical Characteristics at 20°C.

Vibration

All diodes are subjected to severe vibration test after manufacture.

Connection

Soldered joints may be made directly to the wire leads. No special precautions are necessary when carrying out this operation since the diodes will withstand the 10 second test required by R.I.C. Component specifications.

Life Expectation

Shelf life is expected to be greater than 10 years. Operating life is greater than 10,000 hours.

HIGH BACK VOLTAGE TYPES

Common Maximum Ratings (at 20°C.)

Forward current (continuous)	30mA
Repetitive peak (sinusoidal)	100mA
Repetitive peak (brief, recurrent)*	200mA
Occasional peak overload	0.5A
Dissipation with reverse voltage	100mW

* On-Off ratio 1/1000.

The above ratings are for operation at an ambient temperature of 20°C, and for higher ambient temperatures must be reduced. See Fig. 4. Typical Capacitance (at 45 Mc/s) 0.9μμF.

INDIVIDUAL CHARACTERISTICS

High Back Voltage Types

GEX34

Colour code: Red/Orange/Yellow.

TV sound detector, sound noise limiter and high level vision detector. The effective r-f turnover voltage is greater than 60V. Current at +1V not less than 1 mA. Current at –10V not greater than 50 μA. Current at –50V not greater than 250 μA. Replaces GEX44 and GEX44/1.

GEX35 (A commercial equivalent of CV442)

Colour code: Red/Orange/Green.

Low level vision detection. Turnover voltage greater than 30V.

Functionally tested at 35 Mc/s to give 400 μA rectifier current in 6.8k load. Current at +1V not less than 1mA. Current at –10V not greater than 100μA. Average current at –25V, 100μA.

GEX36

Colour code: Red/Orange/Blue.

Mixer diode, for use as telephony modulator at higher voltage levels than GEX64. Turnover voltage greater than 30V. Available in groups matched for forward voltage at 5mA in the range 0.625 to 0.875V. Voltage spread within each group less than 0.1V. Current at –10V less than 100μA.

GEX39

Colour code: Red/Orange/White.

High efficiency diode with good r-f performance and low forward impedance. Current at +1V not less than 15mA. Current at –10V not greater than 100μA.

GEX45/1 (A commercial equivalent of CV425.)

Colour code: Red/Yellow/Green with Brown wire.

Medium back-resistance diode for all purposes. Turnover voltage greater than 75V. Current at +1V not less than 4mA. Current at –50V not greater than 1 mA.

GEX54 (A commercial equivalent of CV448).

Colour code: Red/Green/Yellow.

High back-resistance diode. Turnover voltage greater than 100V. Current at +1V not less than 3mA. Current at –10V not greater than 10μA. Current at –50V not greater than 100μA.

GEX54/3

Colour code: Red/Green/Yellow with Orange wire.

100V diode. Turnover voltage greater than 120V.
Current at +1V not less than 3mA.
Current at −3V not greater than 6μA.
Current at −100V not greater than 625μA.

GEX56

Colour code: Red/Green/Blue.

Very high back-resistance diode for computer use. Current at +1V not less than 1mA. Current at −10V not greater than 2μA.

Low Resistance Types

GEX64 (A commercial equivalent of CV2310).

Colour code: Red/Blue/Yellow.

Mixer diode with very low forward resistance. Typical applications are telephony modulator in multi-channel systems and meter rectifier. Available in groups matched for forward voltage at 5mA in the range +0.2 to +0.3V. The voltage spread within each group is less than 0.02V. Current at −1V is less than 160μA. The comparatively high capacitance of 30μμF limits the effective operating frequency in high impedance circuits.

GEX66 (A commercial equivalent of CV2290).

Colour code: Red/Blue/Blue.

V-h-f mixer for use up to 1,000 Mc/s. In the TV range up to 100 Mc/s the noise as a mixer is no greater than that from a cartridge type silicon mixer. Efficiency is good and noise fairly low up to 1,000 Mc/s and there is considerable response at 10,000 Mc/s. Current at +0.5V is greater than 5mA. Reverse current at −1V less than 50μA.

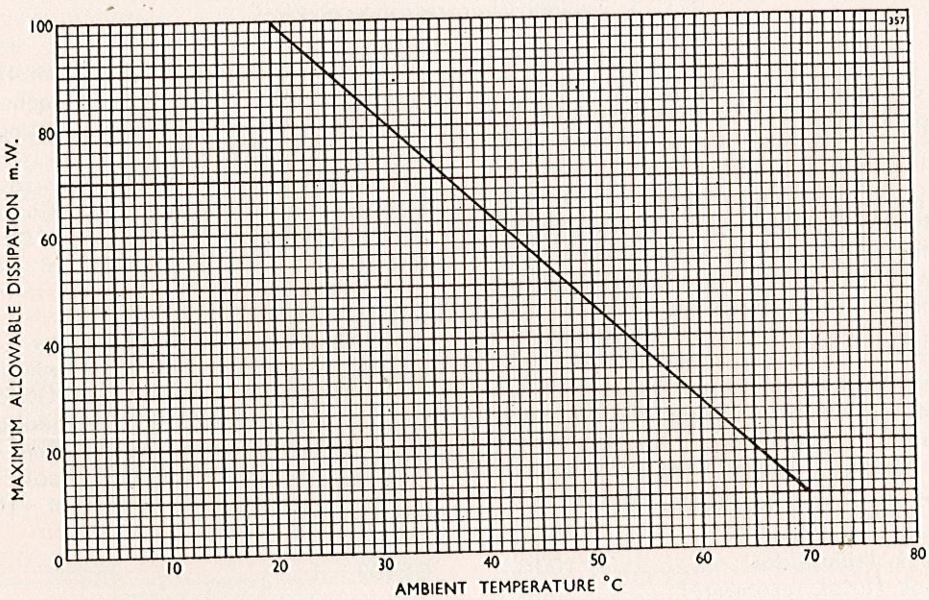


Fig. 4. Derating Curve/Temperature.

GERMANIUM JUNCTION DIODE
GEX541

The GEX541 is a medium-power PN junction germanium diode suitable for operation at ambient temperatures up to 55°C. It is primarily designed for inclusion in complete rectifier stacks, of which a comprehensive range is available. Stacks are available in two forms, with the diodes mounted on 4″ x 4″ cooling fins, or on ⅝″ x 1.$\frac{11}{16}$″ steel mounts. Choice of the form required for a specific application will depend on cost and space considerations.

D.C. CHARACTERISTICS

Max. voltage for forward current = 8A ... 0.6V
Max. current at −80V and 70°C 25mA
Max. peak inverse voltage .... 80V.

TYPICAL OPERATION (Complete stacks).

Typical ratings for convection-cooled stacks for two selected circuit applications are given below:

On all stacks where diodes are used in series and parallel, finned or unfinned, up to a maximum of approximately 30 kVA (finned), derating factors are applied to both current and voltage, depending on the number of diodes used.

Finned Series

In this application the diodes are mounted on 4" square cooling fins. In a single-phase bridge circuit producing a nominal 48V. d.c. output voltage, the maximum d.c. current is 12A at 35°C, 8A at 45°C, and 4A at 55°C. In a three-phase bridge circuit producing a nominal 74V. d.c. output voltage, the maximum d.c. current is 18A at 35°C, 12A at 45°C, and 6A at 55°C.

Unfinned Series

In this application the diodes are mounted on ⅝" x 1.$\frac{11}{16}$" tinned steel mounts. In a single-phase bridge circuit producing a nominal 48V. d.c. output voltage, the maximum d.c. current is 5A at 35°C, 3.6A at 45°C, and 2A at 55°C. On a three-phase bridge circuit producing a nominal 74V. d.c. output voltage, the maximum d.c. current is 7.5A at 35°C, 5.4A at 45°C, and 3A at 55°C.

DIMENSIONS

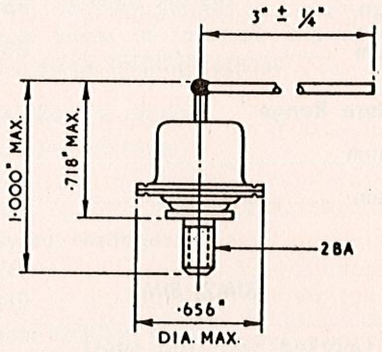


Fig. 5.

COAXIAL SILICON DIODES

The SIM2 and SIM5 are coaxial silicon crystal diodes, and are commercial equivalents of the CV2154 and CV2155 respectively. They are intended for use as mixers at frequencies up to 12,000 Mc/s. The SIM2 has identical dimensions and characteristics to the SIM5, but the polarity is reversed. The two diodes together are intended for use in balanced mixer circuits.

The SIM3 and SIM6 are coaxial silicon crystal diodes, intended as mixers at "X" — band frequencies. The SIM3 has identical dimensions and characteristics to the SIM6, but the polarity is reversed. The two diodes together are intended for use in balanced mixer circuits.

Since most modern centimetric mixer circuits are pre-tuned, these diodes have been specially designed for use in such circuits, and the spread in the admittance of these crystals is very small, even at 10,000 Mc/s.

Frequency

SIM2, SIM5 ...... All bands up to 12,000 Mc/s.
SIM3, SIM6 ...... "X"—band frequencies. (10,000 Mc/s)

Overall Noise Factor

SIM2, SIM5

"X"—band (max.) *	10.5 db.
"X"—band (average)	9.5 db.
"S"—band (average) (2,800 Mc/s.)	7.5 db.
"L"—band (average) (1,300 Mc/s)	7.0 db.

SIM3, SIM6

"X"—band (max.) *	10.5 db.
"X"—band (average)	9.5 db.

* See Note 1.

R-f Admittance

Maximum .... 1.43 VSWR
(See notes 2 and 3.)

Dimensions

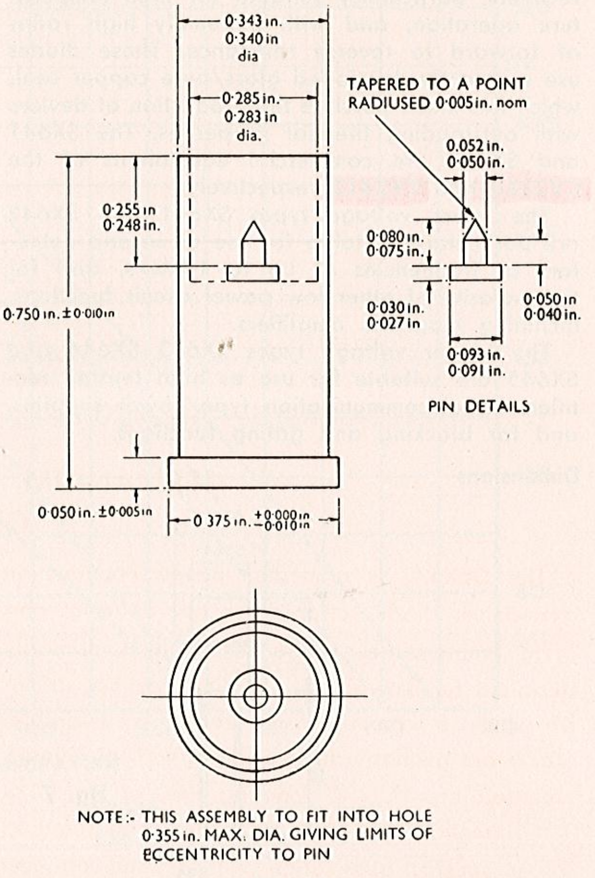


Fig. 6.

I-f Impedance

Maximum	420 ohms.
Average	350 ohms.
Minimum	280 ohms.

Temperature Range

Maximum	+100°C
Minimum	−40°C

Polarity

SIM2, SIM3

Pin	Cathode
Body (marked with red spot)	Anode

SIM5, SIM6

Pin	Anode
Body (marked with green spot)	Cathode

Notes

(1) 100% direct test at 9,500 ±500 Mc/s in a standard holder at 1mA rectified current. Noise factor of i-f amplifier is 2 db.

(2) 100% test at 9,375 ±10 Mc/s with 0.65 mW available power, in a standard holder. For SIM2 and SIM5 only, also 100% test at 3,000 ±3 Mc/s with 0.5 mW available power, in a standard holder.

(3) The nominal rectifier admittance at a plane 0.247 inches back from the open end of the diode (inside the body) is:

$$\frac{1}{83.5} + \frac{j}{350} \text{ mhos}$$

measured at a frequency of 9,375 Mc/s and a rectified current of 1mA.

SILICON JUNCTION DIODES

GENERAL

The SX641, SX642, SX643, SX644 and SX645 silicon junction diodes are small-area PN junction rectifiers, particularly suitable for high temperature operation, and with extremely high ratios of forward to reverse resistance. These diodes use a recently-developed glass/pure copper seal, which has made possible the production of devices with outstanding thermal properties. The SX641 and SX642 are commercial equivalents of the CV2384 and CV2413 respectively.

The lower voltage types SX641 and SX642 are particularly suitable for use as second detectors at frequencies of up to 10Mc/s, and for the majority of other low power circuit functions, including magnetic amplifiers.

The higher voltage types SX643 SX644 and SX645 are suitable for use as high tension rectifiers in telecommunication type power supplies, and for blocking and gating functions.

Dimensions

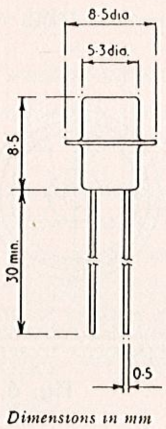


Fig. 7.

Colour Code

The wire lead to the negative end of the diode is coded red; therefore the red wire corresponds to the cathode of a thermionic diode.

Ratings

Max. voltage for 100mA forward current	1.5V
Maximum capacitance at −9V	5$\mu\mu$F
Maximum storage temperature	170°C

SX641, SX642

SPECIFICATION

Maximum voltage for 100mA forward current	1.5V.
Maximum reverse current at 100°C	
SX641 (at −60V)	5μA
SX642 (at −120V)	5μA

RATINGS

Maximum mean dissipation at ambient temperatures up to 80°C (SX641) 70°C (SX642) *	300mW
Maximum peak inverse voltage:	
SX641	60V
SX642	120V
Mean rectified current in half-wave capacitive input circuit at ambient temperatures up to 80°C (SX641), 70°C (SX642) *	200mA
Maximum recurrent peak current	2A
Maximum surge current (1 cycle)	6A

* For operation at other temperatures, refer to the temperature/derating curves in Fig. 8.

OPERATING CONDITIONS

Typical ratings for capacitive input circuits at ambient temperatures of up to 80°C (SX641) or 70°C (SX642), are given below for a variety of operating conditions *

Half-Wave Rectifier (1 diode)

R.M.S. input voltage:
- SX641 .... 21V
- SX642 .... 42V

D.C. output voltage:
- SX641 .... 30V
- SX642 .... 60V

Maximum rectified current 200mA
Maximum value of reservoir capacitor 120μF
Minimum surge limiting resistor .... 47 ohms

Bi-phase Rectifier (2 diodes)

R.M.S. input voltage:
- SX641 .... 21-0-21V
- SX642 .... 42-0-42V

D.C. output voltage:
- SX641 .... 30V
- SX642 .... 60V

Maximum rectified current 400mA
Maximum value of reservoir capacitor 120μF
Minimum surge limiting resistor .... 47 ohms

Bridge Rectifier (4 diodes)

R.M.S. input voltage:
- SX641 .... 42V
- SX642 .... 84V

D.C. output voltage:
- SX641 .... 60V
- SX642 .... 120V

Maximum rectified current 400mA
Maximum value of reservoir capacitor 60μF
Minimum surge limiting resistor .... 47 ohms

Series Operation

Series operating conditions can be derived by direct multiplication of the input and output voltages for single-unit operation. The value of

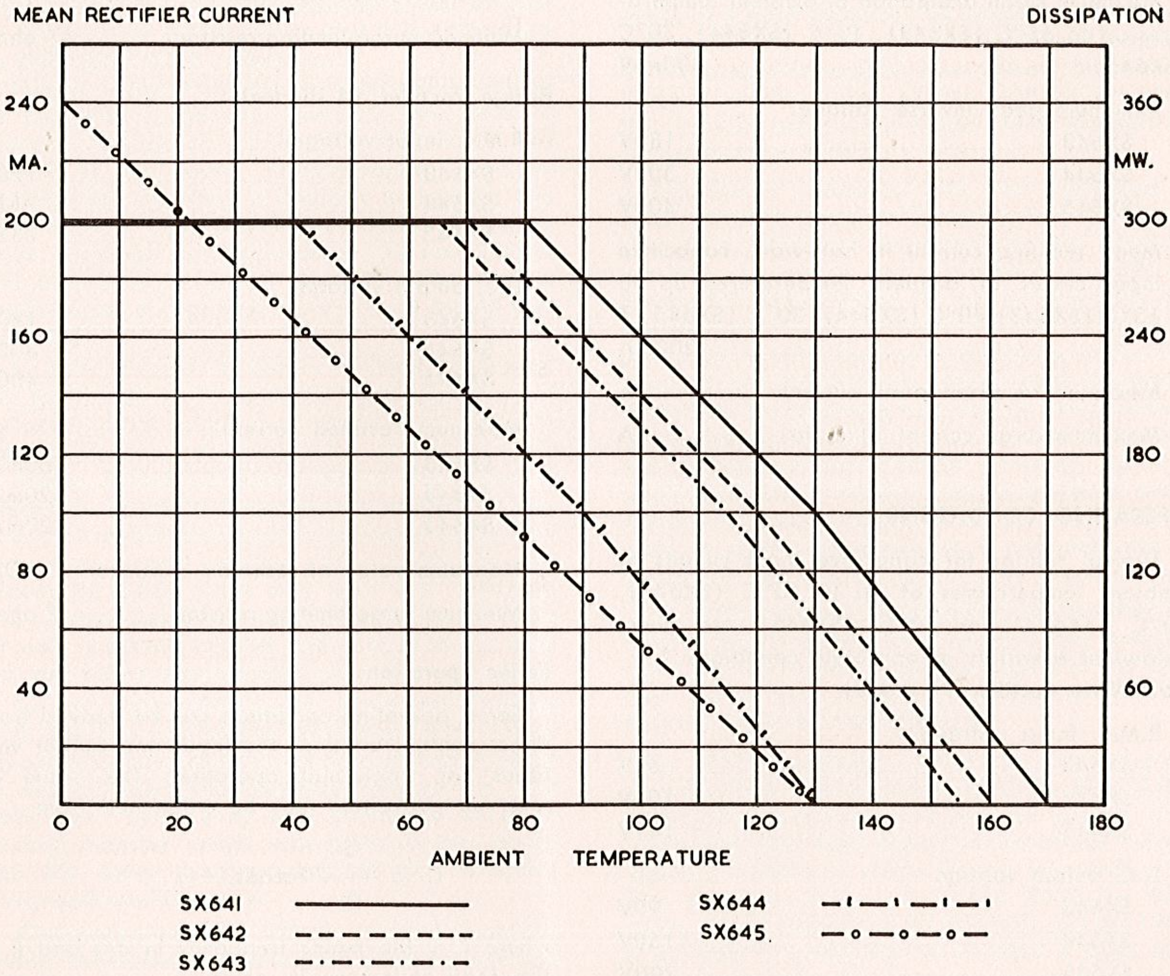


Fig. 8. Derating Temperature Curves.

reservoir capacitor may be calculated from

$$C = \frac{5}{FR} \text{ Farads,}$$

where F is the mains frequency in c/s and R is the load resistance in ohms.

SX643, SX644, SX645

SPECIFICATION

Maximum voltage for 100mA forward current 1.5V

Maximum reverse current at 100°C
- SX643 (at −300V) 15μA
- SX644 (at −300V) 15μA
- SX645 (at −400V) 15μA

RATINGS

Maximum mean dissipation at ambient temperatures up to 65°C (SX643), 40°C (SX644), 30°C (SX645) * 300mW

Maximum peak inverse voltage:
- SX643 .... 180V
- SX644 .... 300V
- SX645 .... 400V

Mean rectified current in half-wave capacitive input circuit at ambient temperatures up to 65°C (SX643) 40°C (SX644), 30°C (SX645) * 200mA

Maximum recurrent peak current 2A

Maximum surge current (1 cycle) 6A

OPERATING CONDITIONS

Typical ratings for capacitive input circuits at ambient temperatures of up to 65°C (SX643), 40°C (SX644), or 30°C (SX645) are given below for a variety of operating conditions. *

Half-Wave Rectifier (1 diode)

R.M.S. input voltage:
- SX643 .... 64V
- SX644 .... 106V
- SX645 .... 141V

D.C. output voltage:
- SX643 .... 90V
- SX644 .... 150V
- SX645 .... 200V

Maximum rectified current:
- SX643 .... 280mA.
- SX644 .... 210mA.
- SX645 .... 210mA.

Maximum value of reservoir capacitor 120μF

Minimum surge-limiting resistor .... 47 ohms

Bi-phase Rectifier (2 diodes)

R.M.S. input voltage:
- SX643 .... 64-0-64V
- SX644 .... 106-0-106V
- SX645 .... 141-0-141V

D.C. output voltage:
- SX643 .... 90V
- SX644 .... 150V
- SX645 .... 200V

Maximum rectified current:
- SX643 .... 560mA.
- SX644 .... 420mA.
- SX645 .... 420mA.

Maximum value of reservoir capacitor 120μF

Minimum surge-limiting resistor .... 47 ohms

Bridge Rectifier (4 diodes)

R.M.S. input voltage:
- SX643 .... 128V
- SX644 .... 212V
- SX645 .... 282V

D.C. output voltage:
- SX643 .... 180V
- SX644 .... 300V
- SX645 .... 400V

Maximum rectified current:
- SX643 .... 560mA.
- SX644 .... 420mA.
- SX645 .... 420mA.

Maximum value of reservoir capacitor 60μF

Minimum surge-limiting resistor .... 47 ohms

Series operation

Series operating conditions can be derived from direct multiplication of the input and output voltages for single-unit operation. The value of reservoir capacitors may be calculated from

$$C = \frac{5}{FR} \text{ Farads,}$$

where F is the mains frequency in c/s and R is the load resistance in ohms.

HIGH FIDELITY

PART 4

RECORDING

Introduction

The phonograph record from its beginning, to the present time, has probably had more effect on the world of music than any other factor. It can be used for study, pleasure, and to preserve the performances of the musically great for those who would otherwise never have been able to hear some of these great performances. Records make it possible to listen to the selection desired, by the artist wanted, at any time.

The phonograph record has changed from just a representation of sound to almost an exact duplicate of high quality sound. The modern plastic record is of such high quality that with a high fidelity instrument, which is within the true high fidelity standard, it produces sound so near to the original performances that it is often hard to distinguish much difference.

History shows that the first successful attempt at recording sound was made by Leon Scott, a French scientist, in 1857. The instrument was known as the Scott "Phonautograph", an instrument for recording a laterally undulating line on a cylinder coated with lamp black. No means were provided for reproducing the sound from this recording. It can be likened to the modern oscilloscope, except that a permanent record was recorded.

In 1877, Thomas A. Edison invented his famous tin foil machine. It consisted of a heavy metal cylinder about which was wrapped a sheet of tin foil. The recorder included a diaphragm and a stylus. Sound vibrations caused the stylus to indent the tin foil as it was rotated on the cylinder. The reproducer was similar to the recorder but was much more sensitive. The results, by our standards today, were very poor and indistinct. The machine itself was cumbersome and essentially of only academic interest, but it opened the door for the future development of a new art.

In the early 1880's, Dr. Alexander Graham Bell, the inventor of the telephone, and several co-workers, developed a process of recording on a wax cylinder. The recording was of the "Hill and Dale" type. They also developed a reproducing machine which was used as the model for the early graphophone, of the American Graphophone Company.

Contemporaneously, Edison working independently developed a recorder for making cylindrical Hill and Dale records in wax, also a reproducer which later was known as the phonograph. As in the case of the Bell machines, ear tubes were necessary for the use of the listener.

About the year 1887, Emile Berliner developed a disc record. This was of the lateral cut type. The special screw feed mechanism which was used in the cylinder machines was no longer necessary. This process included coating a zinc plate with a fine layer of acid resisting material. The recording stylus produced a spiral groove clear through this material to the zinc. The disc was then subjected to an acid bath, the acid eating out a groove in the zinc of sufficient depth to vibrate the stylus of the reproducing machine. This zinc plate was used as a master from which, by suitable processes, commercial records were made of a hard material. His reproducing machine was called the "Gramophone" and the reproduction was loud enough to hear without earphones. Because of the action of the acid on the zinc, the scratch noise was nearly loud enough to drown out the music.

Eldridge R. Johnson, who was operating a small machine shop in Camden, New Jersey at this time, became interested in the Berliner machine. He refined and improved it. In 1896 he began the manufacture of the Gramophone for the Berliner Company. The instrument which they produced at the time was simplicity itself. The machine was operated by a hand crank connected directly to the turntable by a belt. It was necessary to continually turn the crank while the instrument was playing. A small flyball governor, mounted underneath the turntable, assisted slightly in maintaining the proper speed. However, it was impossible to crank the device at a constant rate of speed and the overall results were unsatisfactory.

In 1896, Johnson developed a spring motor for driving the turntable. As a result of this development, he was given reciprocal rights in the Berliner patent and worked in conjunction with the Berliner Company until 1901.

In 1901, the Victor Talking Machine Company was founded. It was incorporated for $2,500,000 and both the Berliner and Johnson patents were purchased. The early history of the Victor Talking Machine Company reads like a fairy tale. The first year's business was barely $500. In three years it had climbed to $3,000,000 and by 1905, it reached $12,000,000. In facilities it grew from a small machine shop 17 feet square to factory buildings with a floor space equivalent to 56 acres. The trade-mark with which everyone is familiar was adopted and made famous the world over.

Although these early instruments were greatly lacking in fidelity of reproduction, at that time the mere idea of recording and reproducing one's voice was astounding.

From this point the phonograph, or as the Victor Talking Machine came to be known — the "Victrola" — passed through the usual growing pains. The first big improvement was the use of the old "morning glory" type horn. After that came the hornless machines, or to be more exact, machines which had the horn built into the cabinet. The volumes of these instruments was controllable by opening or closing the doors.

In the year 1925, a significant milepost in the art of sound recording and reproduction came about. This was the introduction of the orthophonic "Victrola" by the Victor Company which made possible the reproduction of recorded music with far greater fidelity than ever before. The better tone quality of the orthophonic model was made possible by the discovery of the fact that an exponentially tapered horn coupled with a well engineered sound box would allow the passage of lower frequencies than would the earlier type of horns and sound boxes. The orthophonic method of reproduction was instantly a sensation. However, it was destined to only a very short life, because, during the same year, electrical reproduction was being developed. The orthophonic only enjoyed one year of popularity before giving way to the still better method of electrical reproduction.

Modern Recording Procedure

The block diagram in figure 25 shows the modern recording process. It is much more involved than the simple mechanical method previously used, but the results are closely akin to the real thing when sound of any kind is involved.

One or more microphones are used to pick up the artists and orchestras. The placing of the

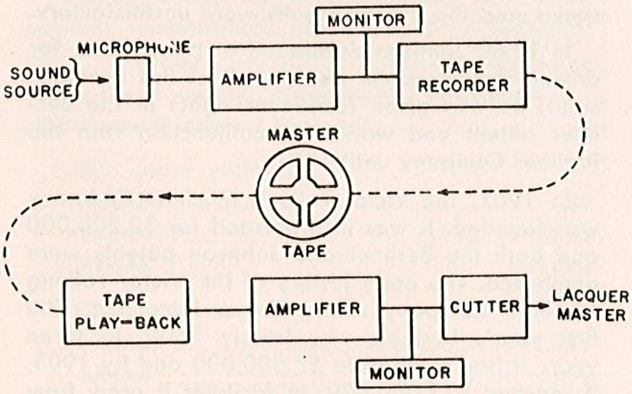


Fig. 25. Modern Recording Procedure.

microphones is important and experience has made it possible to closely duplicate on the recordings through the microphones a very true representation of the performance. The microphones feed into an amplifier, and from the amplifier, a tape recorder. These tapes run at speeds of either 30 inches per second or 15 inches per second. At either of these speeds, tapes of high quality and accurate response can be made, and have been used as masters since about 1948.

The tape is then played through the playback equipment, feeding to amplifiers, and then the record cutter. Instead of using an extremely delicate wax disc in this cutter, it is now common practice to use a much less delicate aluminium disc surfaced with a lacquer coating. The lacquer can be cut for any of the standard speeds: that is, 33, 45, or 78 r.p.m. The lacquer master is then played back with an extremely lightweight, very compliant playback head for quality test. If the quality proves satisfactory, the lacquer master is then forwarded to the plant that will make the record for processing. The lacquers are much lighter than the old type wax discs and they are easier to handle.

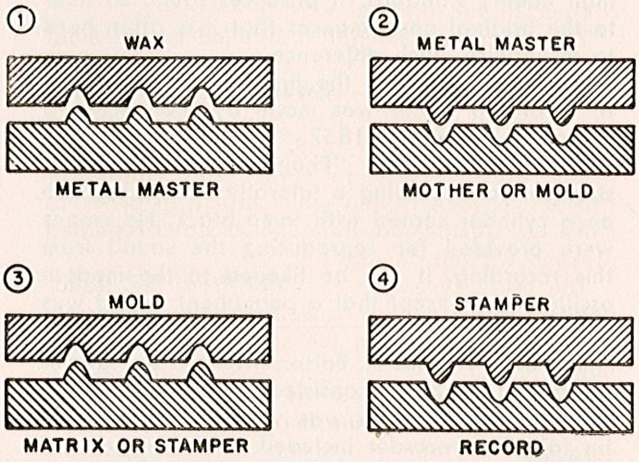


Fig. 26. Record Processing.

Record Processing

Figure 26 shows the order of processing, from the master to the final record pressing.

Originally, the master was made on wax, as already mentioned, then later changed to a lacquer disc. The disc in the early processing was dusted with bronze powder in order to make it conductive. Later, when reproduction and recording quality progressed to a stage where less graininess was desired in the processing (graininess caused by the bronze powder created a very high surface noise) the wax master was coated with a fine layer of gold. This was done by a process called "gold sputtering" which has now become obsolete. This was very expensive and difficult to control and was never used with lacquers. The early lacquer process used a silver coating put on by placing the lacquer master in a silver solution and rocking it until the silver had been evenly deposited over the entire record surface. Now a spray silvering technique is used.

The disc with the surface made conductive is then immersed in a plating tank and a copper coating plated on its surface. When the copper is built up to a satisfactory thickness, it is separated from the wax and becomes the metal master which will be the opposite in contour from the lacquer as is shown in the diagram. Where the lacquer has a groove, the metal master will have a ridge as shown in figure 26 (1). The metal master is now plated with nickel for hardness and silver for smoothness.

The metal master is then coated with a solution called a separating solution and is again put into the plating tanks and an additional plating applied (figure 26 (2)). After this is completed, the additional plating will be separated (made possible by the separating solution) and another stage in the processing is completed. This copper will be called a "mother" or a "mold", and it will be noticed also that it will have the same contour as the original wax or lacquer.

The separating solution is applied to the mold and the process repeated (figure 26 (3)) but this time the plating is nickel instead of copper. The nickel separated from the mold is called the matrix, or stamper, and from this the actual record pressing will be made. This matrix, or stamper, is then plated with chrome in order to make the stamper hard enough to stand repeated pressing without damage.

The early records were poor from the standpoint of sound quality as well as being extremely grainy and noisy from the standpoint of surface noise.

With the improvement of both recording and playback equipment, the improvement of the record material, and processing, it is now possible to reproduce the original performance on records with such quality that, with proper equipment, it is hard to determine which is the real performance and which is the recorded performance if heard side by side.

Types of Recording

A recorded tone is just a wiggly groove in helical form. Actually, it is not a sine wave except in very special cases. In figure 27, the wave form is shown as a sine wave and in greater amplitude than the actual in order to make it easier to understand. The top portion of figure 27 shows a 100 c/s sine wave with the horizontal base line representing time and the height of the wave form representing intensity. In illustration (a), only one cycle has been shown. Now let's look at (b), another wave of exactly the same intensity but in this case it is a 1,000 c/s wave. In exactly the same time required to cover one cycle at 100 cycle frequency, it is found that there will be 10 waves of the 1,000 cycle frequency. (c) shows a 10,000 c/s frequency of the same intensity as used in the other cases, but here again, in the same time, there will be 100 waves. That is 100 times the 100 cycle frequency, or 10 times the 1,000 cycle frequency.

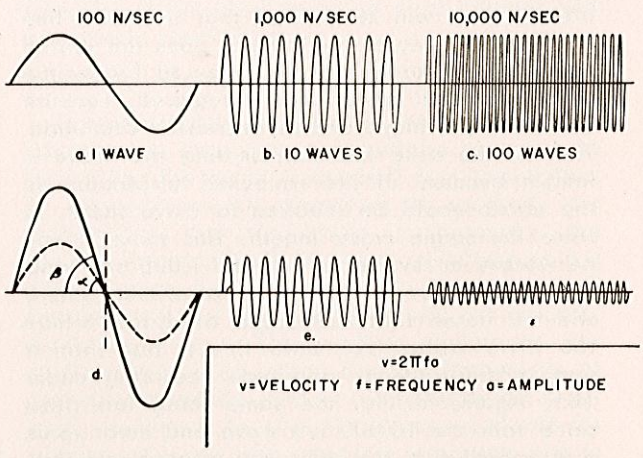


Fig. 27. Types of Recording. Constant Amplitude (top) Constant Velocity (bottom).

The problem comes when an attempt is made to play back a recording made as has just been indicated. The pickup stylus is placed in the groove which was made during the recording process. As the record rotates, the stylus will follow the groove and will be swung back and forth accordingly. The weight of the tone arm and pickup must be such that the inertia will be sufficient that the arm will not move at the frequency in question, otherwise serious distortion will result. At the 100 cycle frequency there would be no difficulty in the stylus following the groove. As 1,000 cycles is approached, instead of the stylus swinging back and forth once, it must swing back and forth 10 times in the same period of time. Naturally, the loading will be considerably greater and with the vertical portion of the groove becoming much steeper, much more work is required to move the stylus. Now, let's look at the 10,000 cycle frequency. It can be seen that the vertical portion of the groove is now practically 90 degrees with relation to the base line and the stylus will not be swung back and forth but will tend to jump the groove wall and proceed in a straight line. In other words, a tracking problem has developed. This type of recording where all frequencies have the same recorded amplitude is called CONSTANT AMPLITUDE RECORDING.

Now comes a real problem. What can be done to record a record so that a 10,000 cycle frequency can be played back satisfactorily? Of course, with present day requirements and high fidelity equipment a record would have very little value if 10,000 cycles could not be heard from it. In (d) a 100 cycle wave is shown at its original intensity by a dotted line. Also shown is that same wave drawn at about double the amplitude. Let's look at the relation of the wave forms with the base line, at the point where they cross the base line. It will be noticed that the solid line has a much greater angle than does the dotted line wave. In order for the stylus to follow the solid line much more work is required, because of the steeper angle and the increased amplitude. That is, the solid line representing the wave is longer because of the increased amplitude, so the stylus would be required to move faster to trace the single wave length. This thinking can be worked in reverse. In (e) the 1,000 c/s wave has been drawn with a lower amplitude and it will be noted that the angle of slope, where the wave crosses the base line is less than it was in the constant amplitude recording under (b). Again, in (f), the same thing has been done with the 10,000 c/s wave and here again it is noticed that the slope has become considerably less steep where the intensity has been reduced proportionately. This type of recording is called CONSTANT VELOCITY. For true constant velocity recording, the angle of the wave where it crosses the base line will be the same for all frequencies, and the speed of the stylus in its swing, as related to the base line, will be the same for the same angle in all cases. It can then be seen that the lateral velocity of the stylus will remain constant. This can be seen also from the formula:

$$V = 2\pi fa$$

V represents the velocity; f, the frequency; and a, the amplitude. If f is increased and a is decreased in the proper ratio, V will remain constant. Of course, the 2π being a constant will have no effect on the change, only on the absolute value.

Playback

If a record could be made with a constant amplitude type of recording and played back with a playback equipment which also had a constant amplitude response everything would be perfect and the constant amplitude recording played back with such an equipment would give a response curve shown in figure 28 (a). As was seen from figure 27, playback at very high frequencies is not possible because of tracking difficulties. Now, what will happen if a constant amplitude type of playback equipment is used to play a record which has been recorded with a constant velocity characteristic? Of course, with the greater amplitude in the base there will be a greater output and with the lower amplitude at the high frequencies there will be a very low output and the response curve will be like that shown in figure 28 (b). Let's use the same considerations if played with a constant velocity type of playback equipment and see what would happen. If a record, which has been recorded with a constant amplitude, is played back with a constant velocity type of equipment, there will be a response curve as shown in figure 28 (c). The bass will have a very low output and the high frequencies a very high output. On the other hand, if a constant velocity recording is played with the constant velocity playback equipment, there will be a flat response curve. Technically, a perfect solution is not possible and compromises must be made. The recording cannot be made with an absolute constant velocity. There will be variations at certain frequencies. On the other hand, there is no pickup which operates exactly linearly. Therefore, the amplifier for both recording and playing back must be compensated to make up for these variations.

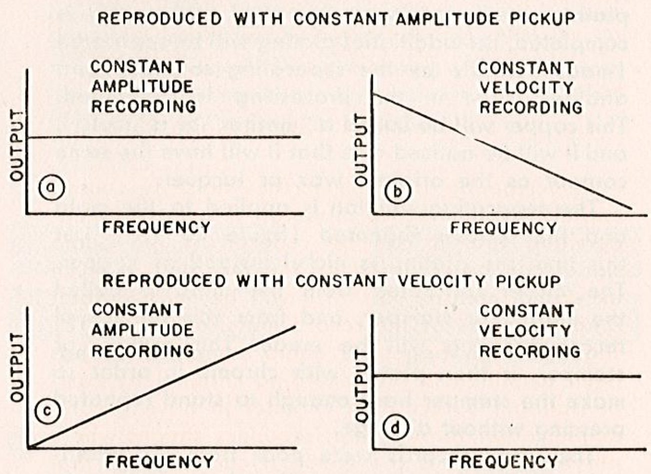


Fig. 28. Playback.

Surface Noise

One of the major record problems is surface noise. This has always been a problem and possibly always will be, though with modern materials and techniques it has now been reduced to a point where the noise is no longer objectionable to the average listener. However, it again is a compromise and is done by a method called PRE-EMPHASIS.

To explain pre-emphasis and how it aids in cutting down the surface noise, figure 29 (a) and (b) are shown. (a) Shows a high frequency audio signal as it would be recorded on a record and played back through a "flat" amplifier with no other compensation. Noise of the type under discussion is created entirely by the grain of the record material itself. Therefore, the volume of the noise as played through the amplifier will be directly proportional to the noise signal in the audio ranges. The noise, because it is created by the record grain which is extremely small, will occur at the very high frequencies. The noise signal will be a very jagged, rough wave, as it is caused by irregular grain, and will appear on a scope or in a record groove more or less as shown in (b). In this case, the noise is approximately one-third of the audio signal and would be very distracting.

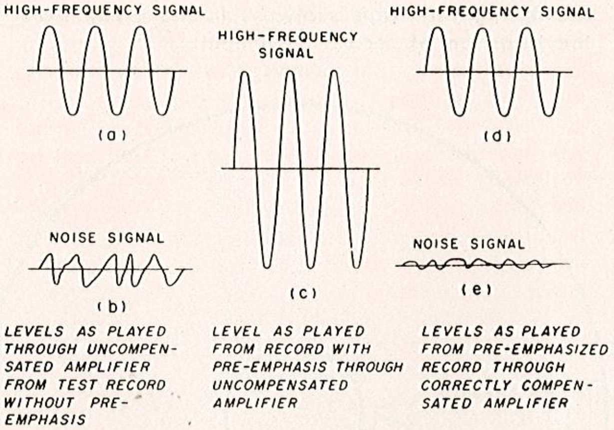


Fig. 29. Surface Noise (Signal-Noise Ratio).

Remembering that the surface noise is caused entirely by the record material, it is easy to understand that it can be reduced if the audio signal can be recorded on the record at a much increased intensity so that it will be much greater than the noise of the record material. Figure (c) shows a high frequency audio signal which has been amplified in the recording channel by compensating the recording channel to have greater amplification through the frequency ranges where playback noise is the worst. It can be seen that the actual recorded signal is approximately three times that of the original recorded level.

If the playback amplifier is compensated in an opposite direction so that all high frequencies in the noise range will be attenuated to approximately one-third of the normal gain it can be seen that this signal, which has been recorded at three times its normal gain, will be played back at its normal volume. At the same time, what has happened to the noise signal? It, of course, will have also been reduced to one-third of its previous level and now will be at such a low level that it will no longer be objectionable and the signal level being so much greater will completely cover it up.

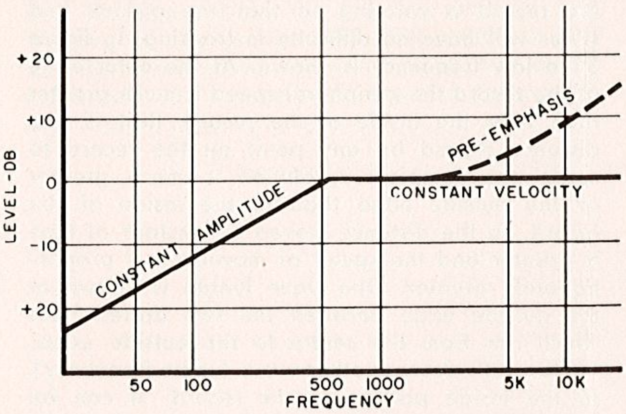


Fig. 30. Recording Characteristics.

Recording Characteristics

In order to meet the requirements of necessary compromise, how can a record be recorded to give all of the qualities needed? It is known that if constant velocity recording is used at low frequencies, that the lower in frequency, the greater the amplitude the wave will have and it can be seen that eventually the amplitude will become so great that the stylus will not properly track the groove. The sensible solution to this problem then is to record the low frequencies at constant amplitude, and to compensate the playback equipment to give the necessary boost for playing it back with properly designed pickup equipment. Normally, constant amplitude recording is used to approximately 500 cycles. Above this point, constant velocity recording is used in order to limit the slope of the higher frequencies. The dotted line in figure 30 shows constant velocity recording where pre-emphasis has been added to improve the noise level.

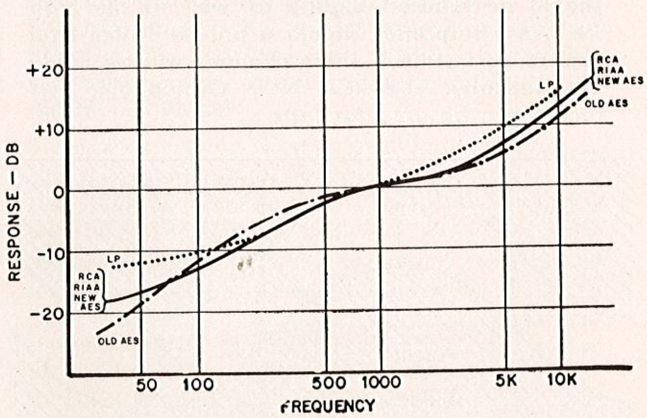


Fig. 31. Recording Playback Characteristics.

Remembering the discussion of figure 28 as to what takes place when a constant amplitude recording is played with a constant velocity pickup, it is remembered that the gain is extremely low at the low frequencies and gradually increases to approximately 500 cycles, which (from figure 30) will be the turnover point. Figure 31 shows that this actually is the case when the constant amplitude recording below 500 cycles is played back with a constant velocity pickup through a flat amplifier. Now, if above this point the recording is made at constant velocity the curve will flatten off and actually show flat response above this point. However, with pre-emphasis, it curves upward.

In order to compensate the flat amplifier to play back a standard record it is only necessary to add compensation to the flat amplifier or its pre-amplifier to give approximately the reverse characteristics of the curves at which the standard record is cut. In other words, if as this curve shows, the response is down approximately 20 db at 30 cycles, it would be necessary to add 20 db of boost to the flat amplifier or its pre-amplifier at 30 cycles, and so on through the entire frequency spectrum.

This curve shows the three major recording characteristics: that is, RCA New Orthophonic, which is the same as the RIAA (Record Industry Association of America) and the new AES; the old AES (Audio Engineering Society); and the LP. A slight difference is noticed in each of them, though in most cases they are all so close together that the average ear would notice hardly any difference except perhaps at the low frequencies. Actually, RCA New Orthophonic and RIAA is now the industry standard and has been adopted by British Standards Group. The majority of current records (all makes) follow the RIAA curve. At any time it is desired to play a record marked AES, it is necessary only to boost the bass a little by adjusting the bass control and also to boost the highs a little by the use of the treble control. With the LP, the bass response should be reduced slightly as well as the high frequency response. Should a pre-set switch-type control be installed, these changes will be made automatically. The RCA New Orthophonic test record can be used for tests.

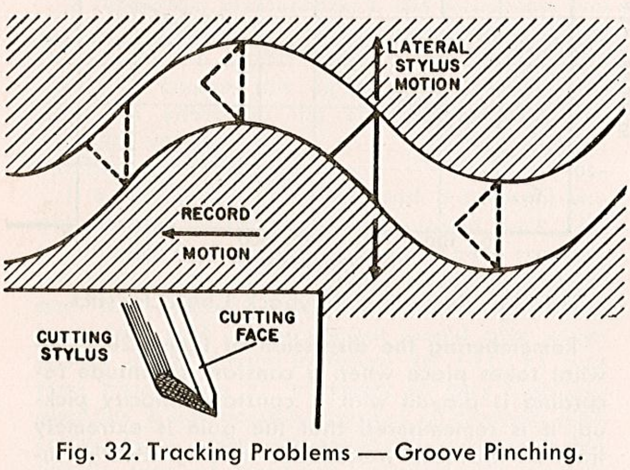


Fig. 32. Tracking Problems — Groove Pinching.

Tracking Problem

In order to cut a groove in a record, a stylus shaped somewhat like a chisel is used. A round stylus such as is used for playback, naturally, does not have the cutting ability to make a clean groove. A chisel is flat with the cutting edges extremely sharp. The small inset in figure 32 gives an idea of the actual shape of a standard cutting stylus.

As this cutting tool is pulled from side to side by the lateral motion of the cutter head as the record turns, a groove is cut. Looking at the groove closely, it will be seen that the width varies because the cutting stylus does not turn, and the flat cutting edge is always facing away from the direction of record movement.

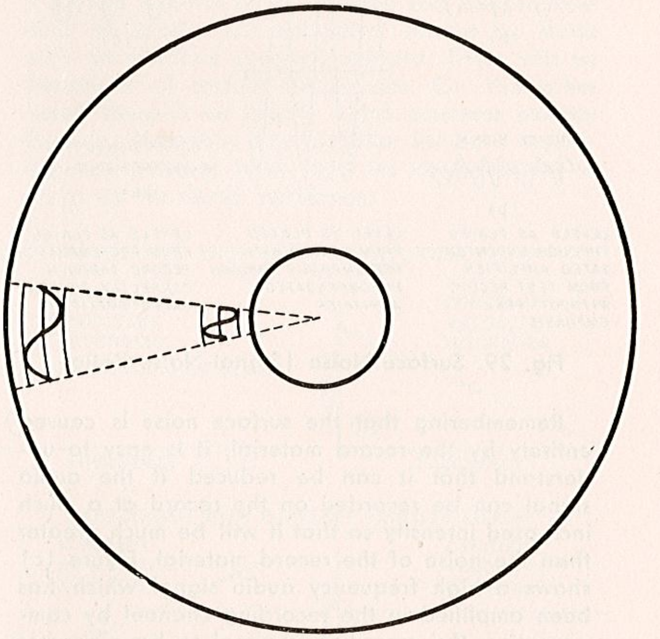


Fig. 33. Tracking Problems — Peripheral Speed.

When a record is played back, a round stylus is used and there is a tendency for the stylus to be pushed or climb from the groove as it passes through one of the constricted areas.

In order to obtain a clean recording and playback of the high frequencies, one wave length must cover sufficient distance at the speed at which the record is rotating so that the pickup and stylus will have no difficulty in tracking. In figure 33 a low frequency is shown. At the outer edge of the record the peripheral speed is much greater than near the inside of the record; that is, the distance moved by any point on the record to make one complete revolution is much greater at the outside edge than at the inside of the record, so the distance moved per instant of time is greater and the speed of movement is proportionately greater. One wave length is shown at the outside edge between the two dotted lines which run from the centre to the outside edge.

Now let's draw another wave (same frequency) at the inside portion of the record. It can be seen that the wave will be much shorter physically because of the lower peripheral speed of this portion of the record than for the single wave length shown at the outer edge of the record. It is quite clear, therefore, that at the inside edge of the record the wave lengths are much more condensed than at the outside edge. If a very high frequency wave is recorded to just barely track at the outside edge of the recording, tracking difficulty will be experienced with the high frequency at the centre of the record because of compressing of the waves as the centre of the record is approached.

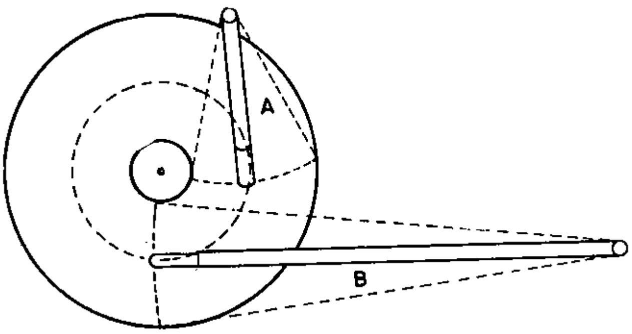


Fig. 34. Tracking Problems — Arm Angle.

In order to have perfect tracking and a minimum of record wear, the stylus should be following a line tangential with the groove at all points along the record. If a comparatively short tone arm is installed on the record player such as is shown at figure 34 (a), it can be seen that the record grooves will be tangential with the tone arm or stylus only near the centre swing of the arm. At the outside edge it will tend to pull across the grooves, creating both a tracking problem and wearing of the inside groove wall. At the extreme inside edge of the record, the opposite will be true.

The longer the tone arm is made the more nearly correct will be the position of the stylus and the less will be the tracking problem and wearing of the groove wall. This condition can also be improved by mounting the pickup at an angle with the arm so as to equalise the outside and inside tracking errors.

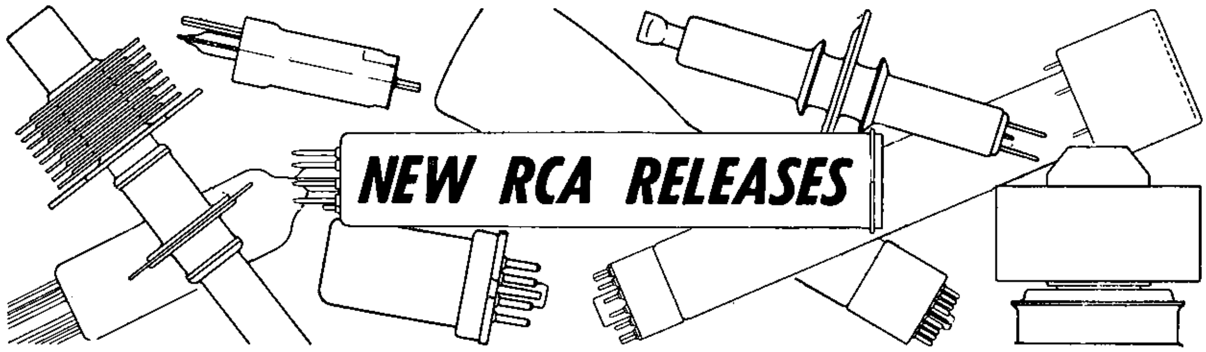
Mechanical Problems

In the playing of records there are many mechanical problems which arise. Probably, the most important of these mechanical problems is that called "Wow" which is due to the record not rotating at a constant speed. This variation in speed can either be at regular intervals or can be at irregular intervals depending upon the type of difficulty. In general, wow can be caused by an idler wheel which is not exactly round and, in this case, the wow would be repeated at regular intervals. Wow created due to slippage of any idler or belt can often be very serious and will occur normally at irregular intervals. Wow created because of a bent shaft again will occur at regular intervals, as will that caused by a record which is pressed off centre. Often the location of the source of wow can be determined by checking the repetition rate of the wow.

Speed is also a major problem because certain individuals have a sense termed "absolute pitch" and can notice a tone that is just a shade off frequency. It is, therefore, important that the speed of the turntable be accurate.

Rumble is another type of customer complaint that is sometimes hard to correct. It usually comes from the vibration of the motor or mechanism feeding to the pickup through the stylus and generating in the playback equipment a rumble dependent upon the motor or turntable speed. The only cure is the use of proper suspension, parts heavily weighted, etc., so that no vibration will occur, in the frequency range of the reproducing equipment.

Another problem which is a greater problem with magnetic pickups, is that of hum pickup. The only cure for this type of difficulty is complete magnetic shielding between the motor, which is usually the source of the hum, and the coils of the pickup. This is usually done by the use of a heavy metal motorboard, a turntable of several layers of metal, and the use of a four pole motor instead of the usual light two pole type of motor used in many small record players. This type of problem is not too serious with crystal pickups where no coil is involved.



Radiotron 7183

The Radiotron 7183 is a 5-inch display storage tube of the direct-view type, with separate necks for the magnetically-deflected writing gun and for the viewing gun. The tube produces a bright flicker-free display of stored information for 20 seconds or more after writing has ceased. The performance of the tube when operated at a screen voltage of 8.5 KV is characterised by a full 4-inch diameter display with a brightness of about 1500 foot-lamberts, and having good resolution capability in half-tone displays.

Applications of the 7183 include air-lane cockpit radar display, airport surveillance, data transmission including half-tones, and visual communication requiring steady, flicker-free narrow-band width transmission over telephone lines.

Improved 2N301 and 2N301A Transistors

Maximum dissipation capabilities of the audio power transistors 2N301 and 2N301A have been increased from the original value of 5.5W (at mounting flange temperature = 71°C) to 11W (at mounting flange temperature = 80°C). This represents a 100% improvement. As a result these transistors can now provide in class A service at a mounting flange temperature of 80°C or below an audio frequency power output up to 5W, an increase of 85% over the original class A power output of 2.7W. The improved 2N301A is the same as the improved 2N301 except that the former is rated to withstand higher maximum d.c. and peak collector/base voltages.

Excellent thermal conductivity is provided by an improved and more compact internal structure. These transistors are specially recommended for use in class A and class B push-pull power output stages of car radio receivers, and in other audio applications where high power efficiency, low distortion characteristics, linear current gain over the full range of collector current, and high reliability are primary design considerations.

Radiotron OC2

The Radiotron OC2 is a new glow-discharge voltage-regulator valve on a 7-pin miniature base, and is intended for applications where it is necessary to maintain across a load a relatively constant dc output voltage substantially independent of load current and moderate line-voltage variations. The OC2 will supply a regulated voltage of approximately 75V at dc cathode currents within the range 5 to 30 mA.

Radiotron 6005

The Radiotron 6005 is a "premium" beam power valve of the 7-pin miniature type, and is designed especially for use in a-f power amplifier circuits of industrial electronic equipment where dependable performance under conditions of shock and vibration is a fundamental consideration. The 6005 is developed from the popular 6AQ5. The ability to resist shock and vibration is achieved by structural refinements, stringent production control, and rigorous testing and quality control procedures.

Radiotron 7038

The Radiotron 7038 is a new vidicon camera tube designed for broadcast, industrial and military TV applications. The 7038 uses an improved photoconductive surface having uniform thickness which permits constant voltage gradient and uniform dark current across the scanned area, and can therefore produce uniform sensitivity and dark current over the entire scanned area, These features allow the 7038 to be operated at higher values of target voltage and dark current than are permissible with previous types, and as a result higher effective sensitivity can be obtained with the 7038 in equipment designed for it. In new designs the 7038 is capable of producing pictures of broadcast quality with as little as 1 foot-candle of highlight illumination on the faceplate. Resolution obtainable is about 600 TV lines.