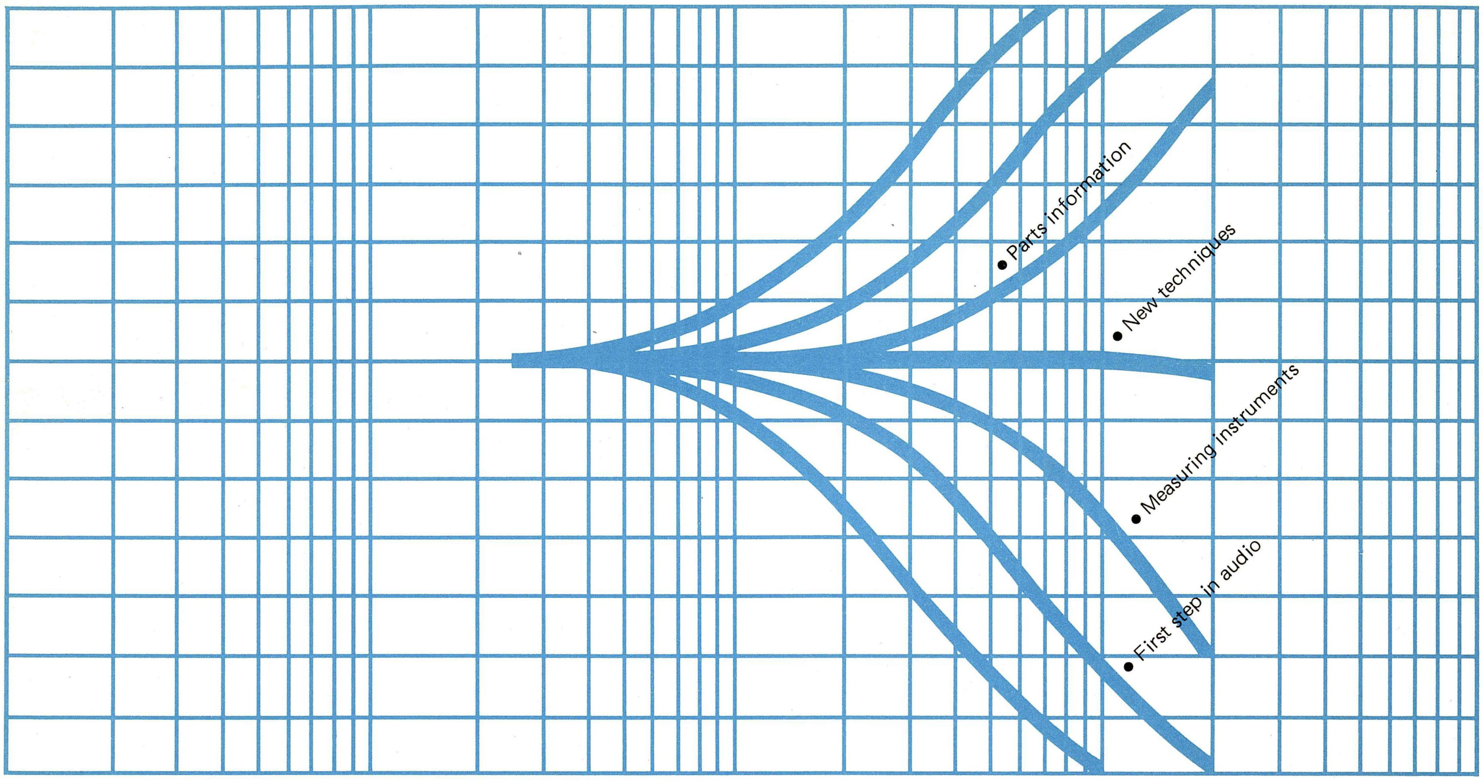
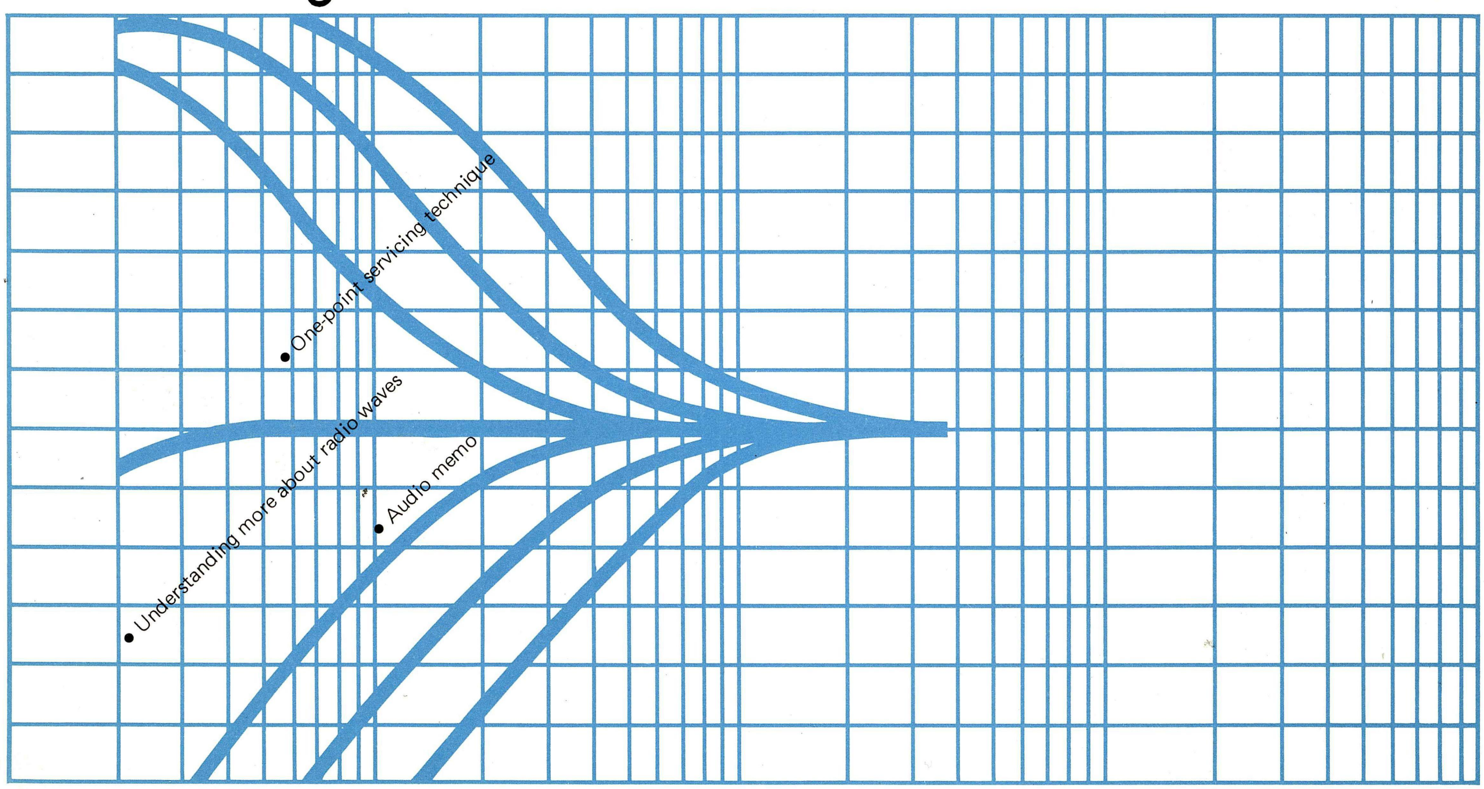



# TUNING FORK

Audio service guide

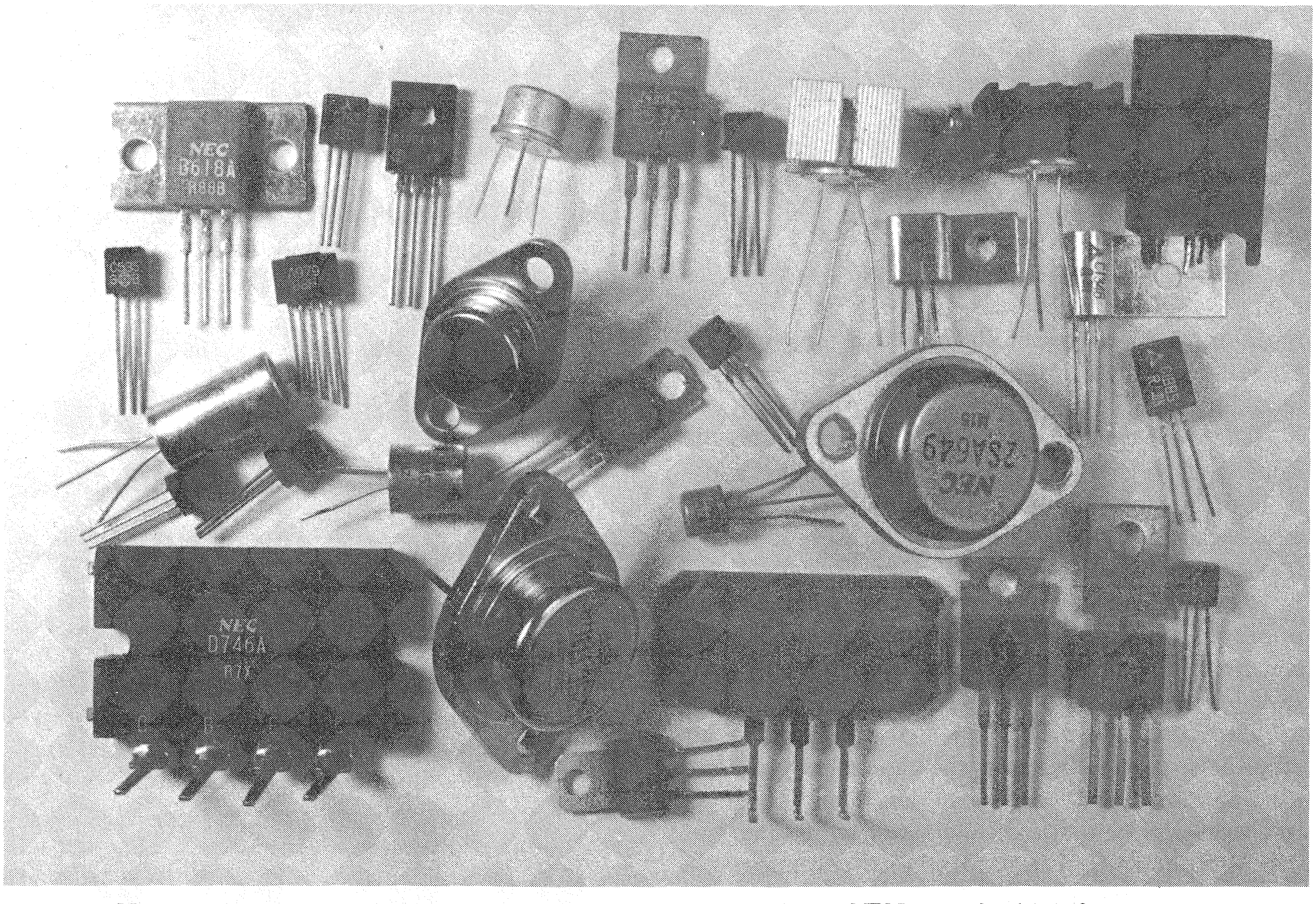
No. 4




PIONEER®

# CONTENTS

# Parts Information (4)
## Semiconductors




**1. Code Names of Transistors**

Transistors used in Pioneer products are all Japanese-made and coded based on the Japan Industrial Standard (JIS). The codes are called the JIS codes. They are also called EIAJ codes because registration of code names and standards is conducted by the Electronic Industries Association of Japan (EIAJ).

A JIS code consists of characters and numbers as shown below to indicate the transistor's polarity and use in outline.

[2] [S] [A] [726] [A]

The first figure 2 indicates that it has three effective electrodes (when the number of effective electrodes is n, the figure is represented by n−1).

The letter S that comes next means it is a semiconductor.

One of four letters—A, B, C and D—comes third, representing the transistor's use.

A . . . PNP-type for high frequencies
B . . . PNP-type for low frequencies
C . . . NPN-type for high frequencies
D . . . NPN-type for low frequencies

Today, the difference between a transistor for high frequencies and one for low frequencies is not so clear. There is a transistor for low frequencies with an $f_T$ (to be explained later) which tops 100 MHz, or a high-frequency transistor whose $f_T$ is just around 50MHz.

The next set of figures (726 in our example) is the number of registration, which starts from 11.

The final letter stands for an improved model as against the original model. Letters used are, for example, A through H, J through L and P, AP, LN, LG, PG, P1, P2, NC, R, S and TM. Each indicates that the product has undergone selection for $h_{fe}$, low-noise, or voltage-withstanding characteristics.

The code is printed on the transistor's surface in figures and letters, or represented in dots or line markings.

Using the above system, the code 2SA726A indicates a PNP high-frequency transistor, registered 716th (keeping in mind that the registration begins with number 11), with selected voltage-withstanding characteristics.

There are also transistors that come with a "suffix," such as -K, -L, -M, -O, -P, -Q, -R, and -S (2SC2275-Q for instance). The suffix represents the *hfe* rank and is sometimes vital.

## 2. Classification of Transistors by Appearance

Transistors can be classified by appearance in two types—the can-sealed and resin-sealed types. The former is a chip type of transistor sealed in a metal container ("can"), while the latter is molded in resin (plastic).

Generally, the can-sealed type is highly resistant to unfavorable environmental conditions, such as high temperature and humidity. Therefore can-sealed types are used in power stages where temperatures are relatively high, and in instruments requiring high reliability.

The resin-sealed type is somewhat inferior to the can-sealed type in terms of reliability. But it is widely used in home appliances because its cost is low, and because, with its self-insulated resin mounting, it is easy to install.

Recently, resin-sealed types have been greatly improved with special manufacturing methods, etc., and now may be applied where formerly only can-sealed types were used.

Pioneer employs both types of transistors in our amplifiers. Generally, only the can-sealed types are used in the output stages of power amplifiers, in low-level-signal circuits of high-grade amplifiers, and in FM front ends. Transistors in other sections are mostly the resin-sealed type.

Can-sealed and resin-sealed types are further classified by dimensions. Typical examples follow:

### 2-1 Classification of Can-Sealed Transistors by Appearance

#### 2-1-1 TO-3 Types [Please see note 1 at page 5]

This type is exclusive for large power-handling uses and is often used in the final stage of a power amplifier. The Pc ranges from 50W to 200W. TO-3 type transistors are used in single, parallel or triple connections for power amplifiers with outputs of from 80W to 250W. The case itself serves as the collector; this type thus has only two leads.

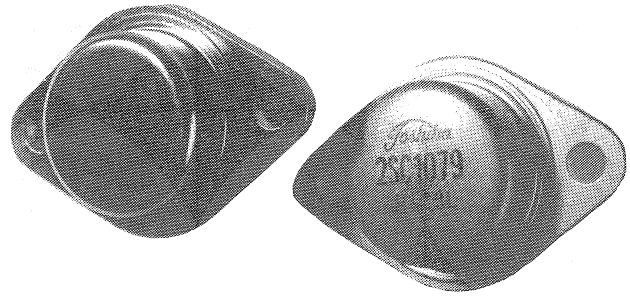



Photo 1

#### 2-1-2 TO-66 Type

This is a little smaller than the TO-3 type, and is generally used in low-power circuits. Having a Pc of from 10W to 40W, it is also used for driving the TO-3. Like the TO-3 it has only two leads. The TO-66 has been applied at least once in the output stage of an amplifier.

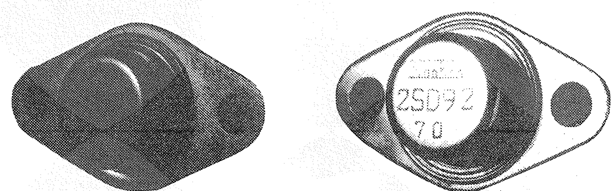



Photo 2

#### 2-1-3 TO-5 Type

This type resembles a smaller TO-66 but has no flange. It also has been applied in amplifier output stages, but today is rarely used at all. Its case serves as the collector, even though it has a collector lead along with its other two leads. The Pc is from 1W to 10W.

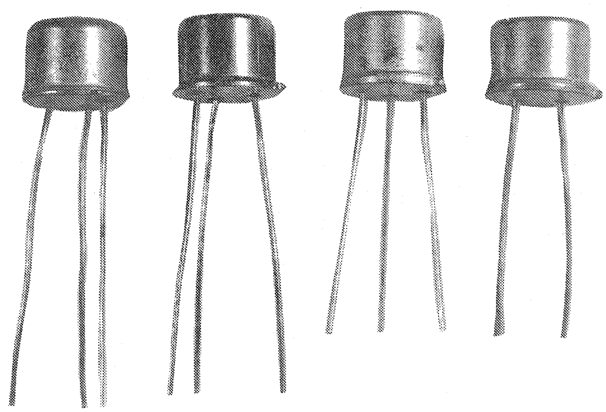


Photo 3

### 2-1-4 TO-1 Type

Since the days of germanium transistors this type has been used in low-level signal circuits, although its use is declining today. Its Pc is from 100mW to 300mW.

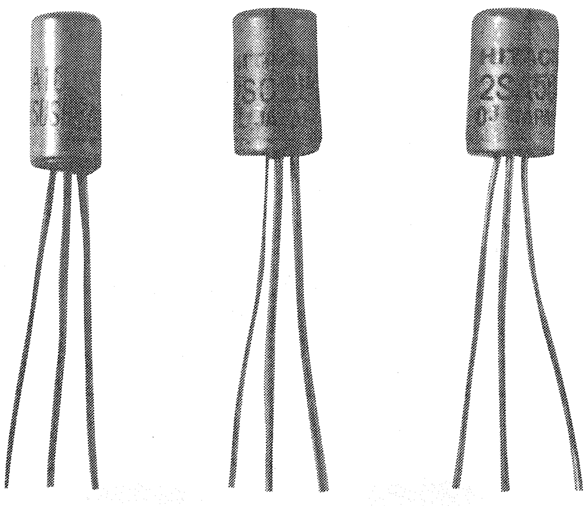
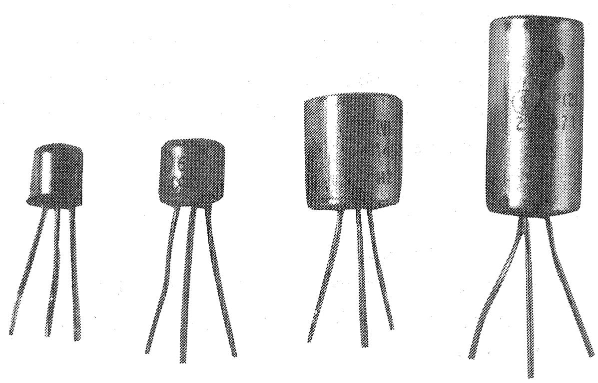


Photo 4

### 2-1-5 Other Can-Sealed Transistors for Low-Signal Use

The transistors pictured in Photo 5 are used for low-level signal circuits: Type A is for low-level signal amplifications with a Pc of 100mW to 300mW; B is for transistors used in pre-drive stages. Types C and D are based on the B transistor type, and have heat sinks for larger Pc. The "cans" of most of these transistors are connected with leads.



(A) (B) (C) (D)

Photo 5

## 2-2 Classification of Resin-Sealed Types by Appearance

### 2-2-1 Resin-Sealed Type with Two Fixing Points

This type, developed several years ago, is designed to be screwed onto a heat sink at two points for better heat conduction. Having a Pc of from 60W to 80W, it features similar performance to some of the TO-3 type transistors, and can be used for the output stages of power amplifiers. The metal section, with holes for screws, acts as the collector.

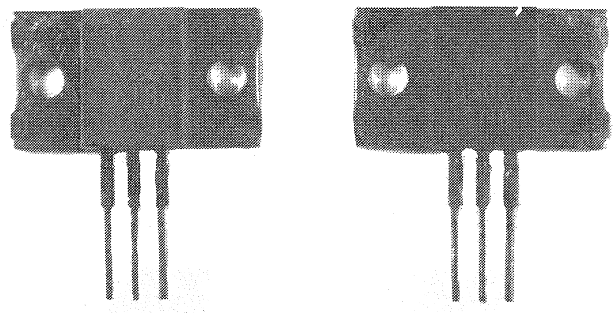


Photo 6

### 2-2-2 TO-220 Type

The TO-220 type, generally called a "resin-sealed transistor," corresponds to the TO-66 type of the can-sealed variety. It has a Pc of from 20W to 40W and is used for power amplifiers with outputs of from 10W to 25W.

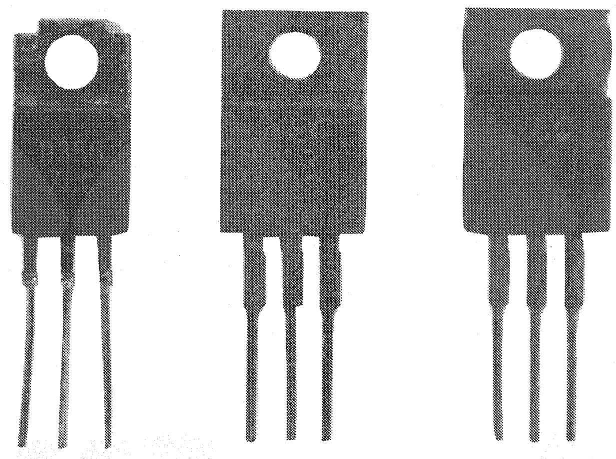


Photo 7

### 2-2-3 Center-Fin Type

This type has a peculiar shape, with a collector fin protruding from the mold. With a Pc of 1W, it is usually used in pre-drive stages.

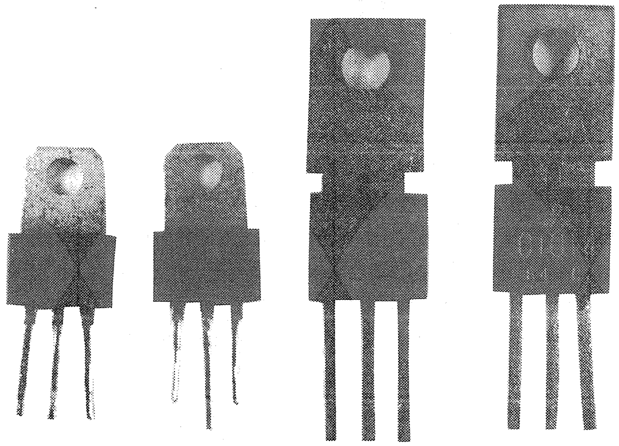


Photo 8

### 2-2-4 TO-126 Type

The TO-126 is large in size and its collector fin is enveloped in its resin body. Its Pc is about 1W. Unlike the three previously-described types, which require insulation (such as mica sheets) for installation on a heat sink, this type of transistor can be fixed to a heat sink without insulation. Its Pc is relatively low, thus it is usually used for pre-drive stages. There are also models for somewhat higher-power circuit use; they feature exposed metal collectors, protruding from their bodies.

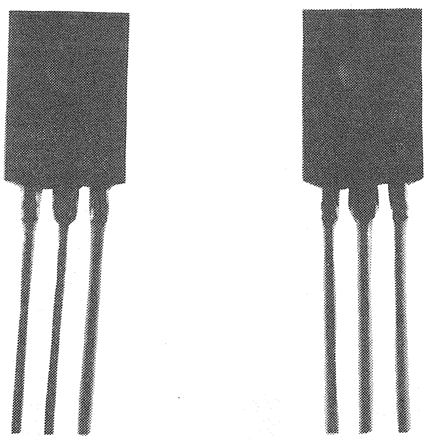


**Photo 9**

### 2-2-5 Low-Power Types

In size, these are slightly larger than those used for low-power applications; some have thicker collector leads for a bit larger Pc, offering from 500mW to 800mW; they are used for relay drives, lamp drives, power sources and pre-amp final stages. Some have noise standards suitable for application in the final stages of pre-amplifiers.

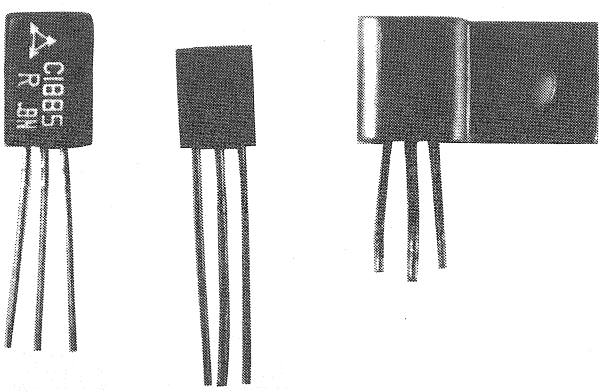
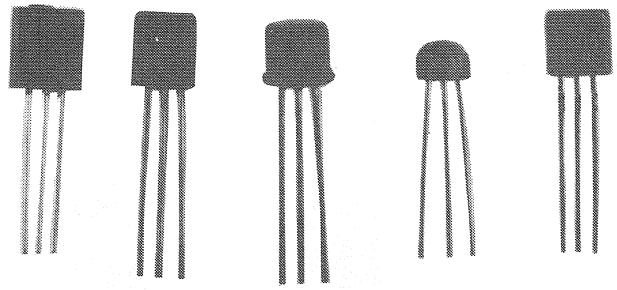


**Photo 10**

### 2-2-6 TO-92 Type and Other Low-Signal Transistors

Photo 11 shows the TO-92 type. Others differ in shape, but fall into the same size category as transistors used for low-level signal applications. The shape "D" is becoming rare in Japan.

The Pc of these transistors ranges from 100mW to 400mW. There are low-noise types for use in signal systems. Other uses can include high-frequency, switching and power source applications.



(A) (B) (C) (D) (E)

**Photo 11**

### 2-2-7 Dual Type

The dual type has two transistor chips in a single encasement. As the characteristics of both transistors are the same, this type is suitable for differential amps. The dual type is used for the input stages of OCL power amplifiers. The Pc is 200mW.

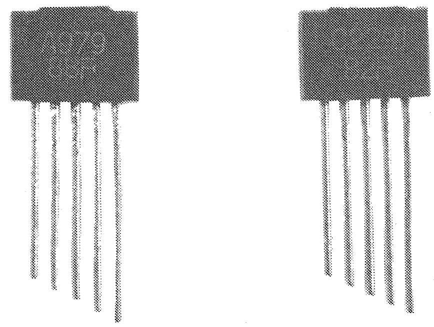


**Photo 12**

### 2-2-8 Dual Fixing-Point Type (New)

This type is relatively new and was created mainly as a substitute for the TO-3 type used for high-power applications. It will be used still more widely in the future as it costs less to manufacture than the TO-3 type, and because its shape improves productivity and decreases heat resistance.

This type of transistor is manufactured by only a few Japanese companies, and thus has no international shape number.

In terms of performance, it is almost similar to the TO-3 type, but its Pc is a bit larger, ranging from 100W to 200W.

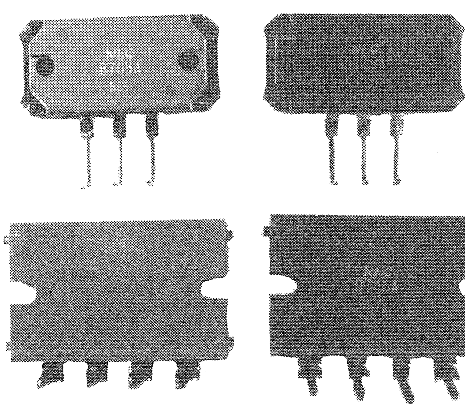


**Photo 13**

[Note 1: The number that comes after TO corresponds to the code on the configuration chart stipulated by the Joint Electron Device Engineering Council (JEDEC), a subordinate organization of EIA of America. JIS and EIAJ numbers are used in Japan, but transistors are also often given JEDEC numbers because they have a wide market abroad. Dimensions may differ slightly even if the number is the same, because the same category allows a certain range of size: TO-3 types may have sizes from 10 to 20, for instance.]

Moreover, each maker has its own peculiar shape, not necessarily distinguished by code numbers. Therefore, transistors are classified by size or use.

## 3. Letter Symbols and Abbreviations Used for Transistors

The following letter symbols and abbreviations are helpful in summing up the performance of transistors:

- $V_{CEO}$: Voltage between collector and emitter (with base open)
- $V_{CBO}$: Voltage between collector and base (with emitter open)
- $I_C$: Collector current
- $I_B$: Base current
- $P_C$: Collector dissipation
- $T_J$: Junction temperature (the maximum junction temperature allowable when power is consumed)
- Tstg: Storage temperature (the temperature range allowable in the state when no power is applied
- $T_C$: Case temperature
- Ta: Ambient temperature (generally 25°C)
- $I_{CBO}$: The reverse current that occurs when a specific DC voltage is applied in the reverse direction to the collector junction while emitter is open-circuited.
- $I_{CEO}$: The reverse current that occurs when a specific DC voltage is applied in the reverse direction to collector junction while base is open-circuited.
- $I_{EBO}$: The reverse current that occurs when a specific DC voltage is applied in the reverse direction to emitter junction while collector is open-circuited.
- $V_{CE}$ (sat): Saturation voltage between collector and emitter.
- $V_{BE}$: Voltage between base and emitter.
- $h_{fe}$ : Amplification factor in DC current (with emitter grounded).
- $f_T$: Transition frequency; the frequency at which the small-signal current amplification factor $h_{fe}$ becomes 1 (gain is 0dB) with emitter grounded. Since $h_{fe}$ at high frequencies drops by 6dB/oct., $f_T$ can be calculated by the following formula:

  $f_T$ = High Frequency $h_{fe}$ x Frequency measured. [$f_T$ is also called GBP (Gain Bandwidth Product).]
- Cob: Collector output capacity (with base grounded).
- NV ($V_N$): Noise voltage.
- $\theta$jc: Thermal resistance between the junction and the case

## 4. Maximum Rating

### 4-1 Definition of Maximum Rating

The maximum rating values are determined according to the transistor's power consumption and maximum allowable voltage and amperage.

The major reason to specify the maximum rating is that a transistor's characteristics greatly depend on temperature, always an important factor when considering semiconductors.

For instance, when the ambient temperature rises as a certain level of voltage is applied to a transistor, the element's specific electric conductivity will be raised, increasing electric current. Consequently, power consumed by the transistor increases, which in turn increases the temperature, further increasing the current and so on in a vicious cycle. If the transistor is left unattended in this state, it will eventually break down.

In determining the maximum rating of a transistor, two things must be always kept in mind: the temperature allowable to the transistor's junction, and the temperature increase in the junction in normal operation.

The maximum rating is the maximum value that must not be surpassed if the transistor's normal life and reliability are to be maintained. These values depend on materials, design and manufacturing conditions, and differ by the transistor's shape.

The absolute maximum rating is the value that must not be exceeded even momentarily. When there is more than one rating, the transistor may be used under any or all of those ratings, provided that no single rating ever be exceeded.

If the maximum rating is ignored, the characteristics of the transistor might not be obtainable.

In designing a circuit, the following points are to be taken into consideration: a change in the main voltage, irregularity in characteristics of electric parts, over-running of the maximum rating during adjustment of the circuit, and a change in the ambient temperature.

### 4-2 Maximum Rating of Transistors

Major items whose maximum ratings should be provided are: (1) electric currents of the transistor's emitter, base and collector, (2) voltage between the terminals, (3) collector dissipation, (4) junction temperature, and (5) storage temperature.

These parameters are closely related with each other and cannot be considered separately.

The items differ in accordance with external circuit conditions.

#### 4-2-1 Current Rating

There are $I_{E\,MAX}$, the maximum value of current that can be flowed in the right direction of the emitter junction, and $I_{C\,MAX}$, the maximum value of current that can be flowed in the reverse direction. But in many cases, $I_{C\,MAX}$ is equal to $I_{E\,MAX}$. These values are determined in consideration of the following points:

(1) The current flow must be kept under the level where internal power loss caused by the existence of collector saturation voltage will not exceed its rating; that is, where the junction temperature will not exceed the rating.

(2) The current must be kept under the level where DC current amplification ($h_{fe}$) will drop by from half to one-third the maximum value. As for medium-powered transistors, the $h_{fe}$ should be ~ 10. It should be ~ 3 in the case of a high-powered transistor.

(3) $I_{B\,MAX}$, the maximum value of current and base current allowable before meltdown of internal leads occurs, is generally the value obtained by the following formula:

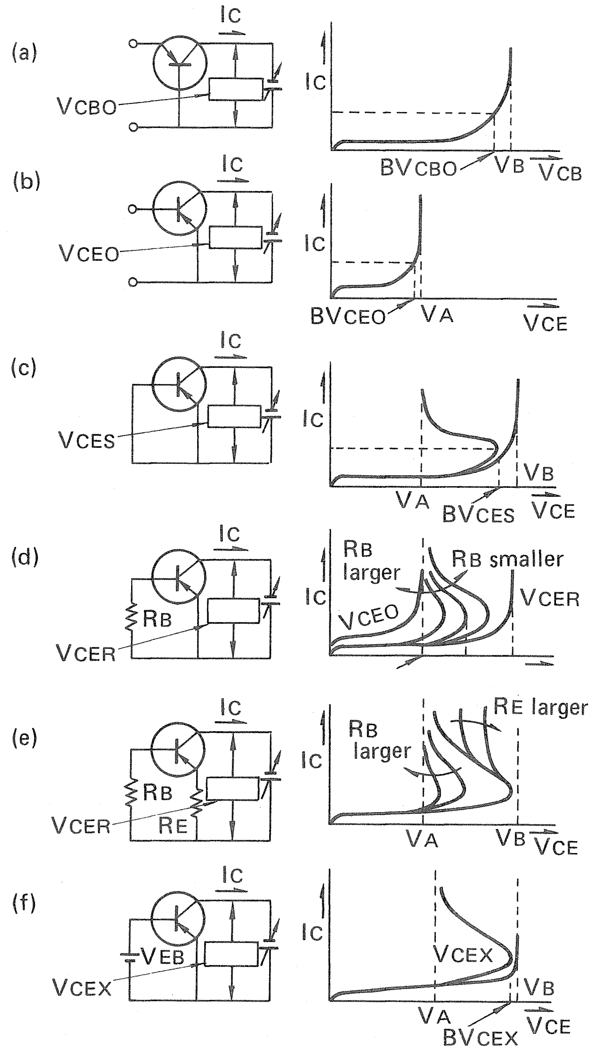
$$I_{B\,MAX} \lesssim 1/2 \sim I_{C\,MAX}/6$$

#### 4-2-2 Voltage Rating

One of the transistor's three terminals (emitter, base or collector) serves as the common terminal of both input and output circuits. Therefore, ratings are provided for voltage: between the collector and the base the rating is $V_{CE}$; between the collector and the emitter it is $V_{CE}$; between the emitter and the base it is $V_{EB}$.

Breakdown voltage (used in determining voltage ratings) is divided into two: one is based on the transistor's own characteristics (such as $V_{CBO}$ and $V_{CEO}$) and the other is based on the characteristics which depend on input circuit conditions (such as $V_{CER}$ and $V_{CEX}$). The breakdown voltage generally represents a value determined from the function of both characteristics.

As transistors are operated with the base or the emitter grounded, the important thing is the collector voltage rating. Collector voltage ratings are shown in Fig. 1 and explained below:




$V_A$=avalanche breakdown voltage with emiter grounded
$V_B$=avalanche breakdown voltage with base grounded

**Fig. 1 Various maximum collector voltages**

- $V_{CBO}$: Maximum voltage between collector and base with emitter grounded.
- $V_{CES}$: Maximum voltage between collector and emitter with emitter-base short-circuited.
- $V_{CER}$: Maximum voltage between collector and emitter when emitter and base are connected with resistance (R).
- $V_{CEO}$: Maximum voltage between collector and emitter with base open.
- $V_{CEX}$: Maximum voltage between collector and emitter when the voltage between emitter and base is reverse biased.

The levels of these collector voltages are:

$$V_{CBO} > V_{CEX} > V_{CES} > V_{CER} > V_{CEO}$$

However, there is no significant difference between $V_{CBO}$ and $V_{CES}$.

### 4-2-3 Temperature Rating

There are two temperature ratings, one for the maximum temperature of the junction (Tj) which is allowable while in operation, and the other for the temperature range allowable for storing (Tstg). These temperatures are determined mainly by the materials of the semi-conductor and its package.

Manufacturers guarantee that the failure rates of transistors will be kept under a certain value (those values differing by manufacture) when the transistors are operated or stored according to the temperature ratings as specified.

Generally, deterioration of a transistor will be accelerated in proportion to the increase of its junction temperature. The relationship between the average life Lm (in hours) and the junction temperature Tj (°K) is as follows, with A and B as the constants peculiar to a given transistor:

$$\log Lm \fallingdotseq A + \frac{B}{Tj}$$

Therefore, the upper limit of allowable junction temperature is specified in accordance with expected failure rate, reliability and life expectancy. Such values are 75–90°C for Ge transistors, 100–150°C for Si transistors and 150–200°C for Si planer-type transistors whose surfaces have been processed for stabilization.

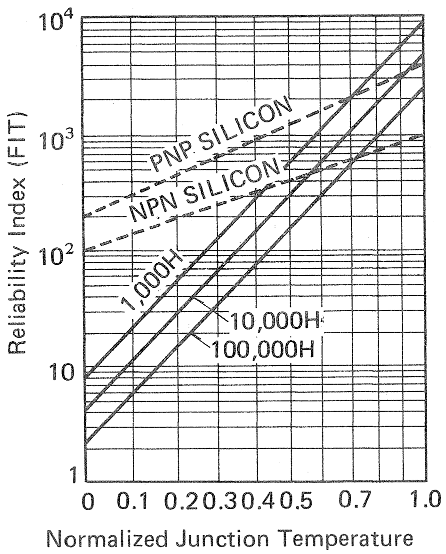



**Fig. 2 Examples of NPN silicon transistor dilating curves**

These data are of transistors made especially for telecommunications.

The dotted lines are from the data shown in Figs. 7, 4 and 4A on pages 7 and 4-12 of MIL-HDBK-217A (12-1-1965).

[Note 2] When r pieces out of $n_0$ pieces tested become defective in t hours, the reliability index will be obtained by the following formula:

$$RI = r/(n_0 \cdot t)$$

The unit of the RI is

$\times 10^{-9}$/hour=FIT

### 4-2-4 Power Rating

The electric power consumed by a transistor is converted into heat energy, raising the interior temperature of the transistor.

The internal power loss of a transistor operating with a certain bias is the sum of the collector dissipation $I_C \times V_{CB}$, and the emitter dissipation = $I_E \times V_{BE}$. But, as the emitter junction is generally biased in the forward direction, $V_{CB} > V_{BE}$. As $I_C \fallingdotseq I_E$, the collector dissipation is determined as follows:

$$P_C = I_C \cdot V_{CB} \fallingdotseq I_C \cdot V_{CE}$$

The parameters that restrict the maximum allowable dissipation $P_{C\,MAX}$ of a transistor are the maximum junction temperature $T_{j\,MAX}$, explained earlier, and the standard temperature To (ambient temperature Ta, or case temperature Tc). The thermal resistance $\theta jc$ (or Rth) of them is as follows:

$$P_{C\,MAX} = \frac{T_{j\,MAX} - T_c}{\theta jc}$$ (with infinite-sized heat sink.)

Ta: Ambient temperature, generally 25°C.
Tc: Case temperature, generally 25°C.
$\theta ja$: Thermal resistance between junction and periphery.
$\theta jc$: Thermal resistance between junction and case.

The thermal resistance is a physical value representing the rise rate of the junction temperature against the unit power dissipation, that is, the difficulty of thermal radiation. Therefore, in designing a power amplifier, it is necessary to select a transistor with a high $P_{C\,MAX}$ in order to obtain a larger power output. Radiation characteristics are very important in designing power transistors.

## 5. Area of Safe Operation (ASO) of Transistors

The area in which a transistor can be used with high reliability without deterioration is called the Area of Safe Operation (ASO).

The operating range of a transistor is usually restricted by the maximum ratings such as maximum voltage, maximum current, maximum collector dissipation, and so forth. But when a power transistor is used in a high-power amplifier, or in a circuit with inductive load (which is replaced with an R · L · C equivalent circuit in ordinary speakers), its characteristics may often deteriorate, or the transistor itself may break down, even though it is used within its maximum ratings. This sometimes could be because of the transistor's secondary breakdown (S/B) phenomenon. Often, in power transistors, the cause of the breakdown could also be heat. This will be explained later. Here is a general briefing on breakdown within the ASO.

### 5-1 Secondary Breakdown (S/B)

When a current is further increased beyond the primary breakdown to a certain level with a certain voltage and current, as shown in Fig. 3, the voltage between the collector and the emitter will suddenly plunge and shift to the low-impedance area within several μsec or faster, often destroying the transistor. This is the phenomenon called secondary breakdown (S/B).

The S/B phenomenon can be observed when the bias between the emitter and the base is in the forward direction, or when it is in reverse, as well as at $V_{CEO}$ and $V_{CBO}$.

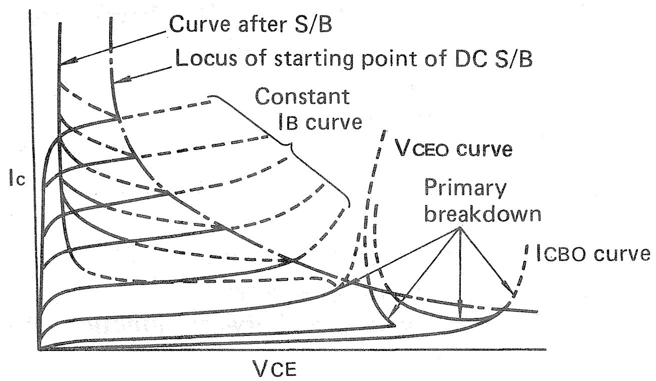



**Fig. 3 Secondary breakdown phenomenon**

However, when the base bias condition is different, the starting point of S/B will change and correspond with the locus shown by the S/B curve in Fig. 3. The figure is giving the case of a transistor operating with DC. The S/B starting characteristics depend on energy, so the S/B curve will change in accordance with the width of the applied pulses. This curve gives ASO against pulses.

The cause of S/B has been explained in various ways. But the theory gaining acceptance now says that S/B is caused by thermal runaway, resulting from the generation of a "hot spot" caused by the concentration of current in a small area.

Causes of such concentration of current include a drop of electric potential in the base area and unstable latitudinal temperature distribution. Uneven base width, imperfect junctions and irregular attachment of chips to heat sinks can also trigger the "hot spot" current concentration.

### 5-2 S/B Phenomenon and Transistor Breakdown and Deterioration.

The S/B phenomenon does not necessarily mean the breakdown or deterioration of the transistor itself. When the applied power is small, or if the power is cut off at the moment of S/B, the electric characteristics may not change at all after a series of S/Bs, or they may only gradually deteriorate.

This of course depends on the type of transistor employed. Some may be destroyed by a single S/B. Generally, when a transistor deteriorates, or is destroyed, by S/B, the curves such as $V_{EBO}$, $V_{CBO}$ and $V_{CEO}$ will become soft, or the transistor's leads will be short-circuited. Short-circuiting between emitter and collector leads is a typical deterioration suffered from S/B, and holes from the emitter to the collector made by melting are especially bothersome.

## 6. Reliability of Transistors

### 6-1 The Concept of Reliability

Reliability is defined as "the probability that an element will achieve the expected performance under a specified condition over a given period of time."

Thus we are dealing with a probability function that contains three independent factors for defining defects:
(1) the time element, (2) spatial conditions such as conditions of use and environmental conditions, and (3) limits of judgement as to whether expected performance is being maintained.

Failures of general electronic parts show a certain trend when observed from the viewpoint of time. They can be divided into the following three periods:

1) Early failure stage
2) Accidental failure stage
3) Wearout failure stage

Early failures can be prevented to some extent by the aging process of our manufacturing line, and also can be foreseen and avoided in the design process. Wearout failures can also be prevented by considering the part's life. However, accidental failures which occur at random cannot be accurately predicted. (Failure rate remains more or less constant irrespective of time lapse.)

Therefore, our target for the time being is to minimize the accidental failure rate (most failures in the field are of the accidental type).

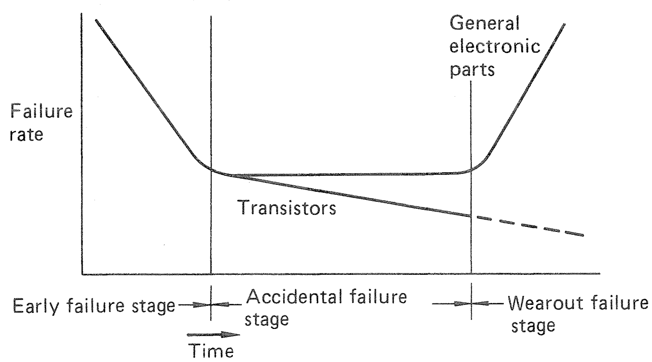



**Fig. 4 Failure rate versus time lapse**

## 6-2 Factors in Reliability of Semiconductors

The reliability of a semiconductor does not depend solely on the element itself. Rather, it depends on operating conditions and other conditions of use, such as environment.

Factors that affect the reliability of a semiconductor are as follows:

A. Factors of Element Itself
   (1) Defects and instability of transistor elements.
   (2) Characteristic dispersion.

B. Factors in Use
   (1) Aim of use and circuit conditions.
   (2) Improper operating conditions.

C. Environmental Factors
   (1) Temperature and humidity.
   (2) Mechanical conditions, such as vibrations and shocks.
   (3) External surges (lightning, electrical surges, static conditions, etc.)

### (1) Defects and Instability of Transistors

These are due to defects inside the element itself, such as improper junction, deterioration of channels caused by adhesion of water and ions, instability of channel formation, imperfection of bonding and mounting caused by poor production, insufficient quality control, etc.

Such kinds of troubles are drastically decreasing today.

### (2) Irregular Characteristics

Because transistor elements are very small in size, and because the transfer of a minority number of carriers within a solid body is utilized, even a tiny amount of impurity in a crystal or a minute difference in dimensions can greatly affect the transistor's characteristics. Those characteristics may be irregular within a certain range because it is difficult to mass-produce transistors whose various characteristics are strictly uniform.

Also, as semiconductors have temperature characteristics which derive from their materials (such as Ge and Si), it is impossible to ignore the impact on circuits caused by temperature changes affecting the $V_{CBO}$, $h_{fe}$ and $V_{BE}$.

### (3) Operating Conditions

Along with environmental conditions, operating conditions are important factors which affect the element's lifetime and reliability. Those conditions include power, current and voltage to be used.

A transistor is given absolute maximum ratings to stipulate its operating conditions. The ratings are values that must not be exceeded, even momentarily, if the element's characteristics and lifetime are to be guaranteed.

As the power used determines a transistor's failure rate and lifetime, appropriate voltage and current values must be set for each circuit used in order to obtain high reliability. Pioneer's Engineering Department has its own strict standards in this regard.

### (4) Temperature

Electric characteristics of semiconductor elements are very sensitive to temperature, and their lifetime is greatly affected by the PN junction's temperature.

The problem of heat, especially critical in transistors, is concretely explained below:

To ensure proper radiation of heat from a power transistor, a heat sink must be used in addition to the transistor's own package. Properly designed products are calculated to provide enough thermal margin to keep the junction temperature within the ratings.

The route through which heat generated at the transistor junction is led out can be represented by heat resistance and heat capacity by considering the transfer of heat as you would the flow of electric current in a circuit. Under a steady state of heat, it can be represented as in the equivalent circuit shown in Fig. 5.

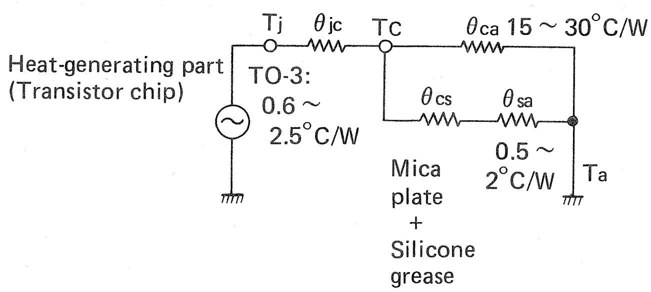



**Fig. 5 Equivalent circuit of heat transfer**

| | | |
|---|---|---|
| Q: | Heat-generating part (transistor chip) | W |
| Tj: | Junction temperature | °C |
| Tc: | Transistor case temperature | °C |
| Ta: | Ambient temperature | °C |
| $\theta$jc: | Heat resistance between junction and case | °C/W |
| $\theta$cs: | Heat resistance between case and heat sink | °C/W |
| $\theta$sa: | Heat resistance of heat sink | °C/W |
| $\theta$ca: | Heat resistance between case and air | °C/W |

In Fig. 5, the following equation is established:

$$Tj-Ta+Q\ (\theta jc+\theta cs+\theta sa)$$

$\theta$ca should be disregarded.

$$\theta jc = \frac{Tj-Ta}{PC}\ (°C/W)$$

The heat resistance factor $\theta cs$ (of the three $\theta jc$, $\theta cs$ and $\theta sa$) can be considered an unstable factor. Actually, $\theta cs$ is the heat resistance of a mica plate and the silicone grease.

If silicone grease is not applied, the heat resistance will become very high. When a transistor is operated under such conditions, the temperature will exceed the junction temperature limit, destroying the transistor. Therefore it is imperative to fully apply silicone grease when replacing transistors. At present, Pioneer uses white-colored silicone grease (Part No. GYA-009).

## 7. Reliability Tests

Methods and conditions of reliability tests conducted by semiconductor makers are based on MIL, EIAJ and JIS standards. Pioneer tests are carried out under the same or even more severe conditions.

Pioneer's Engineering Department established the following test methods in addition to the reliability tests conducted by semiconductor makers:

Test 1: Environmental Test of Semiconductors

This test is designed to confirm the reliability of semiconductors in adverse environments. It was established by correlating the failures which occured in the field in the past.

Transistors and ICs are first immersed in boiling water, then left in the air for a specified period of time. Following this, they are given power. The procedure is repeated ten times, with changes in various characteristics being measured each time for evaluation.

Finally, the transistors (or ICs) are examined carefully, and rejected if not suitable.

Test 2: Breakdown Test of Power Transistors

This test is applied to transistors intended for medium or higher power-handling use. It is the standard EBt test to determine endurability of breakdown time. A specified voltage/current is applied to the subject transistor for a specific period of time. In this way, we ensure that power transistors used in every Pioneer product exhibit excellent and uniform resistance to breakdown.

Test 3: Transistor-Noise Test

This test is applied to low-noise transistors used for amplifying audio frequencies, and is effective in regulating noise levels.

The measuring instrument used is the Noise-Checker NV-1, developed by the Pioneer Engineering Department. The same instrument is used by semiconductor makers to comply with our noise standards.

## 8. Failure Modes and Failure Mechanism

Failures on the assembly line and in the field can be roughly classified into three modes: open-circuit, short-circuit and deterioration.

### (1) Open-Circuit Failures

These occur when a physical stress larger than the guaranteed standard is applied to a transistor, or when an excessively large current melts down a lead. Leads may be damaged or broken down when the transistor's temperature is increased to a level higher than that stipulated, giving stress to the electrode connecting points of the aluminum and gold wires.

### (2) Short-Circuit Failures

These occur when a short-circuit happens between collector and emitter, collector and base, or emitter and base. In such cases, the junction surface inside the transistor is destroyed. There are also cases in which the aluminum electrode is melted down by the extraordinary heat from the destroyed junction surface.

### (3) Deterioration

This is noticed when a drop in breakdown voltage occurs, or when there is an extraordinary increase in $I_{CBO}$. There are also some other cases, such as an increase in the $h_{fe}$ far over the rated value, and the drifting of the values of the characteristics.

Defective samples found in the field are returned to our Engineering Department via the Service Section. But in many cases, our engineers find it difficult to ascertain reasons for failures. The engineers therefore would appreciate obtaining detailed information as to how amplifiers failed, and under what circumstances.

## 9. Compatibility of Transistors

The electric characteristics of recent amplifiers and tuners show remarkable improvement over those of several years ago. This is due to improvement of the electric characteristics of circuit elements, especially semiconductors, and to circuit designs which make it possible to fully assure excellent performance.

Therefore, the selection of semiconductors is an important factor, not only in designing the circuits themselves, but in repairing them as well. It should be noted that if transistors are replaced without full consideration of all factors involved, the repaired product may not be able to maintain its specified performance. Please keep the following information in mind:

### (1) Transistors Selected for Higher Breakdown Voltage

| | $V_{CBO}$ | | $V_{CBO}$ |
|---|---|---|---|
| 2SC116 | 180V | 2SA747 | −120V |
| 2SC116A | 200V | 2SA747A | −140V |

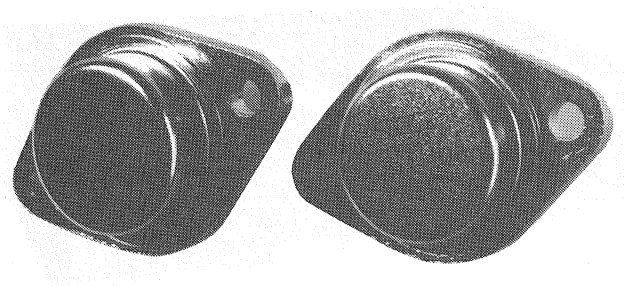


**Photo 14: Selected Transistor (2SC1116A)**

The above indicates there will be no problem in replacing a 2SC1116 with a 2SC1116A, but that the reverse is impossible because the former has a lower breakdown voltage.

### (2) Transistors Selected for Lower Noise

The 2SC1451P is a selected version of the 2SC1451, and is known for low-noise performance. When an ordinary 2SC1451 is used in its place, the product will operate, but the noise level will increase, sometimes to the point where the specified signal-to-noise ratio cannot be achieved.

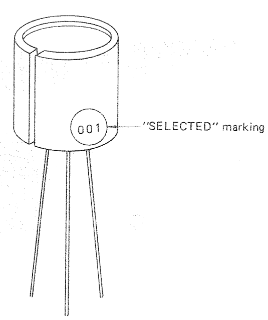



**Fig. 6 Selected model coded "001"**

### (3) Transistors of Designated *hfe* Rank

A transistor's *hfe* rank is specified depending on intended use. For example, transistors to be used in the input, drive, and output stage of a power amplifier will have different *hfe* ranks. Unless replacement transistors of identical rank are used, differences in gain between the positive and negative sides of the push-pull circuit will occur, resulting in deviation at the center point and an increase in distortion.

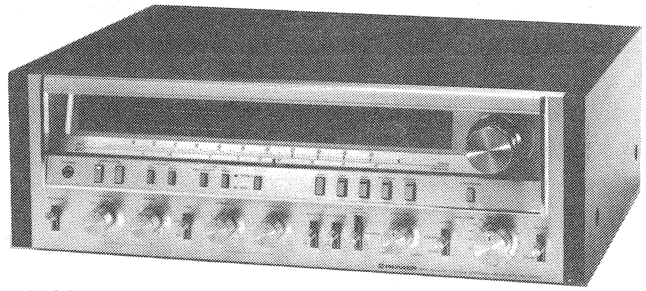
In addition to the above, many other points must be considered when replacing transistors. Problems can occur, for instance, even when an identically-numbered transistor is used. Therefore, special attention is required when replacing transistors with substitutes listed in a transistor substitution manual.

In principle, finally, the quality of a repair job depends greatly on the care with which the transistors are replaced. Never should one resort to the "easy way" by using a transistor not specified in the service manual.

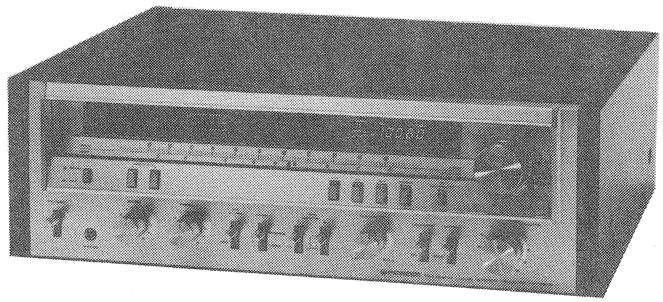
*FET (Field Effect Transistor) will be explained in a future issue.

# New Techniques
## Non-Switching™ Amplifiers

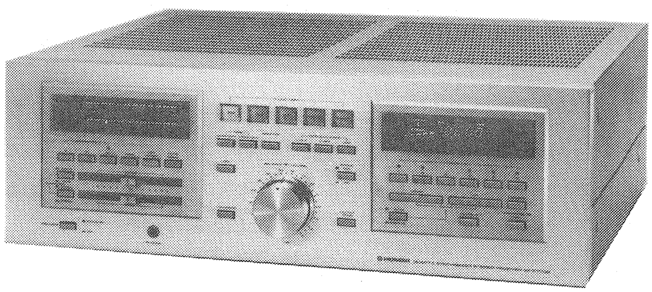

SA-9800

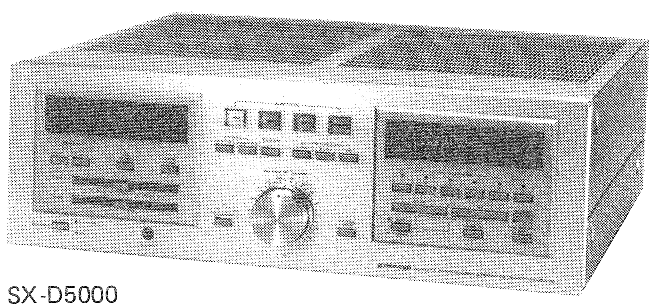

SX-3900


SA-8800


SX-3800


SA-7800


SX-D7000


SX-D5000

Pioneer took a dramatic lead in the audio industry in November 1978 with the introduction of our "Non-Switching ™" (hereinafter called NS) Amplifiers. Now, more than one year after our exclusive NS method was scientifically confirmed, we are receiving equally gratifying response from consumers as to its effectiveness. The three Pioneer NS models SA-9800/8800/7800 integrated amplifiers, (as well as those four new Pioneer stereo receivers SX-D7000/D5000 and SX-3900/3800 which use the technique), are selling extremely well.

Since these models have been available to the consumer, the editorial staff of TUNING FORK has received, together with praise for the NS system, numerous questions as to its technical characteristics. Some of those questions are as follows:

1) How and why does NS result in better-quality sound reproduction?

2) What, exactly, is the "secret" in the circuit operation of NS?

However, to be honest, we have also received comments indicating that some listeners can perceive no difference whatsoever in the quality of reproduction from an NS amp and a conventional one. Nevertheless, it is certain that Pioneer will continue to use NS in our mainstream high-end amplifiers and receivers.

We hope the following will help deepen your understanding of this truly "revolutionary" amplifier circuit technique.

## 1. NS vs. Conventional–Why Is The NS Amp Superior?

### 1-1 Class B Amplifiers & Switching Distortion

Naturally, the major difference between NS and conventional amplifiers is found in the power amp section. Our NS components have power amps which suffer not the least bit of "switching distortion" (a common malady in conventional Class B amps) simply because NS uses a technique which prevents the power output transistors in the power amp from switching on and off. Before tackling the problematical question of whether this actually improves the sound quality of the amplifier, let's look at some of the factors which are known to cause deterioration in sound quality in general.

Harmonic distortion, intermodulation distortion, transient intermodulation distortion, noise, phase characteristics, frequency characteristics, output frequency characteristics, the damping factor–all these are known to affect sound quality in differing degrees. In this discussion, however, let's look at those factors–particularly distortion–which are the most serious.

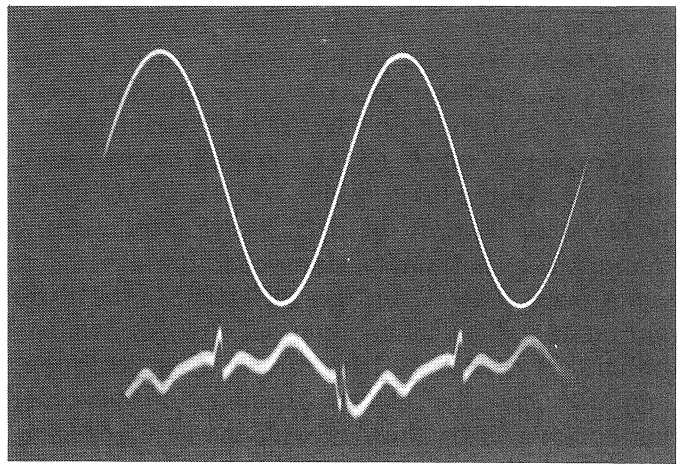


Photo 1 Output & distortion waveforms

Photo 1 shows the output waveform and distortion waveform of a conventional amplifier fed a sine wave input. The distortion contains a lot of high-order harmonics far above the second and third harmonic positions.

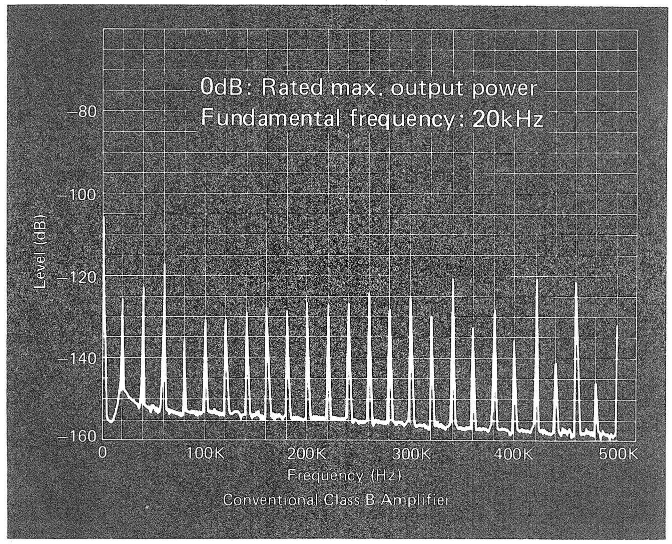



Photo 2 Distortion components

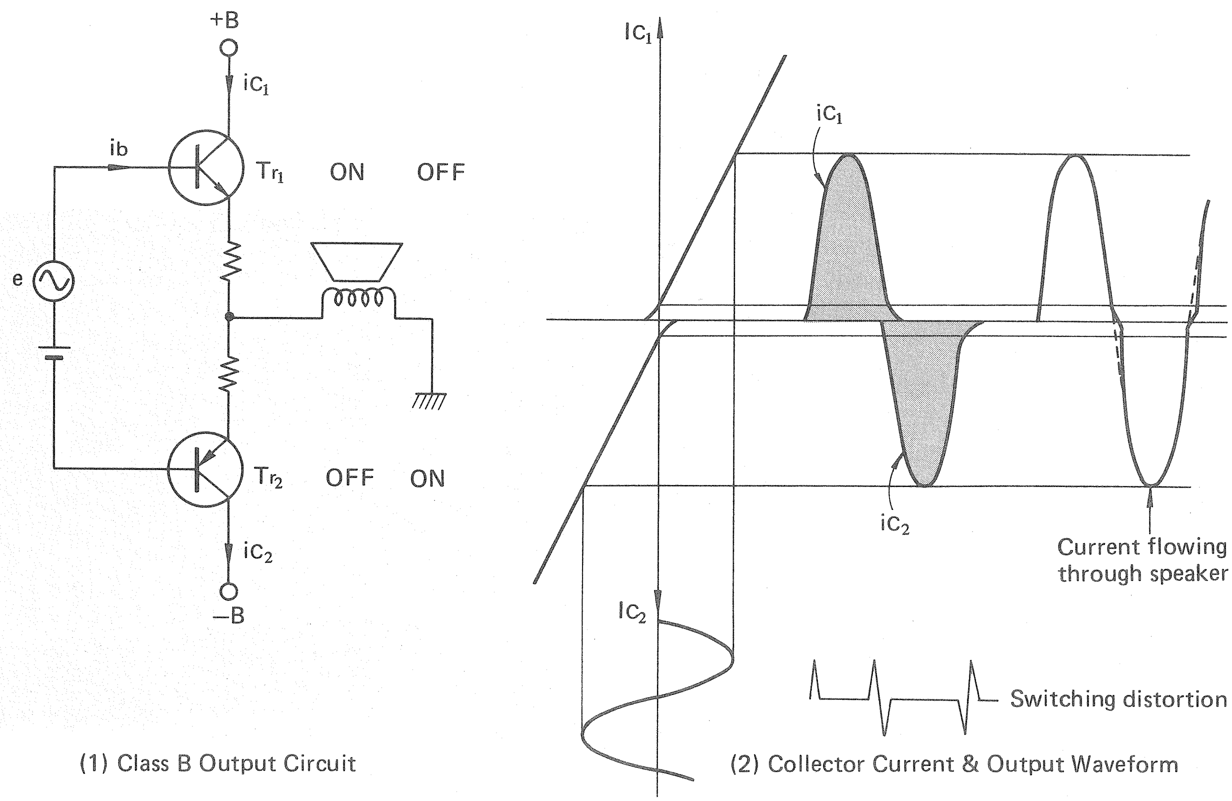
Photo 2 shows a waveform analysis of the distortion components, made by a spectrum analyzer. It proves that a lot of harmonics exist, though their level may be relatively low.

Next, a look at the relationship between distortion components and sound quality. When two amplifiers of identical or very close specifications—including distortion and frequency characteristics—are compared while actually driving loudspeakers, delicate differences in sound are often found. This would seem contrary to logic. But it is true, as any audiophile or hi-fi salesperson well knows.

A main cause of this is a difference in the distribution of the distortion components in the two amplifiers. Experiments have shown that whichever amplifier has the greater amount of high-order harmonics will be the one with the least appealing tone quality.

What causes high-order harmonics? We have learned that switching distortion is the principal cause. Namely, it is that form of distortion produced every time the output signal switches from positive to negative and vice-versa, as shown in Photo 1.

Switching distortion is produced by the collector currents which do not, when input ceases, immediately become nil. Instead, those collector currents continue to flow for a while, in spite of the input (i.e. base current) being cut off due to the carrier-storage effect, when the driver and output transistors are swung to their cut-off regions.



(1) Class B Output Circuit

(2) Collector Current & Output Waveform

**Fig 1 Generation of switching distortion**

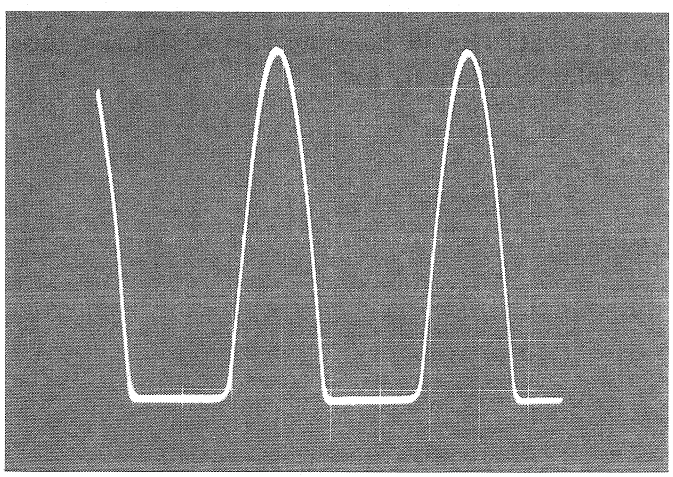


**Photo 3 Collector current waveform of Class B amp**

The higher the signal frequency or the input signal level (that is, the higher the output level), the more conspicuous the switching distortion. Class B power amps, whose output transistors repeat on/off switching alternately, cannot escape suffering this fate.

Transistor elements function just as resistors during the cut-off period, making it impossible to eliminate switching distortion with negative feedback. Therefore, other means must be used, which can only suppress switching distortion unless, of course, the Class B format is abandoned entirely.

Or—is there another answer?

Yes, but first let's look at the classical alternative to Class B, that is, Class A.

## 1-2 Characteristics and Operation of Class A Amps

The simplest way to avoid switching distortion is to operate in Class A, by providing a bias current to the transistors. The current is set to bring the collector current to half of what it would be at maximum output. This keeps the transistors always operating within their active region, never going into cut-off. They do not switch on and off, therefore no switching distortion is produced (See Fig. 2).

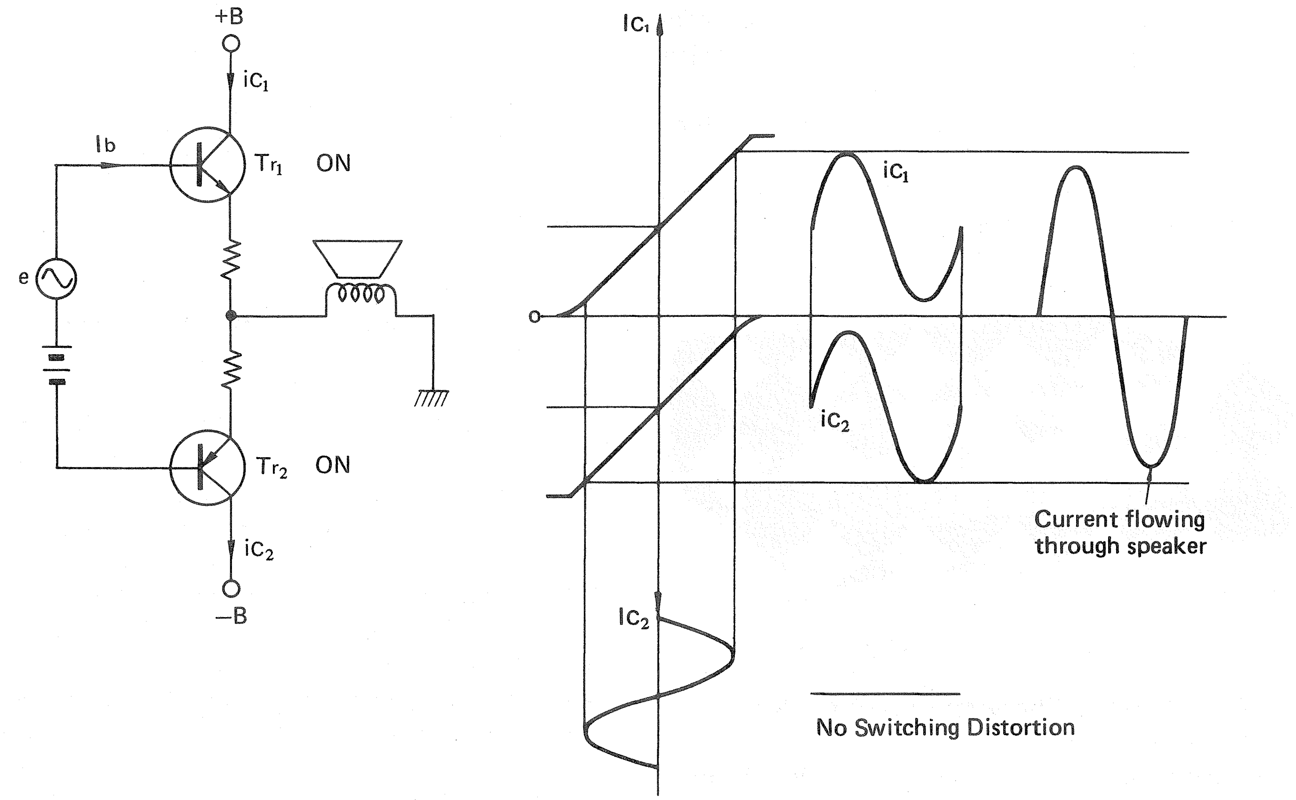
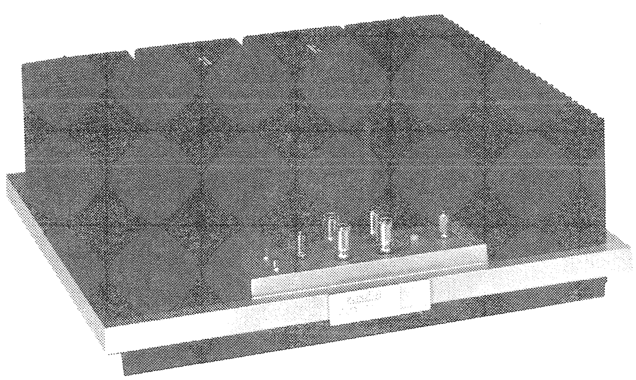


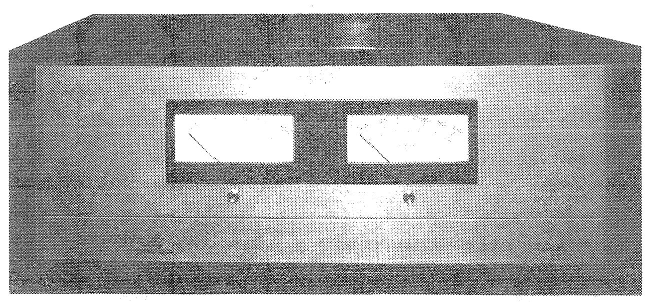

**Fig. 2 Operation of Class A amplifier**

The Class A amp is thus ideal as far as switching distortion is concerned, and high-order harmonics are no longer a problem. However, other problems do exist, namely high heat loss, or inefficiency. As the amp requires continuous current (the bias), a great amount of energy is wasted in the form of heat, reducing efficiency. Heat sinks must be large, as must be the power transformer, smoothing capacitors and the power transistors themselves. This naturally raises the cost (and limits the possible power output) of the Class A amp.

Class A amps are therefore used only when the best possible performance is required and when cost and other factors are no object. Pioneer makes only two Class A type power amplifiers, the M-22 and the EXCLUSIVE M4 (available only in the Japanese market). (See Photo 4)



(1) M-22 Class A power amplifier



(2) EXCLUSIVE M4 Class A power amplifier

Photo 4

In addition, we make a hybrid Class AB amplifier, the A-27 (Photo 5); its power transistors are fed a bias current lower than Class A, but operate in Class A when the output is 3W or lower; seldom is a higher output required in normal listening situations.

When higher output is required, the A-27 goes into Class B operation, the bias current is no longer needed, and efficiency is improved. The AB format is successful in delivering high-quality sound, high output and high efficiency.

But again we ask, is there a better way? And again the answer is yes—Non-Switching.

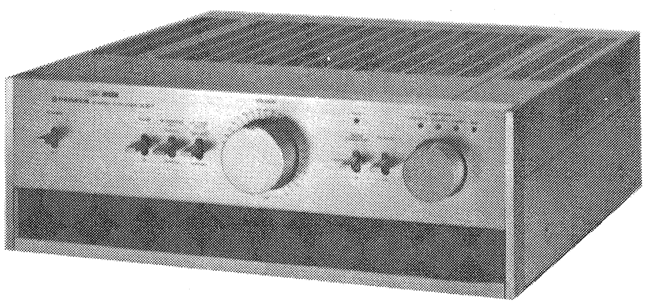


**Photo 5 Pioneer A-27 Class AB amplifier**

## 1-3 Operation and Characteristics of the Non-Switching Amplifier

As explained above, Class A and Class B amps have their merits and demerits, and it is not easy to say which is superior. One thing is definite: the "ideal" amplifier should have the best merits, and none of the demerits, of both formats.

It has been the premise that bias should be a fixed factor. But Pioneer's NS technique changed that; it introduced the idea that bias can be variable so long as it continues to perform its purpose, that of preventing transistor switching.

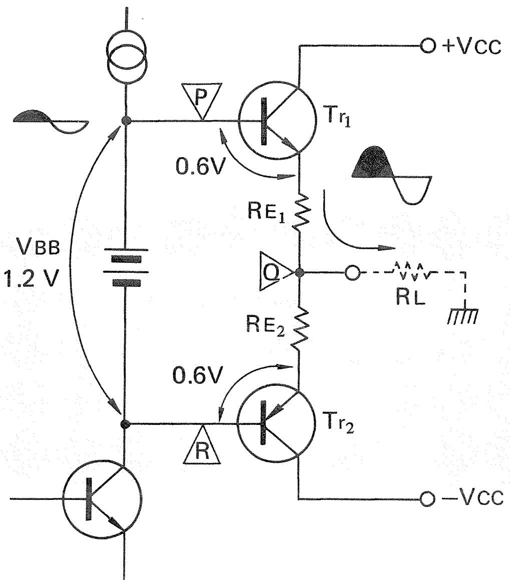



**Fig 3 Basic class B circuit**

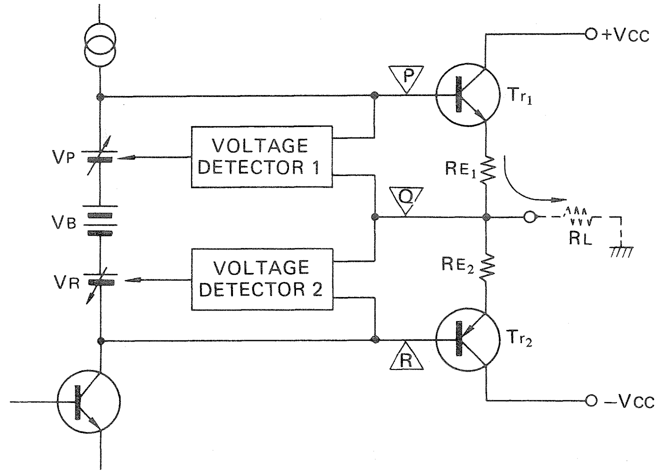



**Fig. 4 Principle of Non-Switching amplifier**

Fig. 4 illustrates the principle of the NS amp. To understand the circuit more readily, please refer to the basic circuit of the Class B amp shown in Fig. 3.

Voltage (1.2V) is provided to the line between $Tr_1$ and $Tr_2$ bases (between P and R) in order to supply the bias current. Suppose a positive half-cycle signal is put into this circuit. The load current will flow in the direction indicated by the arrow, and a voltage will appear across the emitter resistor $RE_1$ in accordance with the quantity of the emitter current.

At this time, the base voltage of $Tr_1$ will be 0.6V higher than the emitter potential.

Then, because the bias voltage (i.e. voltage between P and R) is fixed, the voltage between Q and R will become nil when voltage between P and Q becomes higher than 1.2V. In other words, when the $Tr_1$ emitter current increases, and voltage across $RE_1$ becomes higher than 0.6V, $Tr_2$ will be reverse-biased and cut-off will occur.

Similarly, $T_{r1}$ will be cut off when voltage across $RE_2$ exceeds 0.6V in the case of a negative half cycle. Fig. 5 will explain this.

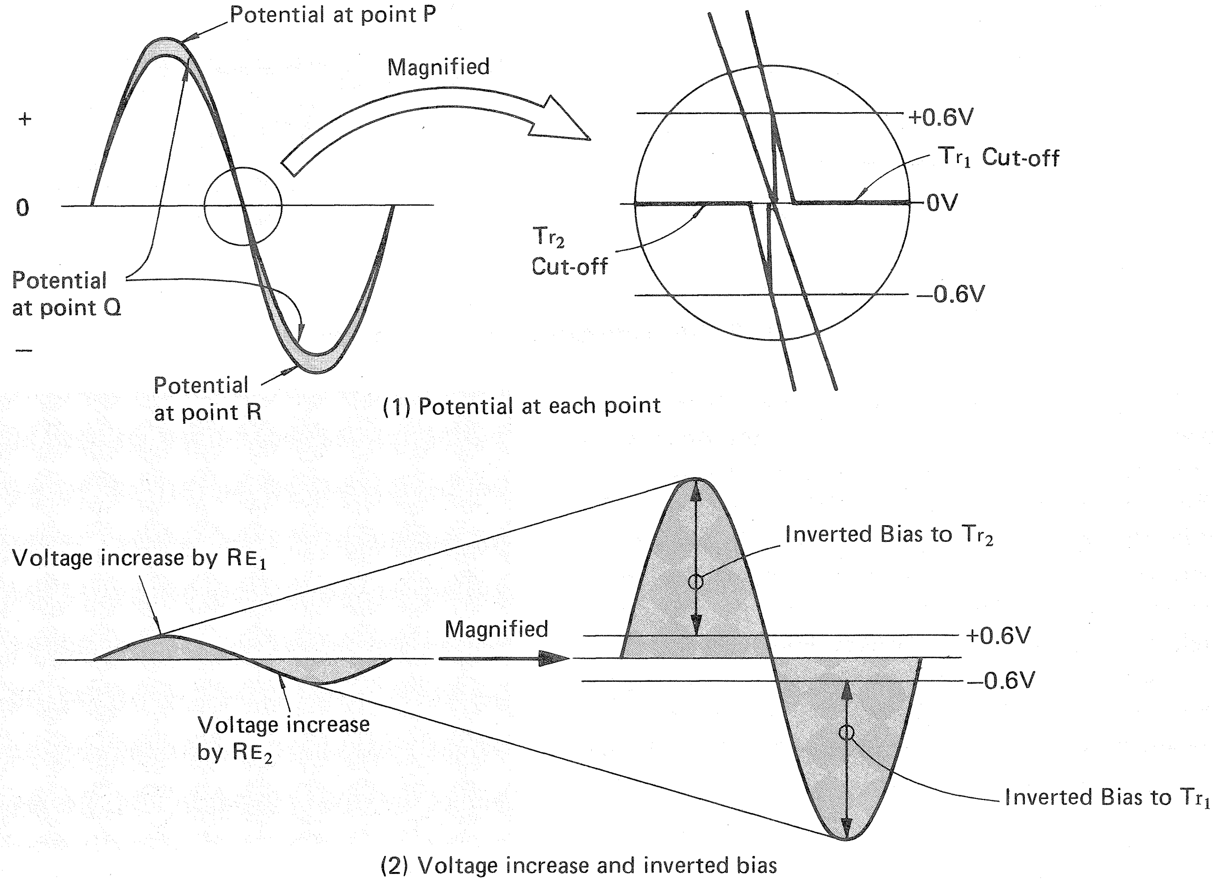



**Fig. 5 Voltage drop by emitter resistors and cut-off**

The gray areas of Fig. 5 (1) represent increments in potential due to $RE_1$ and $RE_2$.

Transistors which do not enter cut-off do not cause switching distortion, as we have said. To achieve this state of operation, potential increments in voltage brought about by $RE_1$ and $RE_2$ (i.e. voltage drops across each resistor) must be cancelled somehow to prevent giving each transistor reverse bias alternatively.

The NS amplifier includes a device to detect potential increments in voltage caused by emitter resistors, and to change (increase) bias voltage (bias current) when needed to prevent transistor cut-off. In this, the Pioneer NS amplifier differs most significantly from a Class B amp using a fixed-value biasing ($V_{BB}$ of Fig. 3) whether an input signal is present or not.

When the input signal is in a positive half cycle (see Fig. 4), the voltage between P and Q increases by the same quantity as the voltage drop across $RE_1$. Voltage Detector 1 detects the increase and changes $V_P$ by the same quantity. As a result, the voltage between P and R is increased by the same quantity as the voltage drop across $RE_1$ plus the emitter voltage with no input signal applied. (During this period, $V_R$ does not change and is kept at the same voltage as that with no input signal applied.)

Similarly, during the negative half cycle, $V_R$ increases by the same quantity as the voltage drop across $RE_2$ because of the operation of Voltage Detector 2. Therefore, $V_R$ is increased, and the voltage between P and R is also increased. As $V_P$ does not change in this case, $T_{r1}$ does not enter cut-off.

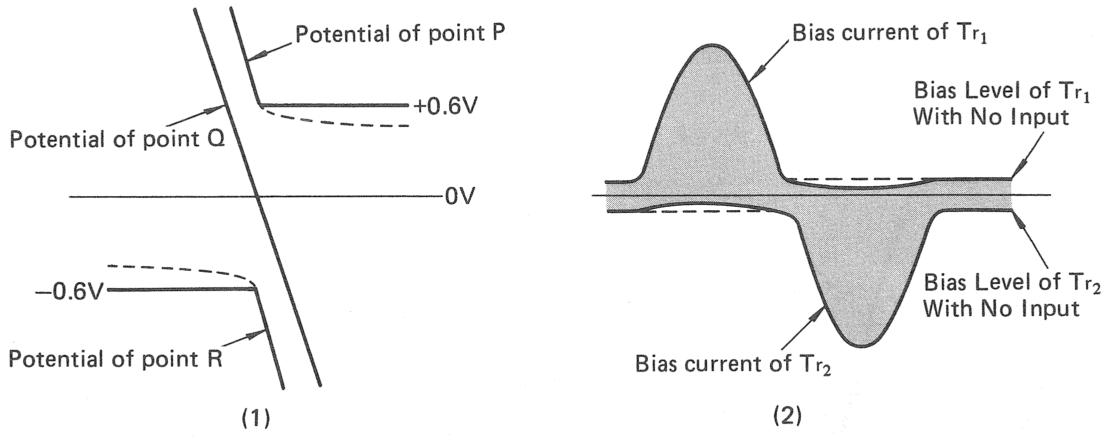



**Fig. 6 Base potentials of $Tr_1$ & $Tr_2$ and bias**

Fig. 6 (1) shows potential changes between the ground and points P, Q and R where the signal shifts from positive to negative. The bias levels of $Tr_2$ when the signal is in positive half cycle, and of $Tr_2$ when the signal is in negative half cycle, are not the same as those when no signal is present. The amplifier circuits are designed to reduce the bias levels slightly, as shown by the broken lines.

Fig. 6 (2) indicates the base current change. There is a significant purpose in making the base current thus, as will be explained in Section 2 below.

Fig. 7 shows the operation of the NS amplifier.

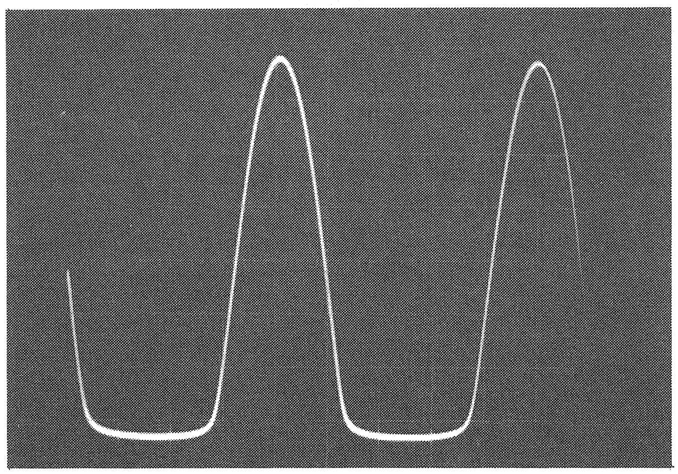


**Photo 6 Collector current waveform of NS amp**

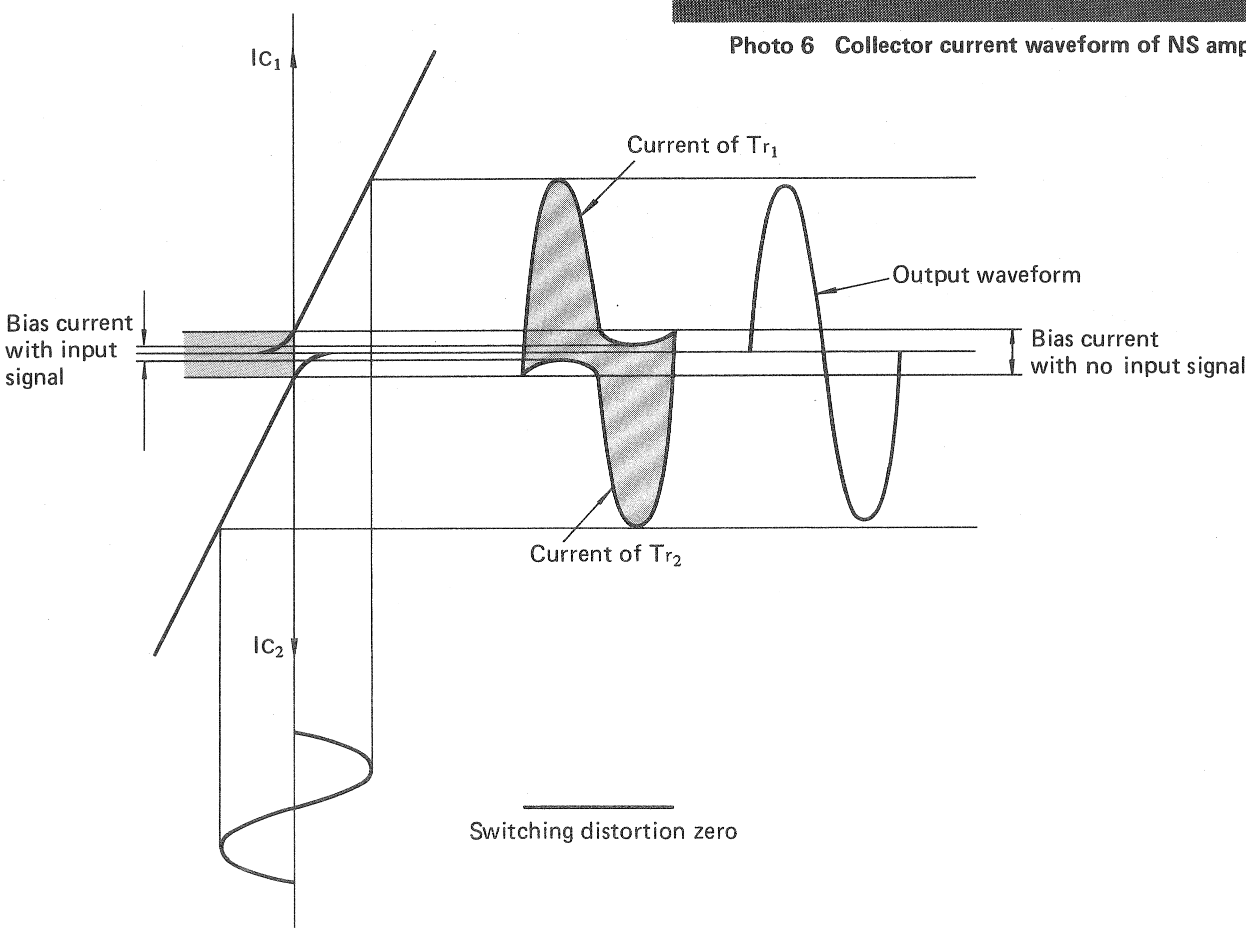



**Fig. 7 Operation of Non-Switching amplifier**

## 2. Actual Non-Switching Circuit Operation

### 2-1 Non-Switching Circuit Operation

The power amplifier circuit of the Pioneer SA-9800 integrated amplifier, an NS model, is shown in Fig. 8 as a typical example. Studying the figure will not in itself provide understanding of the circuit's operation, so we have provided a close-up of the main section in Fig. 9-1 below:

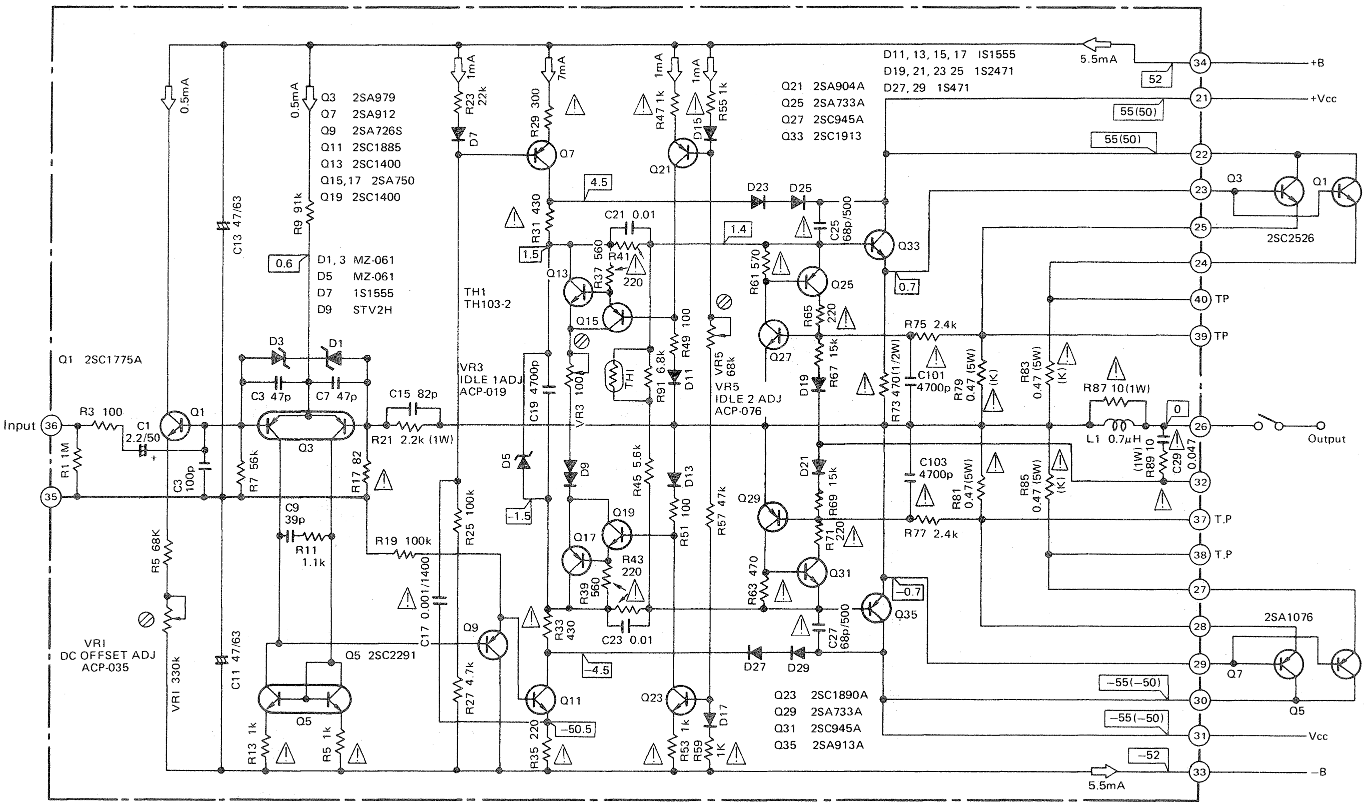



**Fig. 8 Circuitry of SA-9800 Power Amp (Only left channel)**

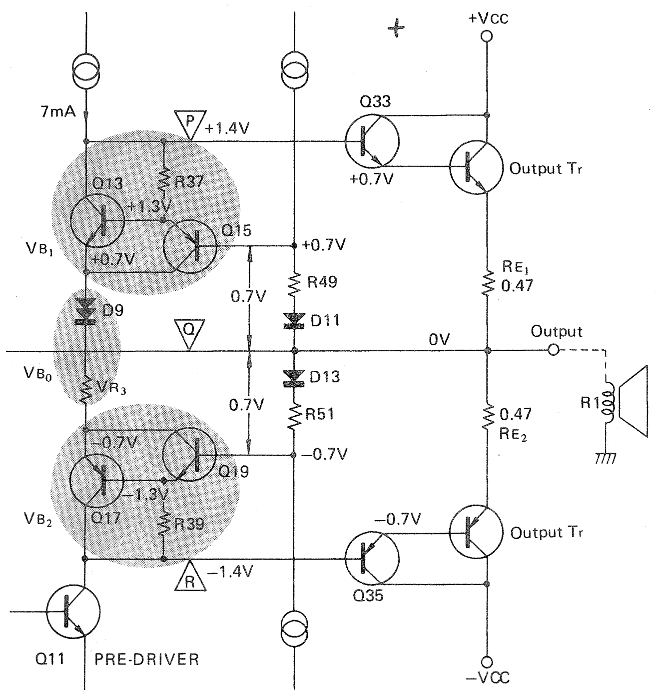



**Fig. 9-1 Basic Non-Switching amplifier circuit**

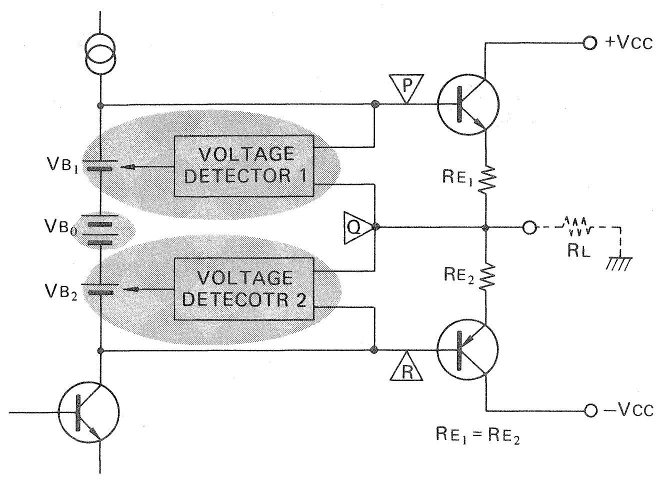



**Fig. 9-2 Principle of Non-Switching amplifier**

To further facilitate understanding, the principle earlier shown is again provided here in Fig. 9-2. Please compare it with the basic circuit, which consists of the Q13, Q15 and R37 circuit, the Q17, Q19 and R39 circuit, and the D9 and $V_{R3}$ corresponding to $V_{B1}$, $V_{B2}$ and $V_{B0}$ of Fig. 9-2. The voltage at each point to ground, when no signal is present, is shown in Fig. 9-1.

When no signal is present, Q15 and Q19 are nearing their cut-off points, but still operating. Q13 and Q17, provided with biases through R37 and R39 respectively, are also active, and collector current is flowing through Q13, D9, $V_{R3}$ and Q17.

Next, let's see how the voltage of each section varies when a signal is put into the circuit. Momentary potential at the peak of the positive half cycle, when output is 100W, is shown in Fig. 10 for easier understanding.

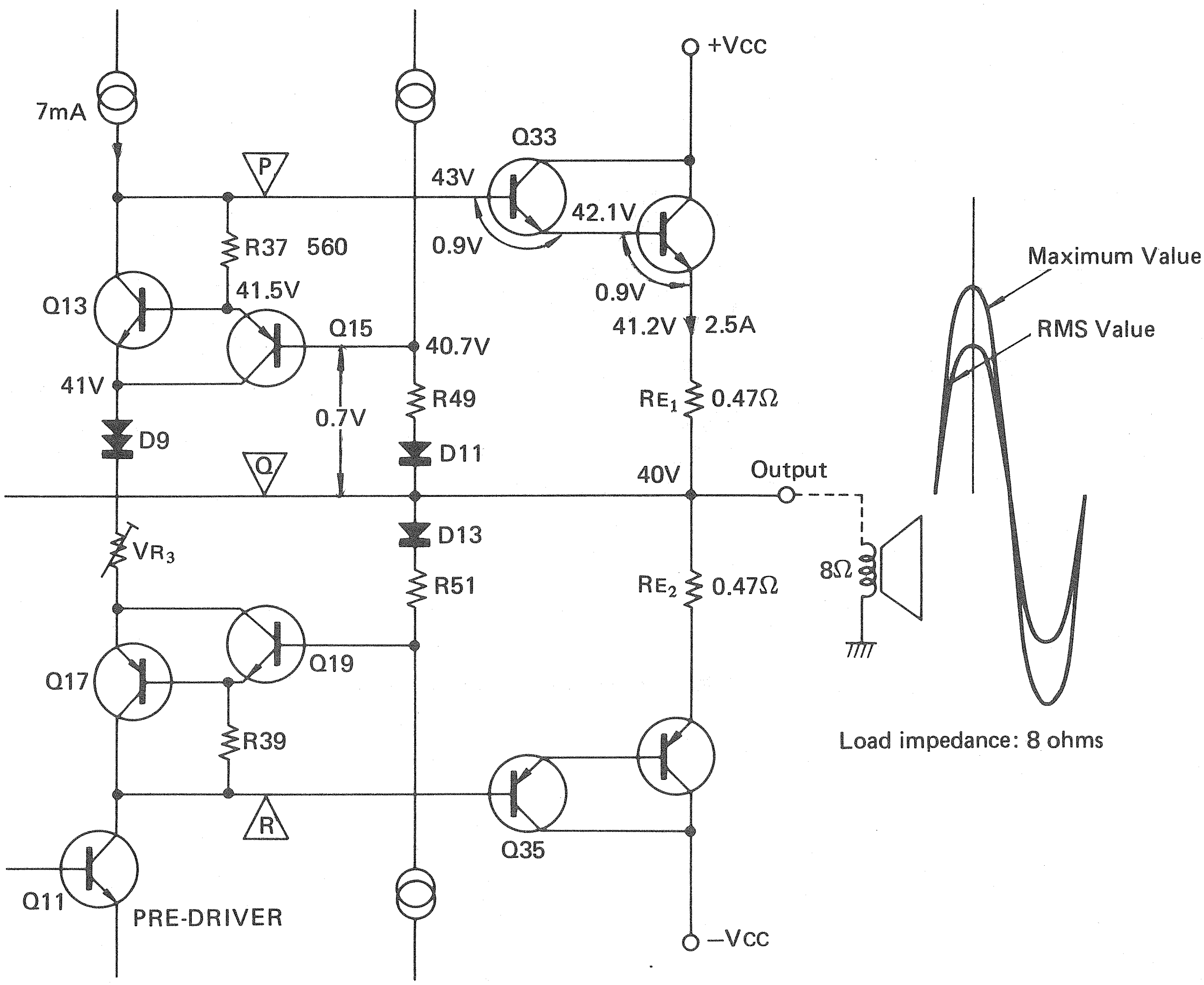



**Fig. 10 Momentary potential at positive peak, 100W output**

As output is 100W, current is obtained by

$$I = \frac{\sqrt{P}}{R}. \text{ That is, } \frac{\sqrt{100}}{8} \doteqdot 3.54 \text{ (A).}$$

As this is an effective value, the maximum value is obtained by multiplying it with $\sqrt{2}$, i.e., 5A.

This current flows through $R_{E1}$ as well. Therefore, $R_{E1}$ raises the voltage drop, and the emitter voltage in the output transistor rises further than the potential at point Q. In the actual circuit, the output stage is designed in parallel push-pull. So a current of 5/2 = 2.5 (A) will flow through each output transistor. Therefore, the emitter potential increase, due to emitter resistance, will be $2.5 \times 0.47 \doteqdot 1.2$ (V).

Meanwhile, potential at point Q is obtained by

$$V = \sqrt{PR} : \sqrt{100} \times 8 = 28.3 \text{ (V).}$$

As this, too, is an effective value, the maximum value is obtained by multiplying it by $\sqrt{2}$, i.e., −40V.

Thus it is proved that the voltages between ground and points P and Q are the same as shown in Fig. 10. VBE of output Tr and Q33 increases by some 0.2V from 0.7V when there is no signal input.

Now, let's discuss the voltage between the point P and the base of Q15. The value is 0.7V when there is no signal input, but increases to 1.5V (positive peak) when output is 100W. As a result, Q15 turns from near cut-off to the conductive state, and current flows from point P through R37 and the emitter and collector of Q15.

As Q15 becomes conductive, voltage between the base and emitter of Q13 (equaling the voltage between the emitter and collector of Q15) drops in inverse proportion to the momentary output of the amplifier. As a result, the bias current of Q13 decreases, reducing collector current.

In other words, when the collector voltage of Q15 increases, the collector current of Q13 decreases; conversely, when collector current of Q15 decreases, collector voltage of Q13 increases. The sum of both collector currents is almost constant (about 7mA). (Please note that currents flowing through both transistors are provided by the constant-current circuit. Strictly speaking, base current of Q33 will also increase, but this can be ignored here as it is far smaller than the currents flowing through Q13 and Q15.)

The total current flowing through both transistors is almost constant in spite of an increase in voltage between point P and the anode of D9. This means that the equivalent resistance of the circuit consisting of Q13, Q15 and R37 changes (increases) and the voltage change between P and Q, brought about by a change in signal (output) level, is absorbed by this circuit. (See Figs. 12 and 13.)

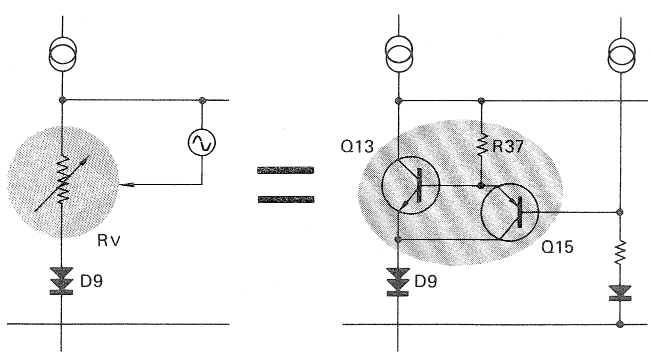



**Fig. 11 Operation of Q13, Q17 & R37**

This indicates that the potential of the Q13 emitter changes little. (Strictly speaking, again, this change depends on the value of resistance of R37. When the R37 value is zero, the potential of the emitter of Q13 does not change at all. When the value is raised above 560 ohms, the variation becomes larger and, eventually, approaches the potential at point Q. The value 560 ohms is obtained by trial and error methods to reach the optimal variation of 0.3V.)

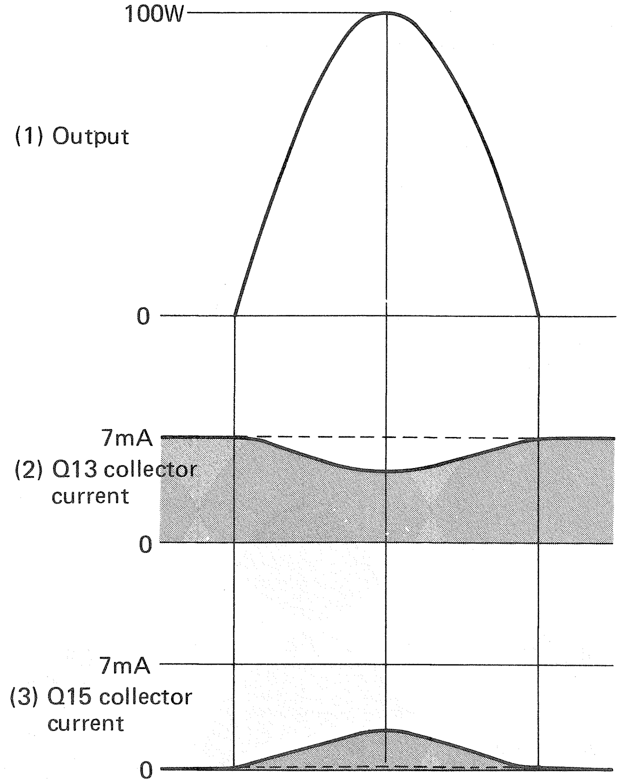



**Fig. 12 Current variation in Q13 and Q15**

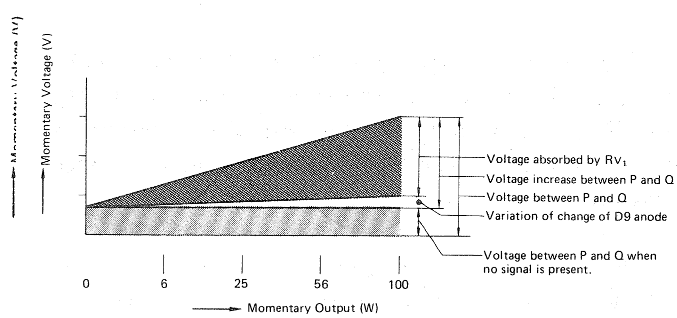



**Fig. 13 Voltage changes per momentary output (1)**

Please refer again to Fig. 10. When the emitter potential of Q13 changes by 0.3V, the potential of the emitter of Q17 changes by 0.3V as well, because, as explained, the sum of currents flowing through Q13 and Q15 is constant, irrespective of signal level. The potential of the emitter of Q17 will thus be 39.6V at the positive peak at maximum output, and the potential difference between the Q17 emitter and point Q will be 0.4V.

Consequently, bias currents of Q33 and the output transistor will lessen, but not to the point where cut-off occurs. This is shown in Fig. 14.

As the driving transistor and the output transistor are Darlington-connected, the base current of the output transistor will change similarly.

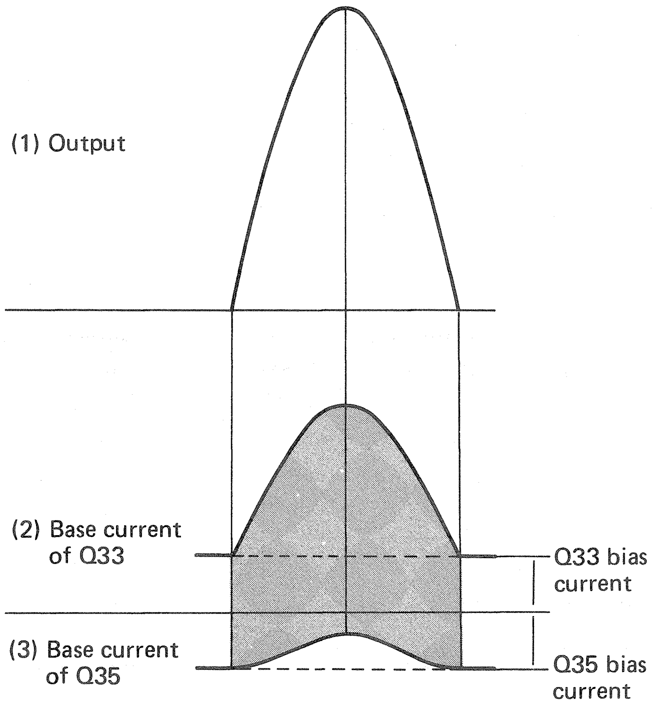



**Fig. 14 Output and base current changes**

Then, what if output is in the negative half cycle? The result is, of course, the same in reverse. In this case, $RE_2$ will reduce voltage and the potential at point R will be lower than that of point Q, proportionately.

The increased amount of voltage will be mostly absorbed by the circuit consisting of Q17, Q19 and R39. But voltage between the emitter of Q17 and point Q will increase slightly, while voltage between the emitter of Q13 and point Q will decline in inverse proportion.

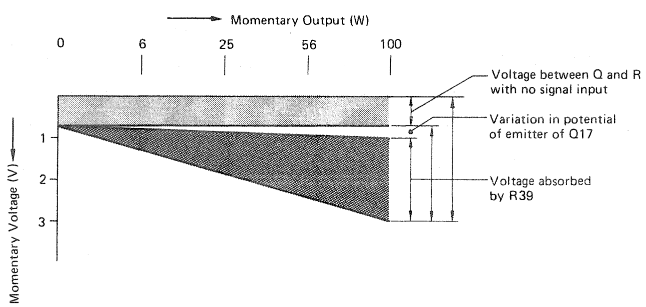



**Fig. 15 Voltage changes per momentary output (2)**

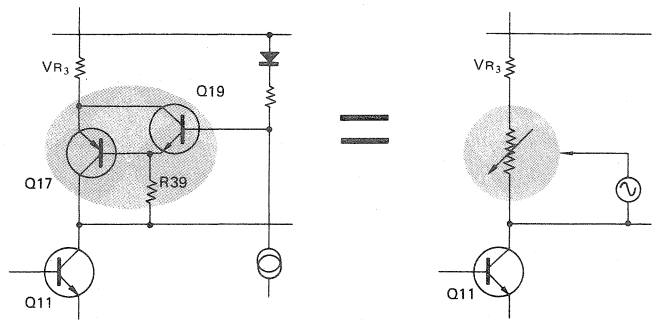



**Fig. 16 Operation of Q17, Q19 & R39**

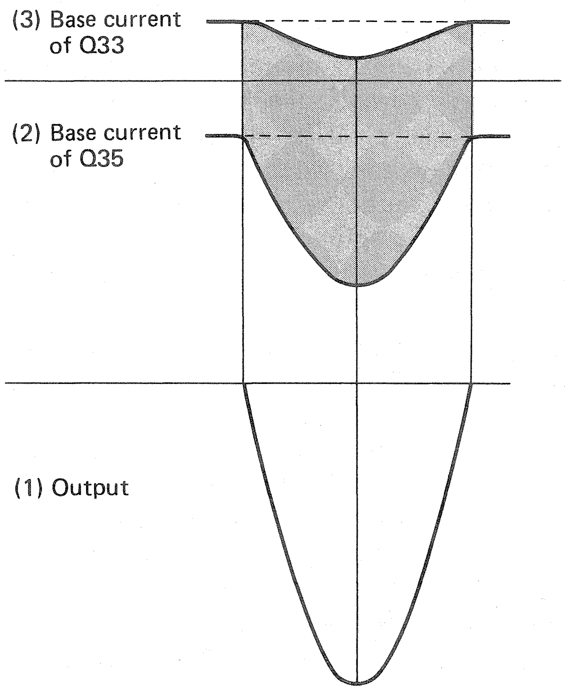



**Fig. 17 Output & base current variations**

As a result, the Q33 base current declines, as does the base current flowing through the output transistor (PNP). But neither transistor will be cut off.

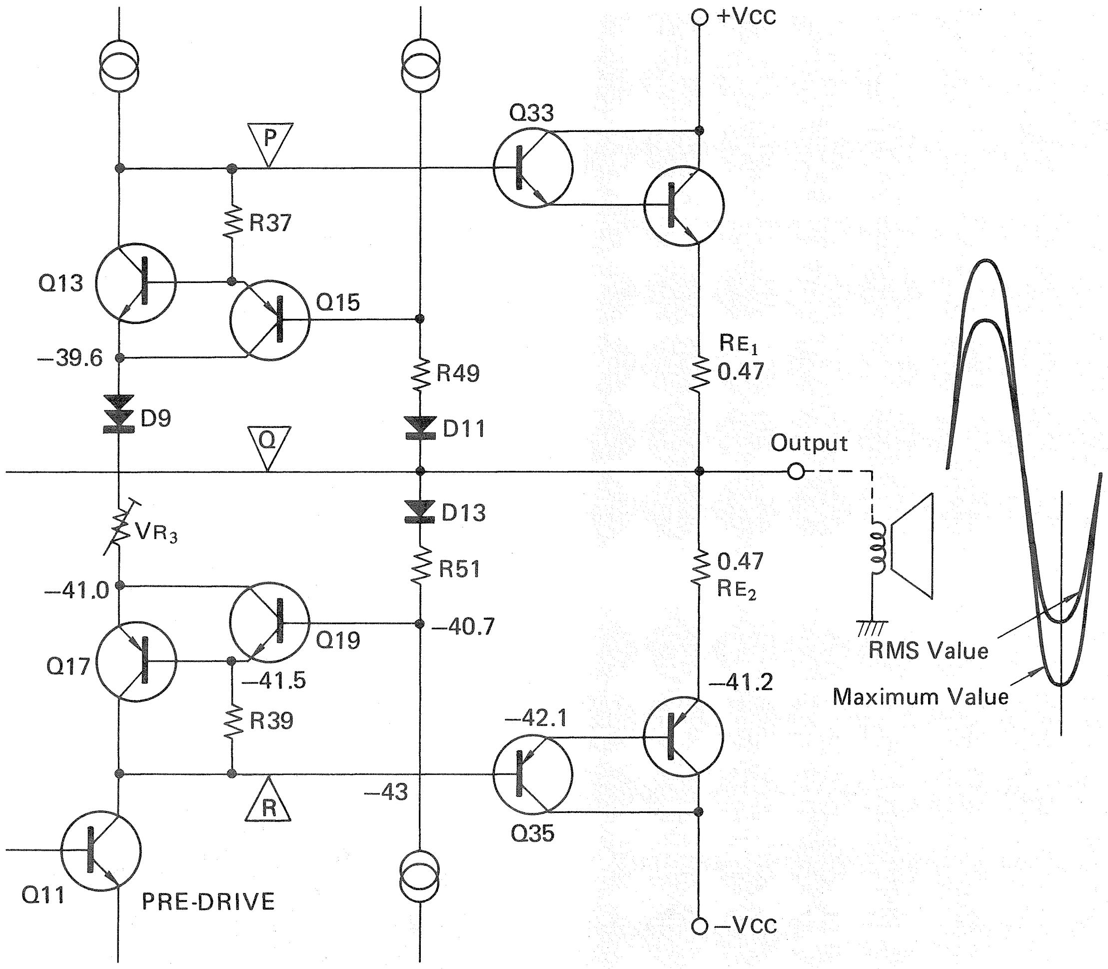



**Fig. 18 Momentary potential & negative peak, 100W output**

Fig. 18 shows the momentary potential at each point during the negative half-cycle peak at maximum output.

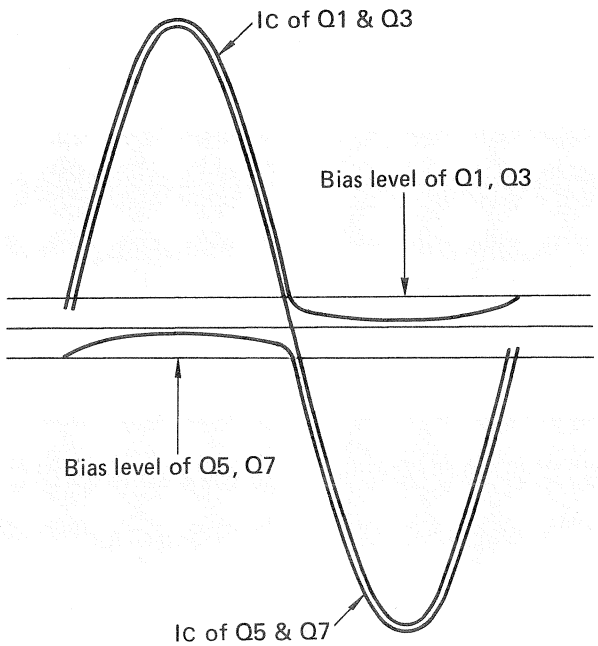



**Fig. 19 Current waveform of output transistors**

Fig. 19 shows the current waveform of the output transistors.

Another important thing to be mentioned is that the collector currents vary gradually as shown in Fig. 19. (Assuming that they did not, as shown in Fig. 20, it is understandable that the sum of both currents would be a proper waveform.) However, since the variation of both currents is very rapid at the rise and fall points, distortion is apt to be produced, especially at the fall points. To avoid this, the $f_T$ of the transistors must be extremely high.

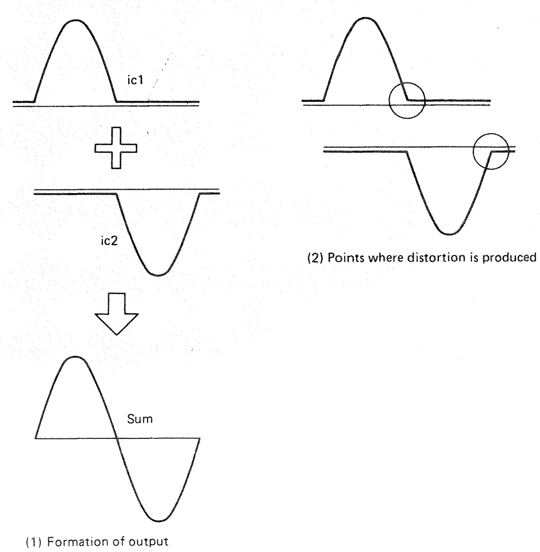
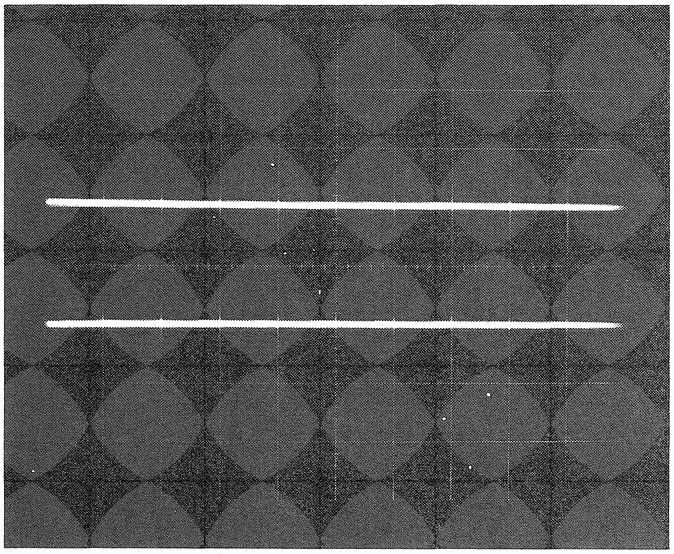
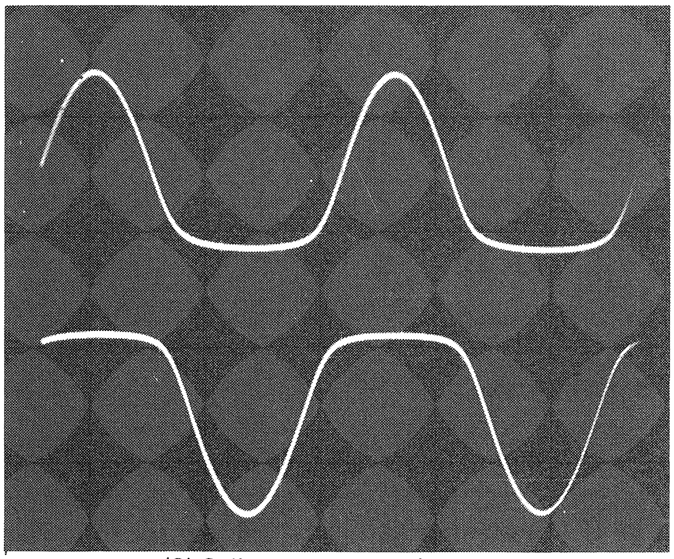


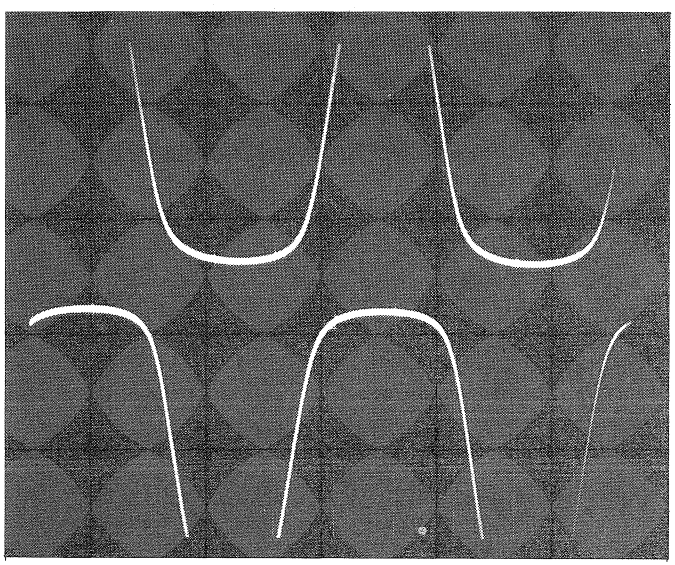

**Fig. 20 In case collector currents are clear-cut**



(1) Bias current with no output



(2) Collector current at low output



(3) Collector current at high output

Photo 7

In the case of Pioneer's NS amp, as explained above, the gradual variation of the collector currents is the result of considering this point.

The NS amplifier thus operates with its transistors active, never switching off. This entirely eliminates switching distortion, as effectively as a Class A amp, and makes it possible to attain high output, such as in a Class B amp, without sacrificing efficiency.

### 2-2 Further Reduction of Distortion

As described so far, the Pioneer Non-Switching technique itself plays a great role in reducing distortion. But now we'll discuss how the careful selection of circuit devices helps reduce it still further.

For example, our NS amps employ RETs (Ring Emitter Transistors) which have excellent high-frequency switching characteristics. RETs are so named because the emitters of hundreds of elements within each are arrayed in parallel, connected in a "ring" shape. Each element within has excellent linearity and high-frequency characteristics, excellent electrical durability, and the capability to yield a high output with low distortion in the high-frequency ranges.

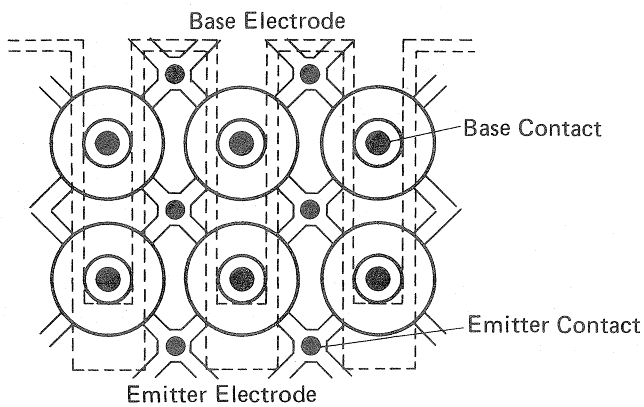



**Fig. 21 Structure of a RET**

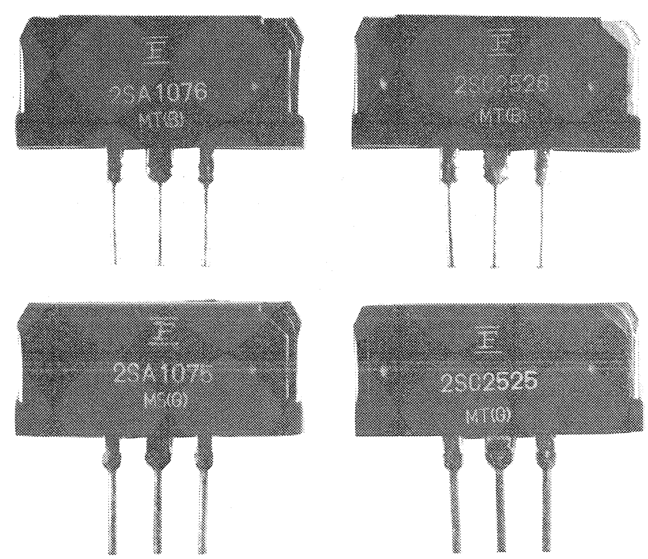



**Photo 8 RETs**

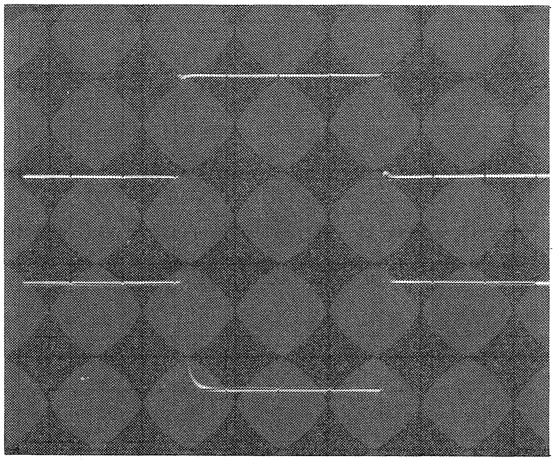


**Photo 9-1 RET switching characteristics**

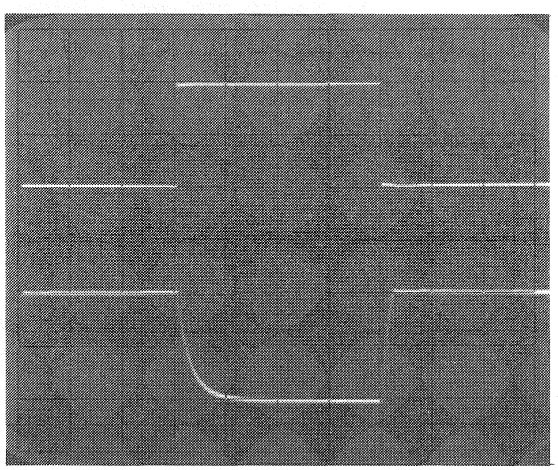


**Photo 9-2 Conventional transistor switching characteristics**

At the same time, serious consideration is paid to the combination of components in our NS amps. For example, each pair of transistors Q13 and Q15, Q17 and Q19, etc., has mutually complementary characteristics. Their rise characteristics are quite close to those of the driving transistors Q33 and Q35. Furthermore, the output transistors match D9 in terms of heat and rise characteristics, and are selected so that distortion is well suppressed despite changes in ambient temperatures or the heat of the transistors themselves.

Of course, D11 and D13 elements are used not only to determine the bias current of the transistors in the NS circuit, but also to compensate for temperature changes.

Now let's take a quick look at the NS circuit again. (Figs. 22 and 23).

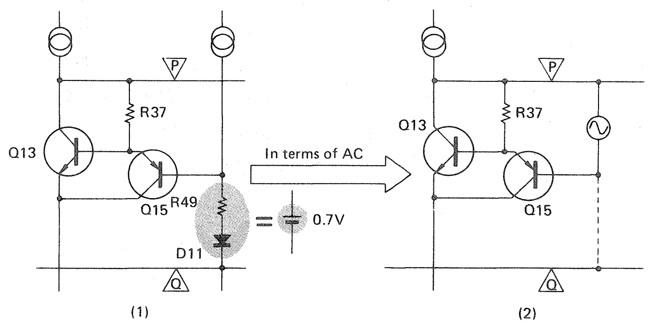



**Fig. 22 Function of Q15 emitter-follower**

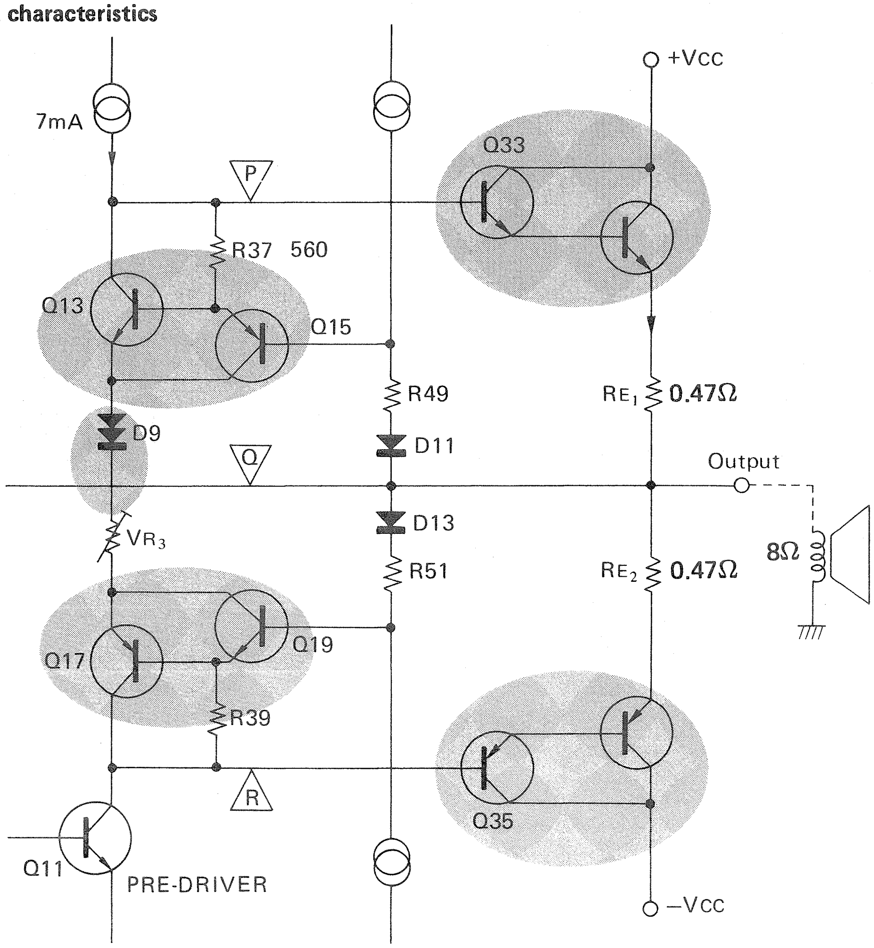



**Fig. 23 Components characteristics—compensated**

In Fig. 22 (1), the change of potential between P and Q appears between P and the base of Q15. So, the circuit can be considered an emitter-follower circuit in terms of AC, as shown in Fig. 22 (2). (The role of R49 and D11 is to keep the DC potential between the base of Q15 and point Q at 0.7V.)

As is generally known, the emitter-follower circuit has high input impedance characteristics, low output impedance, and no voltage amplification. Accordingly, this circuit functions without loading the pre-drive circuit or the Q13/Q15 circuit.

Similarly, Q19 functions as an emitter-follower circuit, and does not load the pre-drive circuit or the Q17/Q19 circuit. Each pair of Q13/Q15 and Q17/Q19 elements complements the other and the driver and output transistors as well; these comprise a part of the predriver's load and do not enter cut-off. Thus fluctuation in the pre-driver's total load is very small regardless of signal strength. This is also one of the reasons why distortion is small in the NS amplifier. (With Class B amps, drive and output transistors repeat on/off switching, and switching distortion is produced at the pre-driver stage as well.)

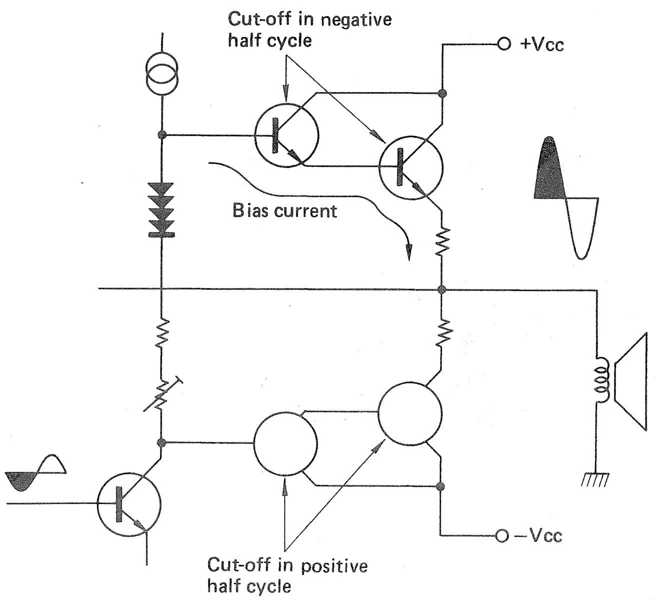
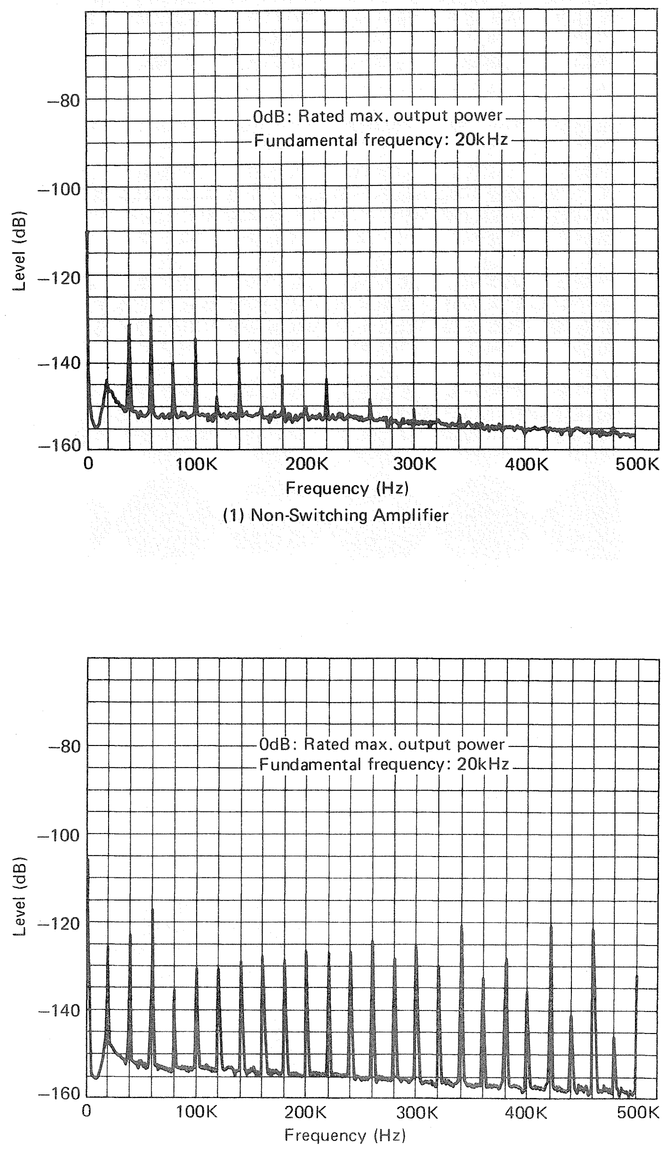



**Fig 24. Load fluctuation of pre-driver in Class B**

Another important point: the NS amplifier has a very high action speed. This is because the circuit is very simple, consisting only of four transistors and two resistors. Its action speed is fast enough to overcome the distortion which often is introduced in circuits using many more parts.

In conclusion, Pioneer's remarkable Non-Switching Amplifiers do achieve high output, high performance quality, high efficiency and very low distortion, especially in the high frequencies, combining, as many people have found to their satisfaction, the best merits and none of the demerits of both the Class A and Class B amplifiers. As a final proof of this, please take a look at our closing figure, Fig. 25 below:

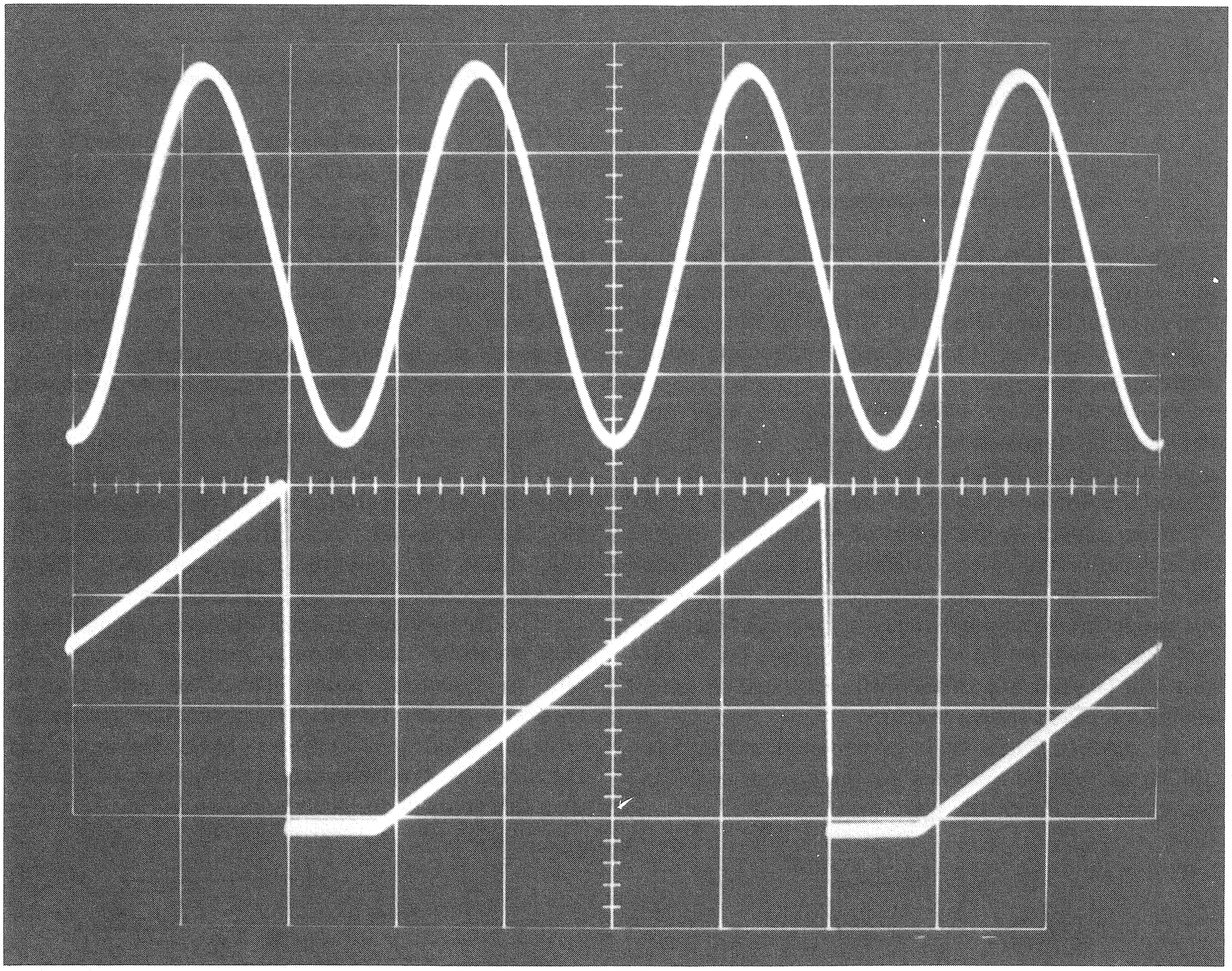



(1) Non-Switching Amplifier

(2) Conventional Class B Amplifier

**Fig. 25 Spectra of distortion in Non-Switching & Class B amplifiers**

# Measuring Instruments (4)
## The Oscilloscope(1)



The oscilloscope (hereinafter also called 'scope) is an instrument for measuring a change in a (electrical) signal, and displaying the findings graphically for visual observation by the naked human eye.

In this issue of TUNING FORK we will look closely at this, one of the most frequently used measuring instruments in daily service in the audio-equipment servicing field.

## 1. Principle

The structure of the cathode-ray tube used in the 'scope is shown in Fig. 1.

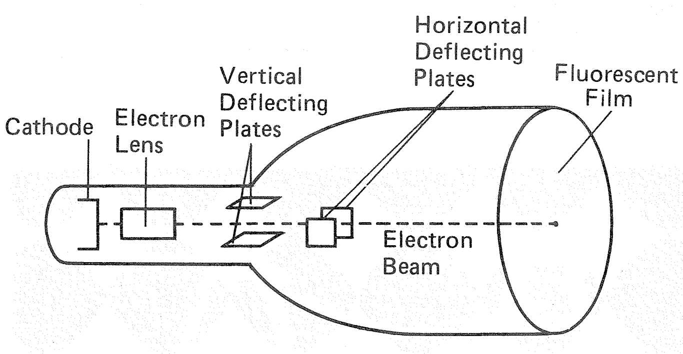



**Fig. 1 Structure of cathode-ray tube**

Electrons emitted by the cathode are focused and accelerated by the electron lens to become a thin electron beam. This beam strikes the fluorescent surface of the tube (i.e. screen), producing a small bright spot.

As electrons are negatively charged, they are attracted or repulsed when different voltages are applied to the deflecting plates facing each other. As this occurs, the position of the bright spot is shifted.

When signals to be observed are applied to the vertical deflecting plates, as shown in Fig. 2 (a), and the horizontal deflecting plates are fed a voltage input which changes linearly against time in a constant cycle, as shown in (b) of the same figure, the bright spot will travel in accordance with the lapse of time, leaving a locus as shown in (c).

By repeating this cycle as depicted in Fig. 3, a still image will be obtained on the screen, enabling visual observation of the waveform.

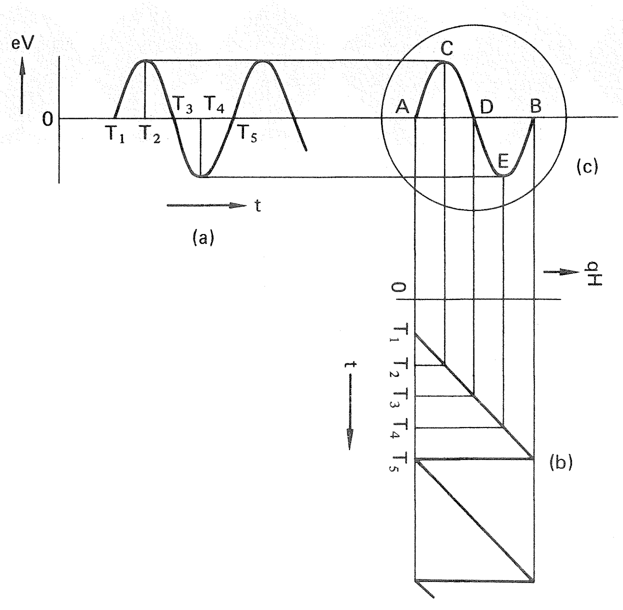



**Fig. 2 Locus of bright spot**

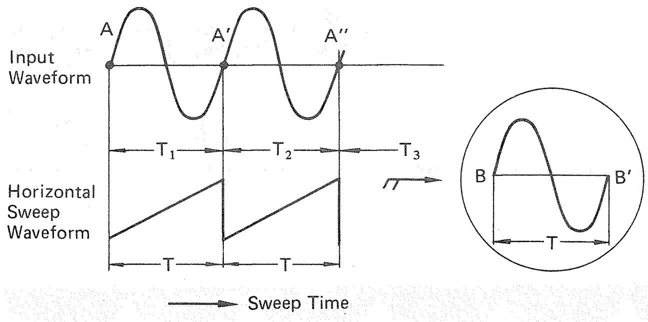



**Fig. 3 Formation of still waveform**

Usually, signals to be observed are applied to the vertical deflecting plates, while sawtooth signals, as shown in Fig. 2 (b), are applied to the horizontal deflecting plates to shift the bright spot on the screen from left to right. This is called "sweep."

The signals to be actually observed (the input signals of the 'scope) can have any frequency. But the sweep signals must change frequency in accordance with the input frequency, in order to change the sweep time.

When the frequency of the sweep signal differs even a bit from that of the input signal, the waveform will not hold still on the screen long enough to be observed visually. Similarly, the image will not hold still if the input frequency is unstable, even if the sweep signal frequency itself is stable.

The frequencies of input and sweep signals must have a certain constant relationship in order to obtain an observable image. The same holds true in regard to phase. To maintain a constant frequency ratio and phase relationship between the input and sweep signals, synchronization is required. To achieve this, the 'scope is designed as shown in Fig. 4.

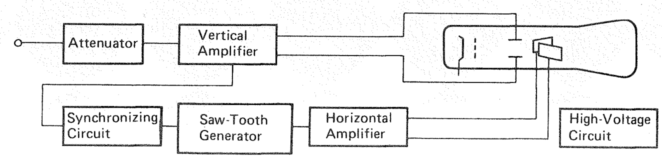



**Fig. 4 Basic structure of the oscilloscope**

## 2. Synchronization and Sweep

As explained, the 'scope must have a synchronization (sync) circuit to control the sweep signal in order to obtain a stable, observable image. Different synchronization methods require different sweep methods, and vice versa; there are two sweep methods: (1) the "repeating sweep" method which uses a constant frequency to sweep repeatedly, and (2) the "trigger sweep" method, in which sweeping starts when a signal is introduced.

Under the first method, a sawtooth wave for sweep is always being generated whether an input signal is present or not. When a signal is introduced, the sawtooth wave's frequency and phase will be adjusted to cause the waveform to hold still.

Therefore, the frequency ratio of the input signal and the sawtooth wave must be integrated. To maintain the integral ratio, the sync circuit of Fig. 4 uses part of the input signal, taking it from the vertical amplifier circuit, to make a sync signal and to control the sawtooth wave generating circuit to coercively synchronize the sawtooth wave with the repetition of the input signal.

It is necessary to adjust the sawtooth wave's frequency beforehand to integrate it with the input signal's frequency; synchronization cannot be achieved if the frequencies are too far from an integral ratio.

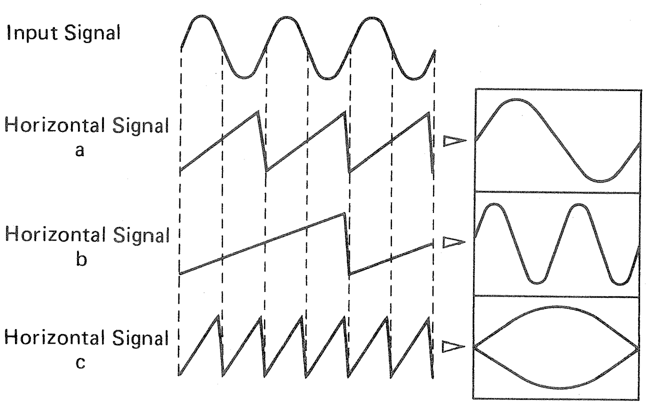



**Fig. 5 Synchronization of repeating sweep type 'scope**

By contrast, the trigger sweep type of 'scope begins to sweep only when an input signal is present; sweeping will not occur when an input is absent, and the screen will remain blank.

The sweep-signal generator operates on a signal from the trigger circuit, and will not sweep again until the next trigger signal comes along. This type of 'scope will thus always produce still waveforms whenever input signals are present.

As the sweep time of the sweep signal can be selected without regard to the input signal, input signals need not necessarily be regularly changing, repeating signals. Therefore it is possible to observe irregular-cycle signals or even a single signal, as shown in Fig. 7. Transient phenomena can also be observed.

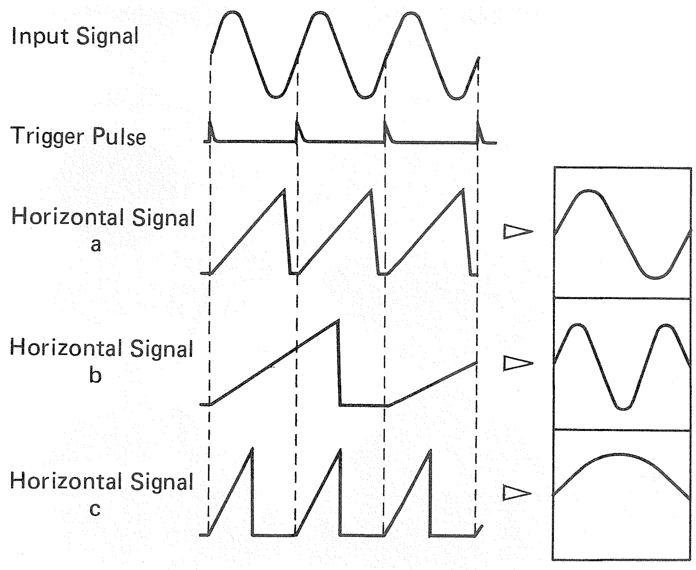



**Fig. 6 Synchronization of trigger sweep type 'scope**

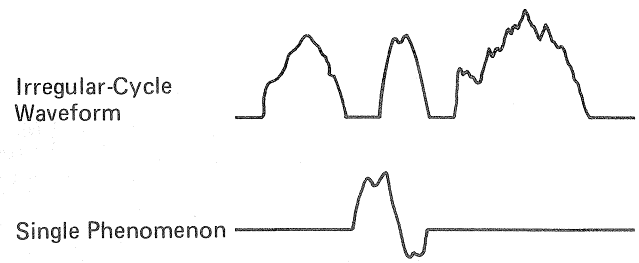



**Fig. 7 Irregularly changing signals**

As the sweep time of the trigger sweep type of 'scope is accurately calibrated, the cycle of the input signal and changes in it can be accurately measured.

The introduction of the trigger sweep system in 'scopes remarkably expanded the scope of observation and measurement, making it possible to use 'scopes in fields other than electronics and communications.

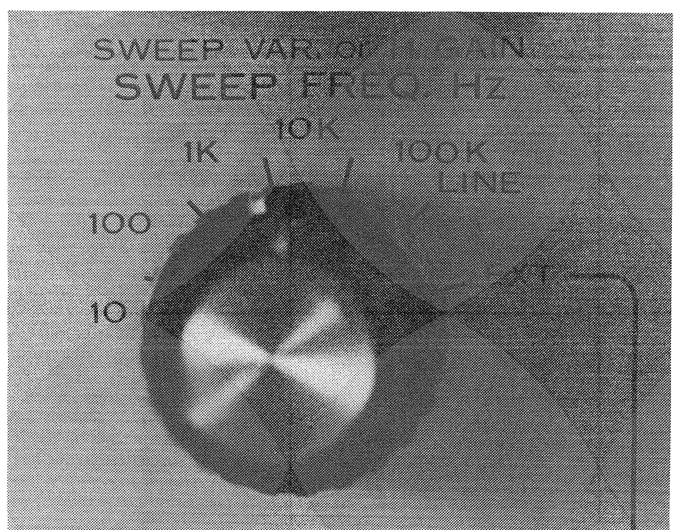



**Photo 1 Time base of repeating sweep type**

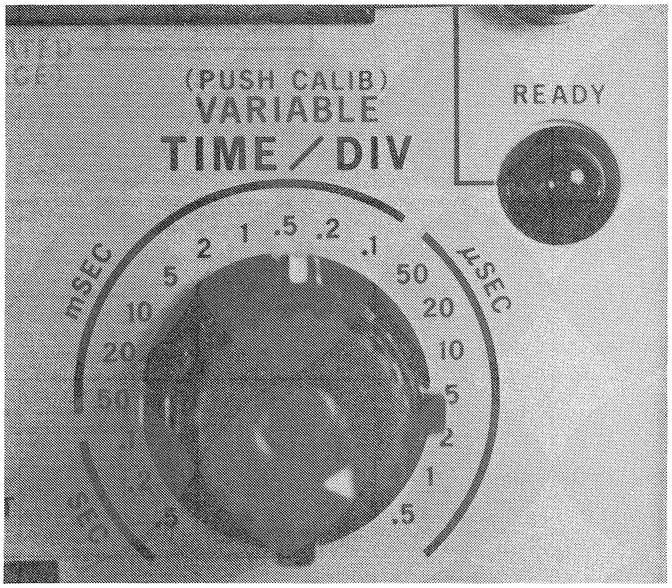



Photo 2 Time base of trigger sweep type

Fig. 8 shows the block diagram of a typical trigger sweep type 'scope.

Most 'scopes now produced, excluding low-end models for ordinary service bench use, are of the trigger sweep type. A 'scope of this type is an absolute necessity if first-class servicing is to be achieved.

### 3. The Dual-Trace Oscilloscope

The dual-trace 'scope used for service is our next topic of discussion. Two types are shown in the photos below:

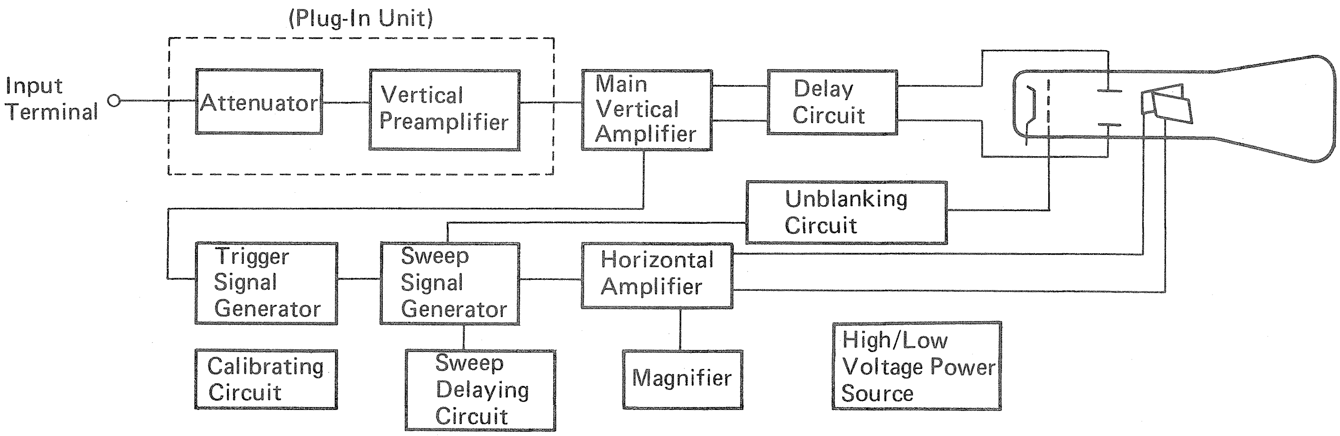



Fig. 8 Block diagram of trigger sweep 'scope

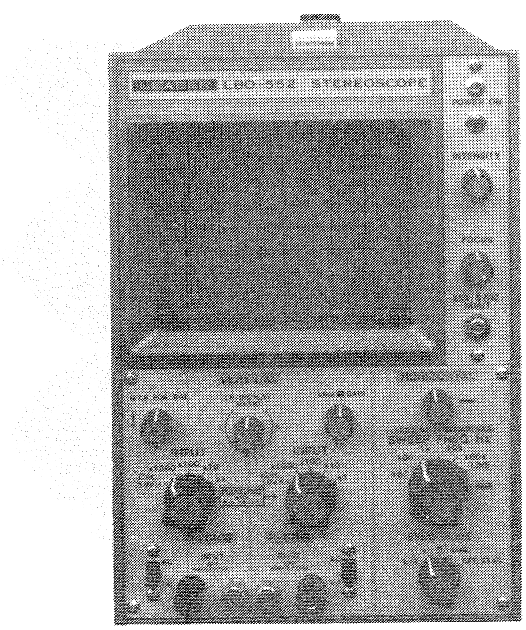



Photo 3 Dual-trace 'scope (1)

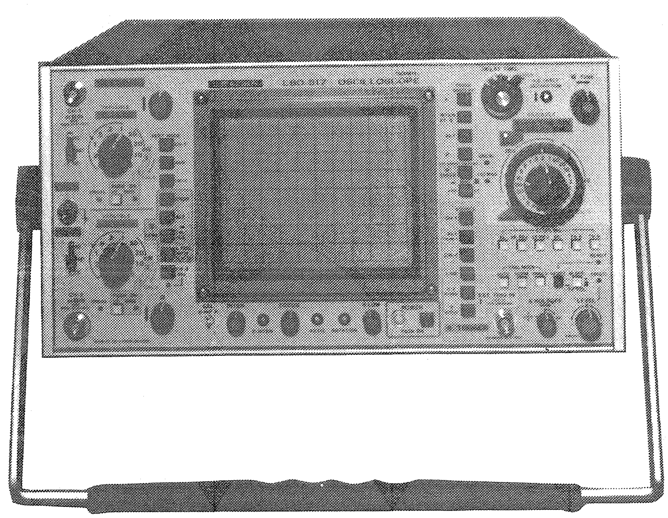


Photo 4 Dual-trace 'scope (2)

One of the types uses two electron guns, the other only one. They are detailed in Fig. 9:

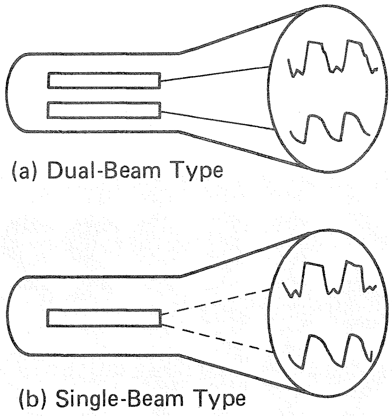



**Fig. 9 Dual-beam & single-beam 'scopes**

Photo 3 shows a dual-trace 'scope of the repeating type, while photo 4 is of a trigger type 'scope. Both use a single-beam cathode-ray tube. The dual-beam type is omitted from our discussion here because it is expensive and used only where super-high performance is required.

The single-beam dual-trace 'scope is equipped with two vertical amplifiers and a switching circuit for switching the amps' outputs alternately into the vertical deflecting plates.

The one in Photo 3 is designed especially for repairing and adjusting stereo equipment. If used only to observe signal waveforms and for comparison of signal levels in input/output, and left/right channels, its functions are sufficient and convenient. As it is relatively inexpensive, this type is widely used not only for servicing but also for checking on assembly lines.

With the flick of a knob it is possible to observe the waveform of either the left or right signals, or of both simultaneously. When you observe signals of both channels, it is especially easy to check level differences, since both waveforms are presented on the same line, separated to the left and right. (See Photo 5.)

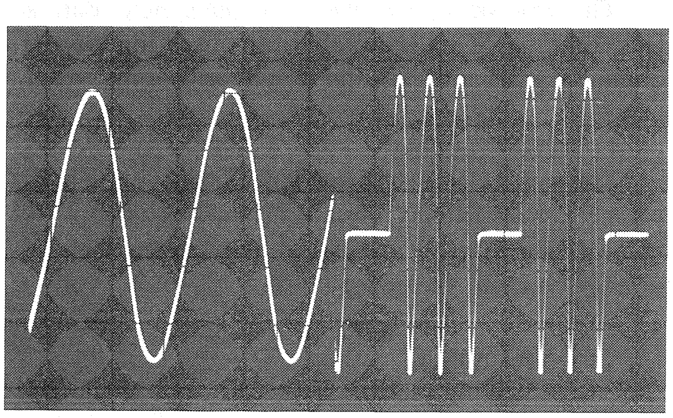


**Photo 5 2-channel type (1)**

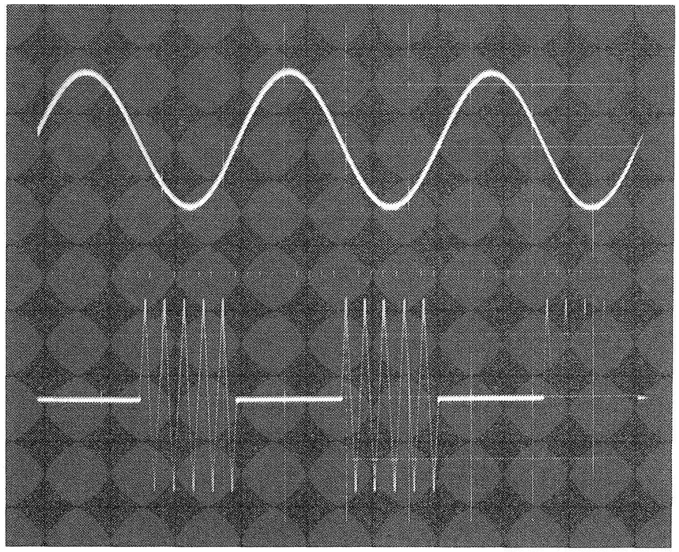


**Photo 6 2-channel type (2)**

But, because this 'scope is a repeating sweep type, it cannot be used for sophisticated purposes. By contrast, the 'scope in Photo 4 provides waveforms on two vertically separated planes, rather than separating them to the left and right on the same level. This enables accurate measuring of phase differences in and the timing of two signals simply by changing the mode of the vertical deflection system.

The vertical deflection modes are usually Channel 1, Channel 2, Chop and Alternate. Some models also offer Addition and Difference modes.

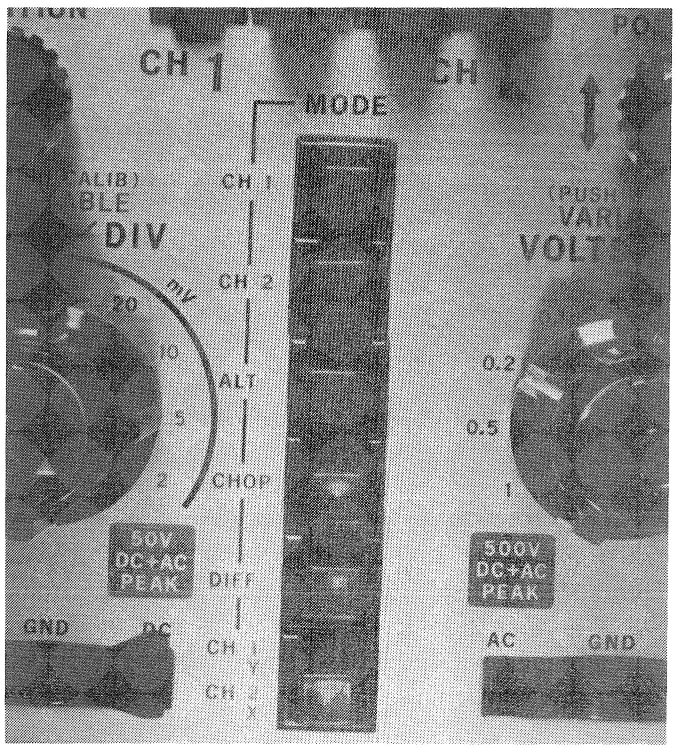



**Photo 7 Vertical Deflection Mode**

To observe two different signals simultaneously, use the Chop or Alternate mode. When the Chop mode is selected, the 'scope will switch from Input 1 to Input 2 signals, and vice versa, at high speed (200kHz to 1MHz), and display them on the screen.

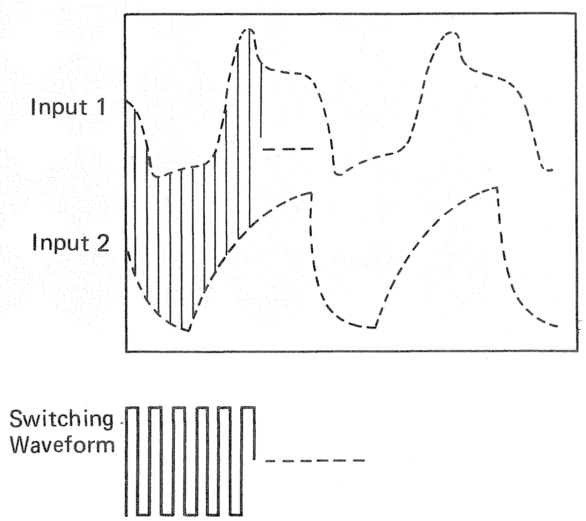



**Fig. 10 Sweep by Chop mode**

To measure time relations between two signals, always select the Chop mode. When the sweep speed is high, it is not easy to observe the waveforms, as they appear on the screen in bits.

The Chop mode is generally used when the input signal frequencies are low and the sweep speed is slow; when they are high, use the Alternate mode.

In the Alternate mode, the waveform of Input 1 signal will be displayed on the screen on the first sweep, and that of Input 2 signal on the second sweep, and so on.

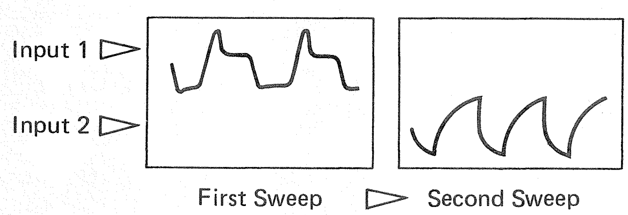



**Fig. 11 Sweep in Alternate mode**

Thus it becomes difficult to observe waveforms when the sweep speed is slow, since the two waveforms will be displayed alternately in a conspicuous way. In the Alternate mode, it is not possible to accurately observe the phase and time relations between the two signals.

4. How to Use Trigger Sweep 'Scopes

## Waveform Observation

We will omit mention of the actual operating procedures of 'scopes here (see individual model's instruction manual) and instead concentrate on some of the more obscure uses and capabilities. In the next issue of TUNING FORK we will continue this discussion, with measurement the main topic; for now, however, it is waveform observation which concerns us:

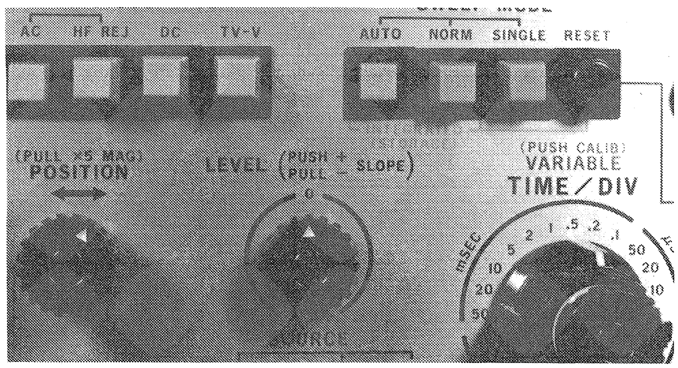



**Photo 8 Trigger coupling and Sweep modes**

### 1) On Trigger Coupling

The methods of trigger coupling—coupling of the sync signal and sync circuit—are AC coupling, low-pass filter coupling (HFREJ), DC coupling, and TV-V coupling for television signals.

The various methods are used in accordance with the nature of the input signal (AC, DC, AC-superimposed DC signal and complex signals of low and high frequencies):

[AC Coupling]

The sync signal is provided to the sync circuit by AC coupling. The DC component of the sync signal is cut off and synchronization is made only with the AC component. Thus synchronization can be done independently of the DC component in the sync signals.

AC coupling is generally the most convenient method. But synchronization is difficult when the frequency of the sync signal is low.

[DC Coupling]

The sync signal is provided to the sync circuit by DC coupling. This is suitable for observing low-frequency signals and irregular signals with long cycles.

[HFREJ Coupling]

The sync signal is provided to the sync circuit via a low-pass filter. Only low frequencies (generally those under 10kHz) are passed, eliminating high-frequency content, including noise.

[TV-V Coupling]

This coupling method is used for observing composite television signals for picture. A filter is used in this method, passing only those sync signals of compound pictures.

2) On Sweep Mode

Generally, a trigger sweep 'scope offers both NORMAL and AUTO sweep modes for use as the situation demands:

[NORMAL Sweep Mode]

Sweeping is carried out only when an input signal is present (the screen is blank when no signal is present). This mode is suitable for observing and measuring irregularly changing signals.

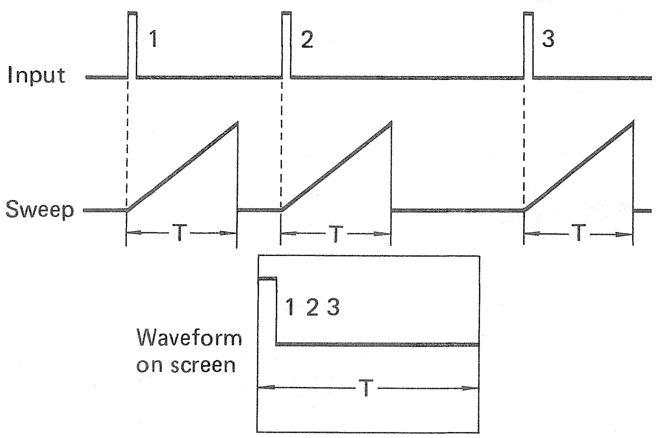



Fig. 12 Sweep in NORMAL sweep mode

[AUTO Sweep Mode]

In this mode, sweeping is carried out even if no input signal is present; the bright line remains on the screen at all times. This mode makes it easy to maintain synchronization even if the level of the input signal changes, or when the signal is superimposed by DC components. Thus this mode is the most frequently used for observing ordinary audio signals.

Use the NORMAL mode for low frequencies (40 Hz or lower) to avoid unstable synchronization.

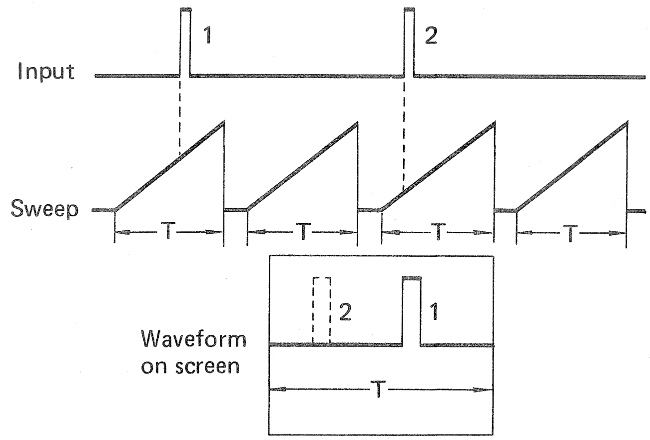



Fig. 13 Sweep by AUTO sweep mode

As mentioned, the next issue of TUNING FORK will discuss waveform measurement using the oscilloscope.

MEMO

## Specifications (3) .... Turntable

| | |
|---|---|
| urntable Platter: | ...otor DC motor (for platter drive) and Ancillary DC motor (for arm cueing). |
| | 12-3/16-inch (310mm) diam. Die-cast aluminum |
| ertial Mass: | 330kg. cm² (including rubber mat) |
| peeds: | 33-1/3 and 45 rpm |
| ow and Flutter: | No more than 0.025% (WRMS) No more than 0.013% (WRMS; measured directly from FG output) |
| nal-to-Noise Ratio: | More than 78dB (DIN B) |
| **ATIONAL CHARACTERISTICS** | |
| -up Time: | Within 90° rotation at 33-1/3 rpm |
| d Deviation: | No more than 0.002% |
| d vs. Load Characteristics: | Stable up to 220 grams drag load |
| d Drift: | No more than 0.00008%/h at 33-1/3 rpm |
| | No more than 0.00003%/degree temp. change at 33-1/3 rpm |
| **ARM** | |
| | Linear motor direct-drive, Static-balance type, Tangential tracking arm |
| Arm Length: | 7-1/2-inch (190mm) |
| g: | 0mm |
| artridge Weight: | 4g (min.) to 14g (max.) |
| | 14g (min.) to 23g (max.) (with auxiliary weight) |
| t Adjustment Range: | ±3mm |
| **E** | |
| | ...Automatic Lead/Cut/Retu... Quick-Repeat/Play/Off, Direct-readout counterweight, Quick-start/stop system, Arm height adjusting device, Electronic cueing device, Free-hinged acrylic cover, Arm clamper, Spirit level |
| **SEMICONDUCTORS** | |
| ICs: | 23 |
| Transistors: | 14 |
| Diodes: | 18 |
| Hall Elements: | 3 |
| LEDs: | 14 |
| Photo Transistors: | 5 |
| CdS: | 1 |
| **MISCELLANEOUS** | |
| Power Requirements: | 110/120/220/240V (switchable) 50-60Hz |
| Power Consumption: | 35 watts |
| Dimensions: | 19-7/16(W) x 6-1/16(H) x 17-15/16(D) inches 494(W) x 154(H) x 456(D) mm |
| Weight: | 26 lb. 8 oz./12kg |

The turntable's only job is to assist in the reproduction of music (or other audio information) recorded on a phonograph record. Basically, it consists of a cabinet, a platter, a motorized drive system for that platter, and a tone arm/cartridge/stylus.

Because the turntable is the "entrance" to the sound reproduction system for disc-recorded sound, it must be able to deliver good performance; if the signal it sends to the phono equalizer/amplifier is poor, the quality of the resulting reproduction will also be poor, no matter how good the other components are.

There are many factors to be considered in judging the performance of a turntable. Among them are: output voltage, preproduction frequency characteristics, distortion. separation, signal-to-noise ratio, wow/flutter. As most high-quality turntables these days are equipped with a universal-type tone arm to permit the changing of cartridges, we will omit from this discussion all references to tone arms and cartridges and concentrate on platter-drive and related systems.

The first subject to be covered will be the performance of the phonomotor (hereafter called, simply, motor) and the performance criteria by which it is judged, namely wow and flutter and the signal-to-noise ratio (hereafter called wow/flutter and S/N, respectively).

# I. WOW/FLUTTER

## 1. Definition of Wow/Flutter

Wow and flutter are fluctuations of reproduction frequencies which stem from distortion of motion of a turning body (the platter, in the case of a turntable). They are evidence of changes in rotating speed. A fluctuation of relatively slow cycle is called *wow;* one occurring at a higher cycle is termed *flutter*. When a fluctuation has an extremely slow cycle, it is called *drift*, and considered separately from wow/flutter.

The International Electro-Technical Commission (IEC), which adjusts and unifies international standards in the electric field, defines irregularities in rotation as follows:

- Wow: An undesirable frequency modulation component introduced into a signal due to the irregular motion of a recording medium, usually at a frequency ranging from 0.1 to 10Hz, during recording or reproducing operation.
- Flutter: An undesirable frequency modulation component introduced into a signal due to the uneven motion of a recording medium, usually at a frequency higher than 10Hz, during recording or reproducing operation.
- Drift: A slow deviation in the speed at which a recording medium travels through a recording or reproducing device.

As specified in the definitions, wow/flutter signals are a kind of FM wave and are represented in percentage of the value obtained by $\Delta f/f$ as shown below:

$$\text{wow/flutter} = \frac{\Delta f}{f} \times 100\ (\%)$$

## 2. Standards on Wow/Flutter Measurement

Because wow/flutter factors are equal to the reproduction signal's frequency change as explained above, a wow/flutter value can be obtained by detecting, in the same way as an FM receiver does, and measuring the amount of deviation.

Fig. 1 shows the principle of wow/flutter measurement. For actual measurement, a wow/flutter meter is used as shown in the block diagram of Fig. 2:

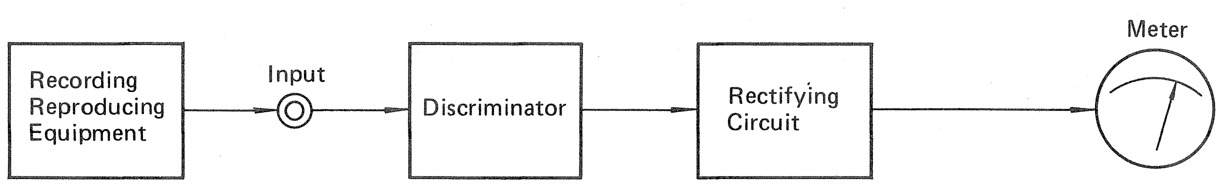



**Fig. 1 Measuring wow/flutter**

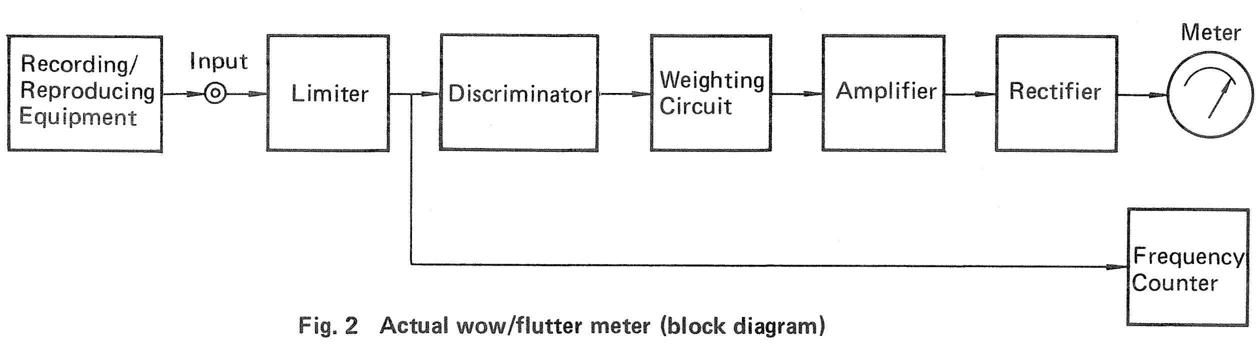
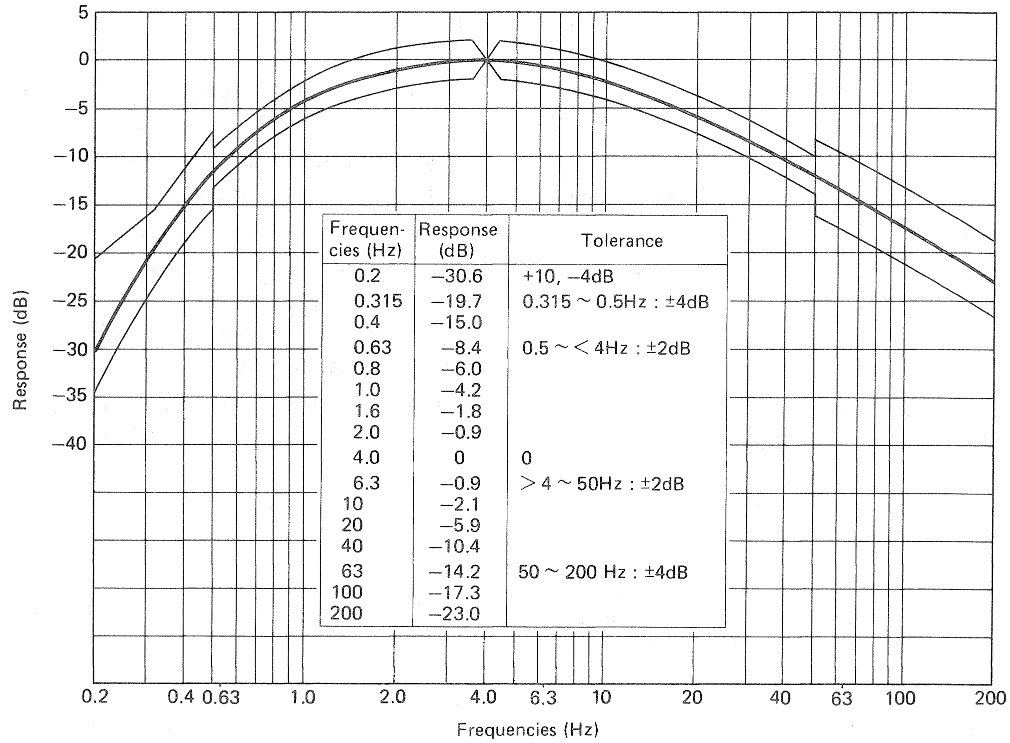



**Fig. 2 Actual wow/flutter meter (block diagram)**

The human ear's sensitivity to sound level differs with frequency. Wow/flutter frequencies are low—in the area where human hearing is relatively insensitive. Therefore, in measuring wow/flutter, the measured value is compensated (weighted) to make the measuring instrument's response similar to a human's. This is achieved by raising the meter's response to those frequency components which are easily heard by the human ear, and by stepping down its response to those which are not.




| Frequencies (Hz) | Response (dB) | Tolerance |
|---|---|---|
| 0.2 | −30.6 | +10, −4dB |
| 0.315 | −19.7 | 0.315 ~ 0.5Hz : ±4dB |
| 0.4 | −15.0 | |
| 0.63 | −8.4 | 0.5 ~ < 4Hz : ±2dB |
| 0.8 | −6.0 | |
| 1.0 | −4.2 | |
| 1.6 | −1.8 | |
| 2.0 | −0.9 | |
| 4.0 | 0 | 0 |
| 6.3 | −0.9 | > 4 ~ 50Hz : ±2dB |
| 10 | −2.1 | |
| 20 | −5.9 | |
| 40 | −10.4 | |
| 63 | −14.2 | 50 ~ 200 Hz : ±4dB |
| 100 | −17.3 | |
| 200 | −23.0 | |

**Fig. 3 Weighting curve**

It is worthwhile to touch here on the indication system in connection with the rectifying circuit and the meter. It is possible to display a wow/flutter value on the meter in three ways:

1) the peak value,
2) the average value, and
3) the effective value.

Which display method to select depends on one's way of thinking, and none can be said to be "best."

A difference in views affects not only the meter indication system, but also other matters, such frequencies to be measured, the range of wow/flutter, operational characteristics of a meter and weighting characteristics. Therefore, there are many different standards concerning wow/flutter in such countries as West Germany, the United States and Japan. Those standards are shown in Table 1. Details of wow/flutter standards are shown in Table 2.

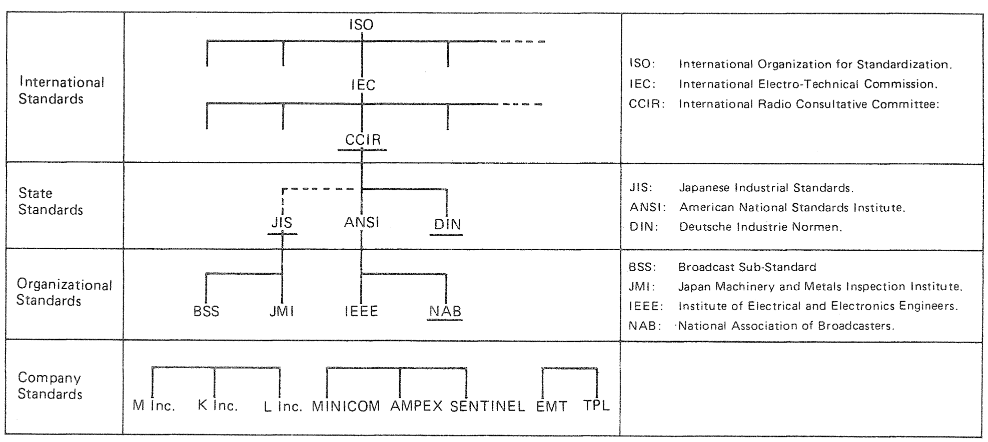
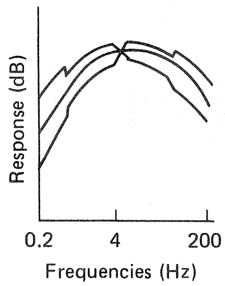
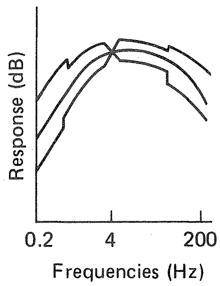
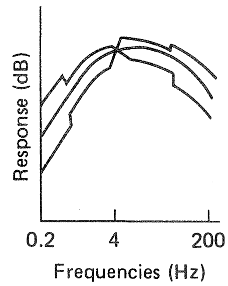
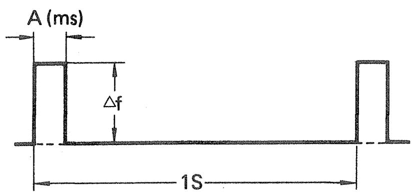
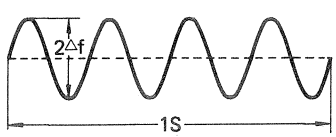
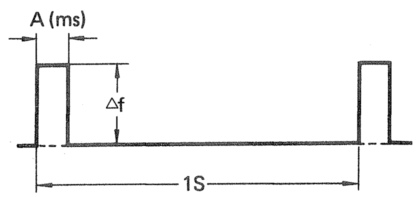
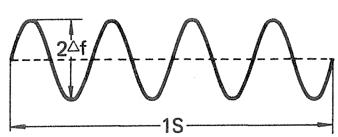



**Table 1 Various wow/flutter standards**

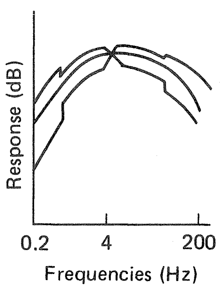
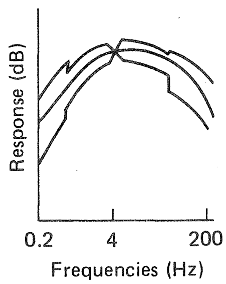
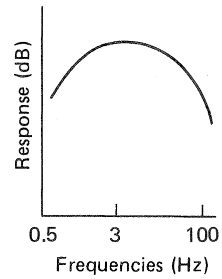
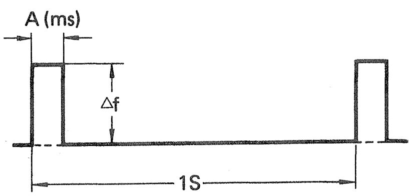
<table>
<tr><th>Standards / Items</th><th>IEC<br>1969</th><th>CCIR<br>1966</th><th>JIS<br>C-5551-1971</th></tr>
<tr><td>Meter indication</td><td>Peak value</td><td>Peak value</td><td>Effective value</td></tr>
<tr><td>Measuring frequencies</td><td>3,150Hz</td><td>3,000Hz</td><td>3,000Hz</td></tr>
<tr><td>Wow/flutter frequencies</td><td>0.2–200Hz</td><td>0.2–200Hz</td><td>0.2–200Hz</td></tr>
<tr><td>Weighting characteristics</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Meter's dynamic characteristics</td><td>When pulses, having a repeating cycle of 1Hz and width (A) mentioned below, are given to the meter, it must indicate the values (B) respectively, as follows:
<table><tr><td>A (mS)</td><td>10</td><td>30</td><td>60</td><td>100</td></tr><tr><td>B (%)</td><td>21±3</td><td>62±6</td><td>90±6</td><td>100±4</td></tr></table>
For meter calibration, an FM wave, bi-directionally modulated by a 4Hz sine wave having the same amplitude in P-P value as that of the above-mentioned pulse, is used for 100% scaling.<br>As to the recovery characteristics, pulses having a repeating cycle of 1Hz and width of 100mS are given to the meter.<br>The meter must indicate 40±4% of full-scale between the pulses.</td><td>When pulses, having a repeating cycle of 1Hz and width (A) mentioned below, are given to the meter, it must indicate the values (B) respectively, as follows:
<table><tr><td>A (mS)</td><td>10</td><td>30</td><td>60</td><td>100</td></tr><tr><td>B (%)</td><td>21±3</td><td>62±6</td><td>90±6</td><td>100±4</td></tr></table>
For meter calibration, an FM wave, bi-directionally modulated by a 4Hz sine wave having the same amplitude in P-P value as that of the above-mentioned pulse, is used for 100% scaling.<br>As to the recovery characteristics, pulses having a repeating cycle of 1Hz and width of 100mS are given to the meter.<br>The meter must indicate 40±4% of full-scale between the pulses.</td><td>Pulse width 5 sec.<br>Indication 100±5%</td></tr>
<tr><td>Test signals</td><td>

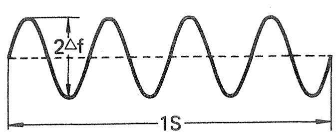
(1) Pulse to specify meter deflection


(2) Sine wave for FM modulation used for meter calibration.</td><td>

(1) Pulse to specify meter deflection


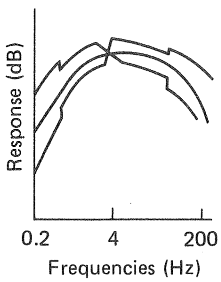
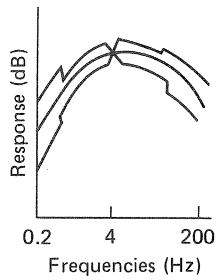
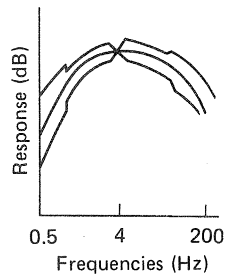
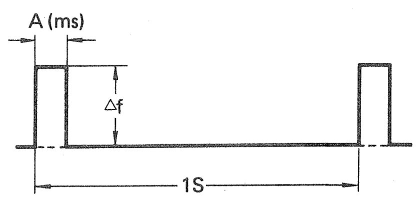
(2) Sine wave for FM modulation used for meter calibration.</td><td></td></tr>
</table>

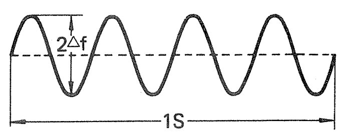
<table>
<tr><td>ANSI<br>S4.3-Drft-1971</td><td>DIN<br>45507-1966</td><td>BSS<br>21-9603-1964</td></tr>
<tr><td>Peak value</td><td>Peak value</td><td>Effective value</td></tr>
<tr><td>3,150Hz</td><td>3,150Hz</td><td>3,000Hz</td></tr>
<tr><td>0.2–200Hz</td><td>0.2–200Hz</td><td>0.5–100Hz</td></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Same as IEEE</td><td>When pulses, having a repeating cycle of 1Hz and width (A) mentioned below, are given to the meter, it must indicate the values (B) respectively, as follows:
<table>
<tr><td>A (mS)</td><td>10</td><td>30</td><td>60</td><td>100</td></tr>
<tr><td>B (%)</td><td>21±3</td><td>62±6</td><td>90±6</td><td>100±4</td></tr>
</table>
For meter calibration, an FM wave, bi-directionally modulated by a 1Hz sine wave having the same amplitude in P-P value as that of the above mentioned pulse, is used for 100% scaling.<br>
As to the recovery characteristics, pulses having a repeating cycle of 1Hz and width of 100mS are given to the meter.<br>
The meter must indicate 41±4% of full-scale between the pulses.</td><td>Not specified</td></tr>
<tr><td></td><td>

(1) Pulse to specify meter deflection


(2) Sine wave for FM modulation used for meter calibration.</td><td></td></tr>
</table>

**Table 2 Details of various wow/flutter standards**

<table>
<tr><th>JMI<br>1967</th><th>IEEE<br>193-1971</th><th>NAB<br>1965</th></tr>
<tr><td>Effective value</td><td>Peak value</td><td>Average value</td></tr>
<tr><td>3,000Hz</td><td>3,150Hz</td><td>3,000Hz</td></tr>
<tr><td>0.2–200Hz</td><td>0.2–200Hz</td><td>0.5–200Hz</td></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Not specified</td><td>When pulses, having a repeating cycle of 1Hz and width (A) mentioned below, are given to the meter, the meter must indicate the values (B) respectively, as follows:
<table>
<tr><td>A (mS)</td><td>10</td><td>30</td><td>60</td><td>100</td></tr>
<tr><td>B (%)</td><td>21±3</td><td>62±6</td><td>90±6</td><td>100±4</td></tr>
</table>
For meter calibration, an FM wave, bi-directionally modulated by a 4Hz sine wave having the same amplitude in P-P value as that of the above-mentioned pulse, is used for 100% scaling.<br>
As to the recovery characteristics, pulses having a repeating cycle of 1Hz and width of 100mS are given to the meter.<br>
The meter must indicate between 36–44% of full-scale between the pulses.</td><td>Use the standard decibel meter as stipulated in ASA C-16. 5-1961.</td></tr>
<tr><td></td><td>

(1) Pulse to specify meter deflection<br>


(2) Sine wave for FM modulation used for meter calibration.</td><td></td></tr>
</table>

The existence of various standards for measuring wow/flutter makes comparison difficult. Each standard once had its own weighting curve. But DIN, that West German one with the most clear-cut regulations, was proposed to CCIR, an international standard council, as an international standard. CCIR adopted it in 1966.

The CCIR weighting curve was then adopted by most of the major organizations, such as IEC, JIS, ANSI, IEEE and NAB, one after another, finally becoming the common international standard.

Only four standards—CCIR, DIN, JIS and NAB—are used internationally at present.

Pioneer provides measured values based on JIS as far as wow/flutter is concerned. DIN-based measured values are used for supplementary purposes when called for.

The letters WRMS (Weighted Root Mean Square) seen in specification sheets means that the value is the effective reading after weighting—that is, the value in RMS obtained through measurments made in accordance with JIS.

### 3. Measuring Wow/Flutter

There are three methods most commonly used in measuring wow/flutter. They make use of:

1) a test record or a lacquer disc,
2) a rotary encoder, or,
3) direct reading of an the output of a Frequency Generator (FG).

#### 1) Test Record/Lacquer Disc Method

A test record, in which a 3kHz or 3.15kHz signal is recorded, is played and the reproduced signal is measured by a wow/flutter meter.

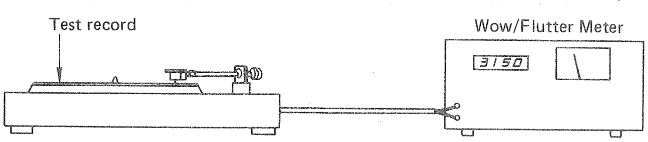



**Fig. 4 Test record/lacquer disc wow/flutter measuring**

This method was once widely used because it is simple and requires no special apparatus. However, it is seldom used now because it is difficult to perfectly center the test record, thus a different value is produced every time measurement is made. Also, the high residual wow/flutter makes it impossible to measure high-performance turn-tables, such as those direct-drive types using quartz-DD servomotors. Also, this method cannot measure wow/flutter of less than 0.05%.

In place of the test record, a lacquer disc may be used. Such a disc, made with special consideration to circular precision, raises the accuracy of wow/flutter measurement to 0.02%.

However, because the disc is made of an easily deteriorated material, it cannot be used repeatedly, and is generally employed only in cases requiring the evaluation of nominal wow/flutter values under designated measuring conditions. Also, lacquer discs are not generally available.

Photo 1 shows a typical wow/flutter meter:

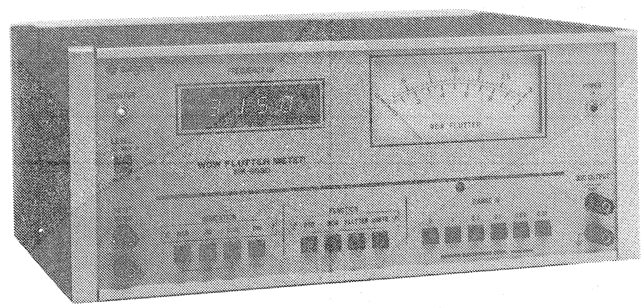


**Photo 1 Wow/flutter meter**

#### 2) Rotary Encoder Method

A rotary encoder can be used in place of a record as the source of signals for wow/flutter measurement. (See Fig. 5.)

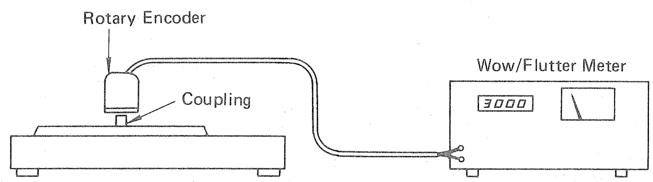



**Fig. 5 Wow/flutter measurement using rotary encoder**

A rotary encoder is a kind of transducer that generates signals of a frequency proportional to the speed of rotation. Photo 3 shows such a rotary encoder, while Fig. 6 shows its principle.

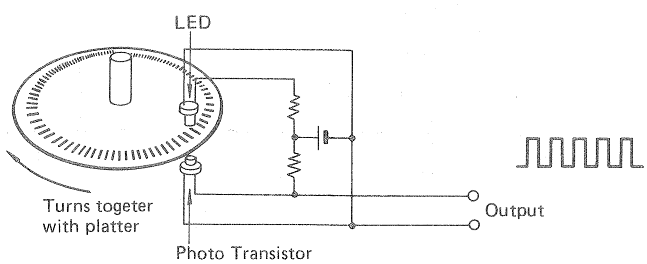



**Fig. 6 Principle of rotary encoder**

Basically, a rotary encoder consists of a photo coupler and a rotating glass disc which has numerous stripes inscribed on its perimeter with very high precision. The disc turns together with the platter.

The number of stripes is determined by the frequencies required. When the platter's rotating speed is 33-1/3 rpm and the frequency is 3,000Hz, the number of stripes $\chi$ can be obtained as follows:

$$\frac{100}{3} \times \frac{1}{60} \times \chi = 3{,}000$$

$$\frac{100\chi}{180} = 3{,}000$$

$$\therefore \chi = \frac{180 \times 3{,}000}{100} = 5{,}400$$

Similarly, when the frequency is 3,150Hz, the number of stripes is 5670.

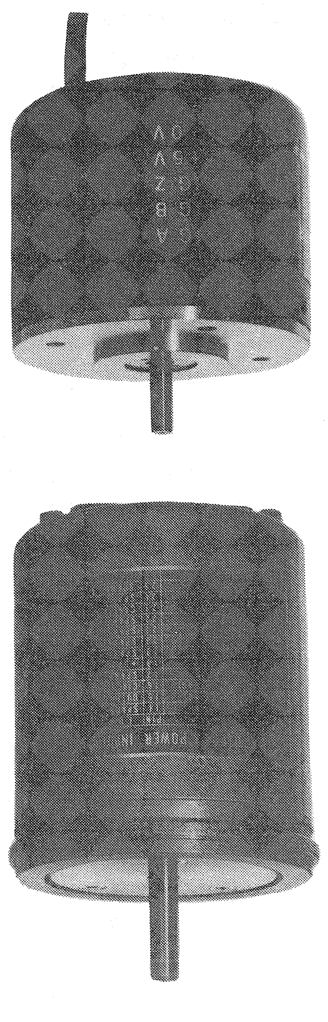


Photo 2 Rotary encoder

Wow/flutter measurement using a rotary encoder is somewhat complicated when compared with the test record method. But the measuring precison is far superior; even the residual wow/flutter of the rotary encoder itself (0.01%) can be measured, theoretically. A drawback is that this measuring system can become large (and expensive), and is not suitable for general use. Instead, it is employed on the assembly line in situations requiring high precision and high productivity.

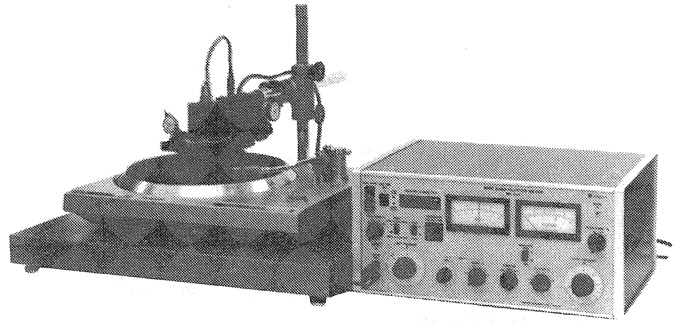


Photo 3 Wow/flutter measurement using rotary encoder

3) The FG Output Reading Method

It is no exaggeration to say that the history of turntables is the history of the phonomotor. The Pioneer EXCLUSIVE P3, recently marketed, features a wow/flutter of only 0.003% or less.

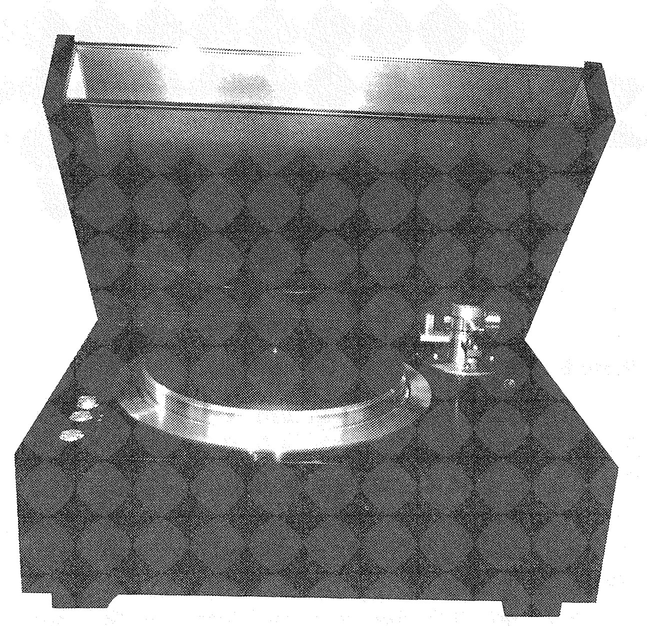


Photo 4 EXCLUSIVE P3 turntable

When the value is so small, it is impossible to measure with conventional methods. This is where the FG output direct-reading method is useful.

The surprisingly small wow/flutter value of the P3 was made possible only with the introduction of a motor with a quartz-PLL DD servo. This type of motor has a built-in frequency generator (FG) that generates a signal of a frequency proportional to the rotation speed. Under the FG output direct-reading system, the output of the FG is, after appropriate amplification, introduced directly into a wow/flutter meter for measurement.

This is an ideal method with, theoretically, no measuring error because nothing exists between the object of measurement and the measuring instrument.

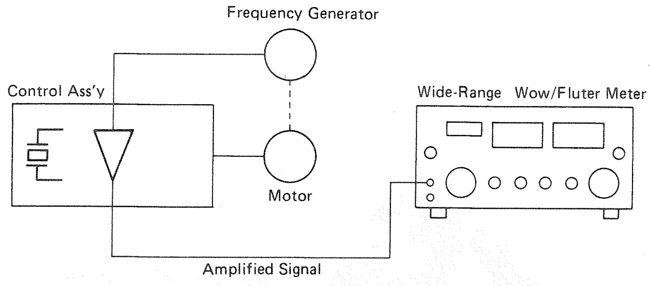



**Fig. 7 Wow/flutter measurement with FG output direct-reading method**

Photo 5 depicts the frequency generator of a quartz-PLL DD motor.

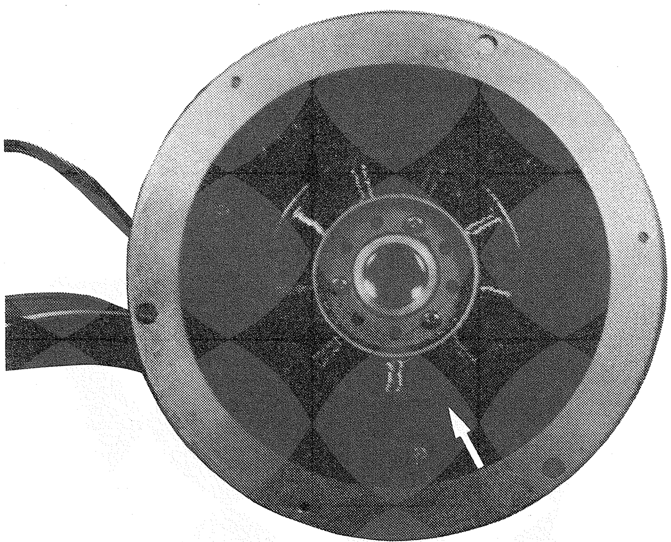


**Photo 5 FG in Quartz-PLL DD motor**

But there is one problem. Conventional wow/flutter meters cannot be used in this method because the FG output frequency is neither 3kHz nor 3.15 kHz (the FG output frequency of a quartz-PLL DD motor is 55.5 or 222Hz at 33-1/3rpm and 75Hz or 300Hz at 45rpm).

In order to measure wow/flutter with frequencies other than those designated (3kHz or 3.15kHz), a wide-band type wow/flutter meter has been recently developed (Photo 6).

As any desired frequency (from 10Hz to 100 kHz) can be used as the input signal, this new meter is quite appropriate for directly measuring the FG output.

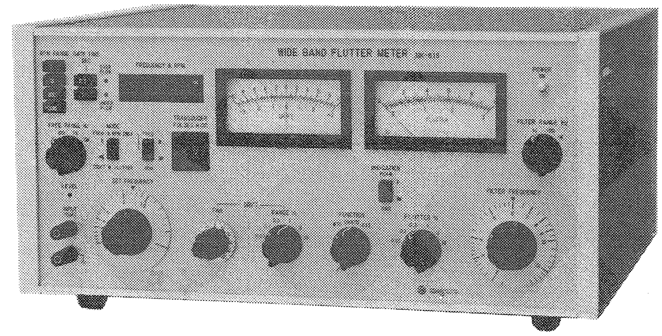



**Photo 6 Wide-band wow/flutter meter**

Wow/flutter values obtained by the FG output direct-reading method are so noted in Pioneer specifications sheets when appropriate.

## II. SIGNAL-TO-NOISE RATIO

### 1. Definition of Signal-to-Noise Ratio

The term signal-to-noise (S/N) ratio is used in audio, telecommunications and related fields. The S/N ratio used for turntables is also defined as the following:

$$S/N\ RATIO = 20 \log \frac{S}{N}\ (dB)$$

S stands for the required signal, or the output level of a record in which a signal of a designated frequency is recorded at a designated (i.e. standard) level.

N is for the unnecessary (and undesirable) noise generated by the turntable. The noise level is determined by reproducing noise from a soundless groove of a record with a very low noise level.

Most turntable noise is due to mechanical vibrations from the motor. In practice, noise generated by electric and magnetic induction to signal lines as well as that of the test record used for measurement, are also to be considered.

The noise level described here means the level measured after the turntable's output signal is passed through a weighting filter, which will be explained later.

### 2. Various Standards on S/N Ratio

Like wow/flutter, no internationally unified standard exists for measuring the S/N ratio. Therefore, S/N VALUES may reflect different measuring methods.

The standards usually used for measuring S/N are DIN-A, DIN-B, JIS and IEC-B. Each has a different S, or standard level, and uses different weighting characteristics in relation to N. Therefore, simple comparison of specified S/N values cannot tell which turntable is superior unless one confirms the standards by which the values were measured.

JIS, DIN-A, DIN-B and IEC-B are the standards currently used internationally. A test record is used for measuring S/N, whichever standard is employed. Table 3 shows regulations on test record modulation.

S/N ratios of all Pioneer turntables represent figures obtained by DIN-B measurement.

| Standard | Standard Signal | Weighting Standard |
|---|---|---|
| DIN-A | 315Hz 5.42cm/sec. 45° direction peak speed | 1 |
| DIN-B | 315Hz 5.42cm/sec. 45° direction peak speed | 2 |
| JIS | 1kHz 5cm/sec. Horizontal direction peak speed | 3 |
| IEC-B | 1kHz 5cm/sec. Horizontal direction peak speed | 4 |

**Table 3 Modulation standards for test record used in measuring S/N**

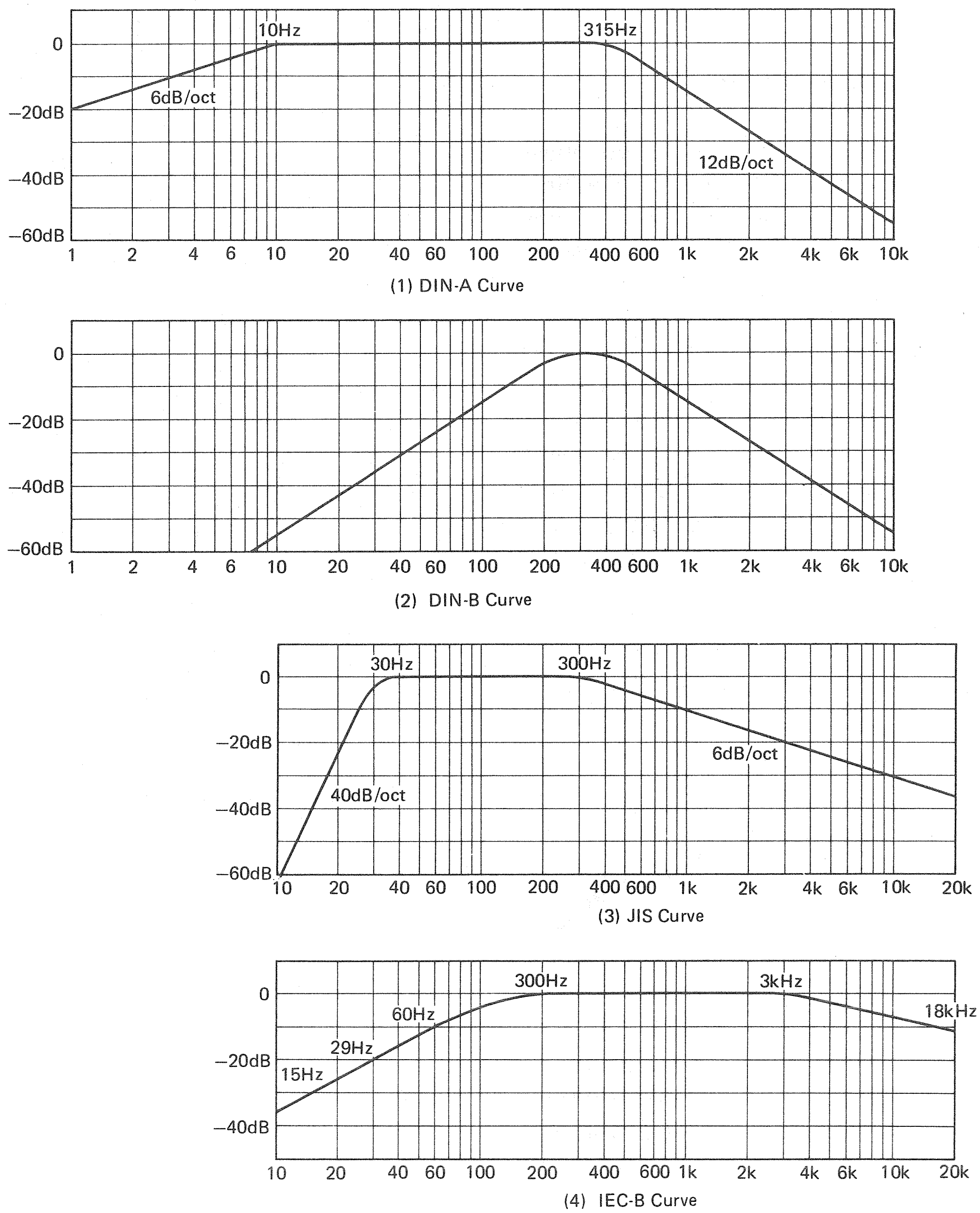



**Fig. 8 S/N weighting curves**

## 3. Measuring S/N Ratio

Ambient vibrations must be paid special attention when undertaking the measurement of S/N in a turntable. Unlike other audio equipment, such as amplifiers, tuners and tape decks, turntables are prone to influence from vibrations in the environment, such as floor vibrations. These must be kept small enough to be ignored completely. Otherwise, a turntable's true S/N ratio cannot be measured.

To avoid the influence of ambient noise, S/N measurements are carried out as shown in Fig. 9 (measuring by DIN-B standard).

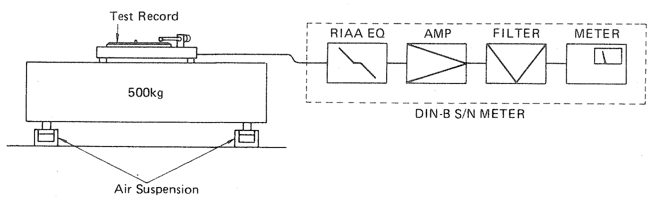



**Fig. 9 Measuring S/N ratio**

The subject turntable is placed on a special measuring stage, which is 500kg in weight, "floating" free of the floor on an air-suspension device having an automatic balancing function. Thus it is possible to completely ignore the effects of floor vibration in measuring S/N.

It goes without saying that the test record to be used must be manufactured to DIN-B specifications, including the modulation standard shown in Table 3.

Turntable output is amplified to a necessary level after going through an RIAA equalizer, then passes through a designated filter [See Fig. 8 (2)] to be input to the level meter. (The entire section contained in the broken line is the S/N ratio meter designated by DIN-B.)

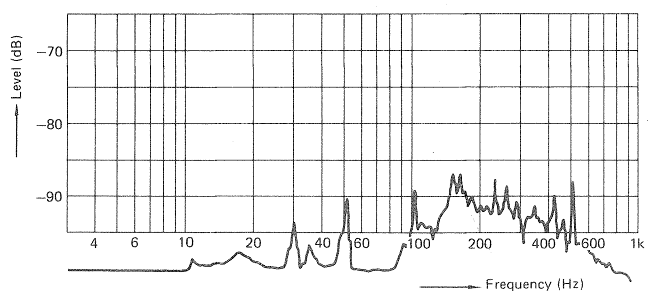



**Fig. 10 Noise spectrum**

The stylus traces the soundless groove of the test record from the beginning to end, and measurements are made of noise levels in both the left and right channels. The S/N ratio displayed represents the lowest (i.e. worst) level measured.

DIN-B stipulates, further, that the ratio must be 55dB or more for turntables.

The S/N ratio as total value can be learned from the S/N meter in Fig. 9. For further confirmation, a spectrum analyzer is connected to the meter's output to analyze noise components. (Even if the total S/N ratio is good, the noise level could be high at a specific frequency. A noise component analysis is conducted to see if such high noise peaks exist.)

Fig. 10 is an example of the noise spectrum.

## III. EVALUATION OF TURNTABLE PERFORMANCE

The performance of turntables has made remarkable progress in recent years. As specification sheets of Pioneer turntables show, even our low-end models boast wow/flutter of less than 0.025% and S/N ratios of more than 75dB.

What do these values mean in practice?

Suppose you are playing a record which is made on a cutting lathe whose wow/flutter is zero or nil, and that your turntable also has negligible wow/flutter. If the record itself has uneven concentricity—that is, if there is even the most minute amount of play between the record and the turntable's center shaft,—wow/flutter can be introduced.

If the record is 0.05mm off center on the platter, the total eccentricity will be 0.1mm. Therefore, wow/flutter at the outermost groove of a 30cm dia. record will be 0.033333% from $\frac{0.1\ (\text{mm})}{300\ (\text{mm})} \times 100$. (Naturally, the value will be much larger as the stylus traces the inner grooves.)

Because it is difficult to manufacture records with perfectly-sized center holes, and because the wow/flutter values in the cutting lathe and turntable are never zero in reality, it can be said that it is impossible to reproduce music entirely free of wow/flutter of better than 0.03%. Unless, that is, the shape of the record itself and the kind of system used to play it are changed.

Next, let's discuss what an S/N of, for instance, 60dB actually means.

The figure represents a ratio of noise components to signal in the area of 1/1000. In turn, this means that when reproduced sound has a similar value, noise can be totally disregarded—that is, it is inaudible by the human ear. (When you listen to music with a peak output level of 100W, the noise level will be about $\frac{100\text{W}}{1{,}000^2}$ or 0.1mW.)

This, as you will appreciate, presents no problem whatsoever as far as the appreciation of music is concerned.

Actually, however, noise will become conspicuous when the volume is raised, even if high-quality records are used, such as those recorded with the Dolby A or a similar noise reduction system, or those made by the direct-to-disc method.

Record noise consists of noise components derived from the recording material, and from the pressing process, those caused by the cutting lathe, by the hiss noise of master tapes, etc. When all these are translated into a S/N ratio, it is apparent that a value of 60dB is difficult to reach.

Thus as shown, the values now obtained in Pioneer turntables—namely 0.03% or better wow/flutter and 60dB or better S/N—already surpass those of a record.

As explained earlier, it is no exaggeration to say that the history of turntables is the history of the motors used therein. Before the development of the quartz-PLL DD motor, now commonplace, motor rotation was conveyed to the platter by one sort or another of speed-reduction system, such as idlers and/or belts. The material characteristics and design limitations of these systems limited those turntables' performance severely, and the astounding figures that are now easy to obtain were impossible then. Thus it is no longer enough to judge the quality of a turntable merely be comparing wow/flutter and S/N values.

For instance, although S/N ratio measurement on the DIN-B standard is conducted with the DIN-B-designated S/N ratio meter, the meter's own measuring limitation is 80dB. Therefore, if S/N ratios are in the area of 78dB to 80dB, they nearly exceed the meter's range; the difference of 2dB at this level has no significance. Instead, we must go by other factors.

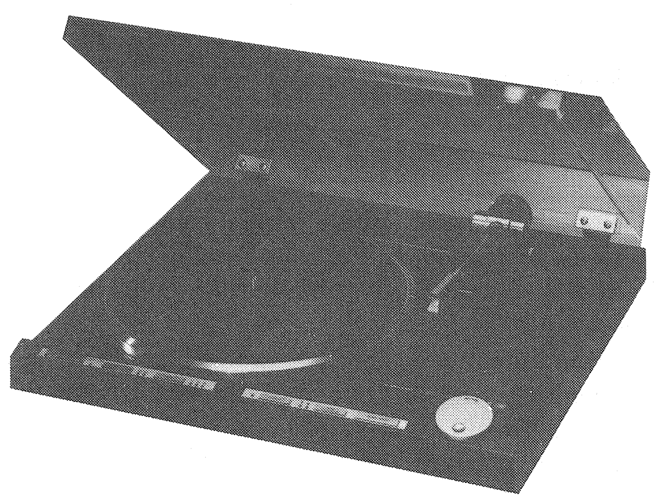
Actually, the turntables on the market today have been designed with great attention to such as the tone arm's sensitivity, small moment of inertia, and so on. This requires the reduction of a tone arm's weight and an increase in its rigidity, and the concentration of the mass of the arm on the fulcrum—these factors improve performance when lightweight cartridges are used. Other areas now being improved relate to the prevention of "howling" (acoustic feedback) through redesigned platter mats, resonance-free cabinets, etc.

However, most of these factors cannot be estimated or measured in terms of specifications. Even when values are assigned to them, the lack of internationally-accepted standards prevents true comparison among turntables. For the sake of better understanding on the part of the consumer, specification sheets may give these values in terms of limits.

Finally, it is still wise to use the one rule-of-thumb which always is relevant in audio—actual listening. After all, this is the end purpose of the continuing search for better and better specifications, and is really the only one that counts in the end.

As for tone arms and cartridges, we hope we can cover them in a future issue of TUNING FORK.

**PL-L5**
Linear-motor drive, tangential tracking turntable with heavy and thick cabinet



**PL-L1000**
With full-automatic function

* Truly innovative turntables from Pioneer

# One-Point Servicing Technique

## Square-Wave Test

One of the widely-used methods for checking an amplifier's frequency characteristics and the stability of its operation is the square-wave test. It involves giving the amplifier a square-wave input signal, then observing the amp's output waveform on an oscilloscope.

This method does not, unfortunately, yield absolutely accurate results. Nonetheless, it is a very useful method in that one can easily check the following items:

(1) Frequency Characteristics
- Tone control characteristics
- Filter characteristics
- Loudness characteristics
- Equalization curve
- Left/right channel differences

(2) Operational stability of the amplifier

Before discussing the square-wave test, let's take a look at the square wave itself and see why it is suitable for such tests.

### 1. Square Wave

Frequency analysis of a square wave shows it consists of a fundamental sine wave and its limitless odd-number harmonics.

Technically, the square wave is defined as "a square or rectangularly shaped periodic wave which alternately assumes two fixed values for equal lengths of time."

From this it is easily understood that the variation (varying rate) of (1) and (3) in Fig. 1 below is very small, while that of (2) and (4) in the same figure is very large. This means that the frequency content of the wave ranges from very low to very high in comparison with the square-wave frequency $(\frac{1}{T})$.

These facts indicate that a circuit or an amplifier must have a flat frequency response over a certain range in order that its output waveform be identical to that of the square-wave input.

In practice, the flat frequency response required to reproduce the input accurately is roughly from $\frac{1}{100}f$ to $100f$.

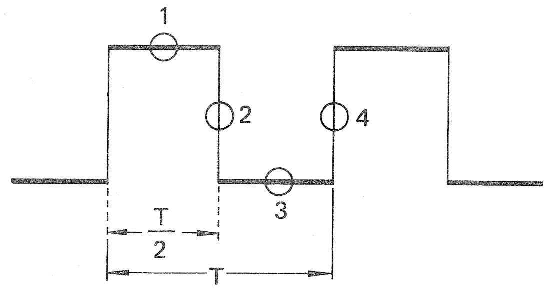
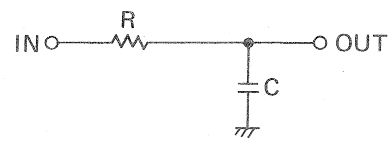
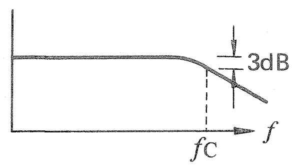



**Fig. 1 Square wave**

Now, let's consider the relationships between a circuit or amplifier's output waveform and its frequency characteristics.




(a) Circuit




(b) Frequency Characteristics

**Fig. 2 Low-pass filter circuit**

The circuit in Fig. 2 is low-pass filter represented by: $fc = \frac{1}{2\pi Rc}$.

What kind of waveform will appear at the output when a square-wave input is introduced? The following Fig. 3 shows that the output waveform will change according to the charging current passing through C, and to C's discharge current.

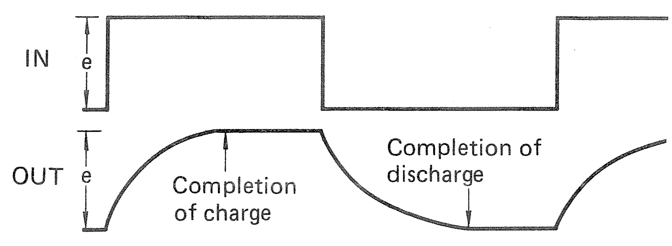



**Fig. 3 In/output waveforms of a low-pass filter circuit**

Thus, the response in the high frequencies appears as in (2) and (4) of Fig. 1.

Now please look at Fig. 4 below:

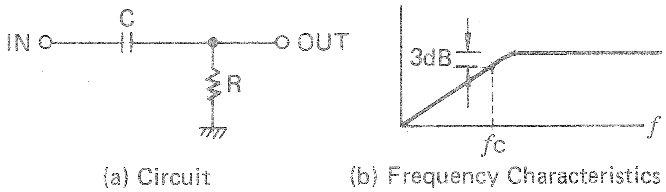



**Fig. 4 High-pass filter circuit**

The circuit in Fig. 4 is a high-pass filter that can be represented by: $fc = \frac{1}{2\pi Rc}$ .

The waveform will change according to the charging current passing through C and C's discharge current, as shown in Fig. 5 below:

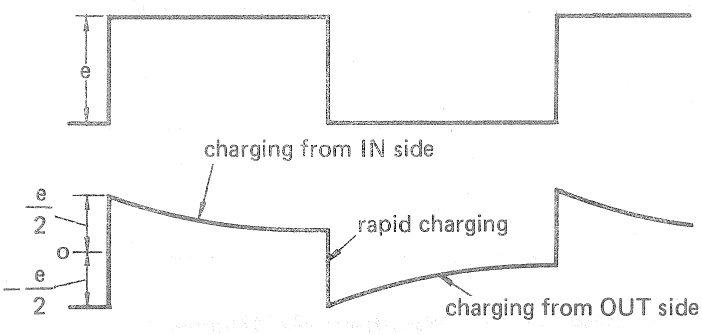



**Fig. 5 In/output waveforms of High-pass filter circuit**

The low-frequency response of the circuit will thus appear as shown in 1 and 3 of Fig. 1.

Thus, the frequency response of a subject circuit or amplifier, fed a square-wave input, can be determined with a glance at the oscilloscope.

Next, let's discuss the relationship between various other waveforms and frequency characteristics.

## 2. Relationships Between Various Waveforms and Frequency

### 2-1 When Output and Input Waveforms are Identical

Frequency characteristics in this case are flat from $\frac{1}{100}$ $f$Hz to 100$f$Hz with the input square wave frequency ($f$) as the center.

For instance, when the square wave frequency is 1kHz, the frequency response is roughly flat from 10Hz to 100kHz.

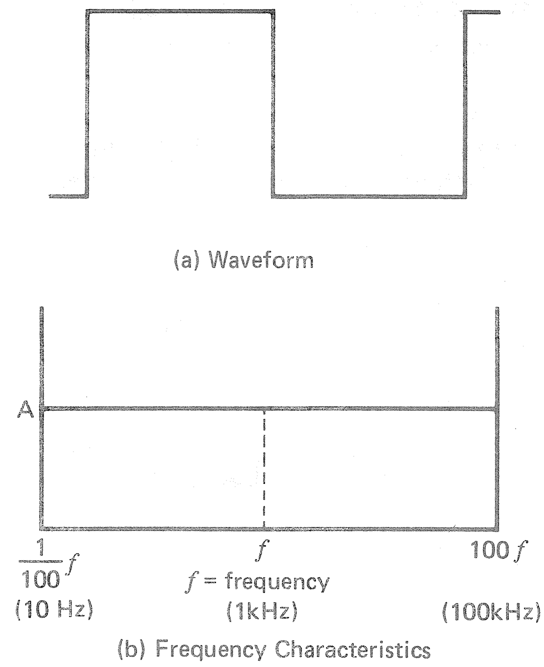



**Fig. 6 When waveforms of in/output are identical**

### 2-2 When Output Waveform Has Longer Rise (Fall) Time

Such a waveform appears when there is attenuation in a high range of the frequency characteristics, as shown in Fig. 7. The lower the frequency where attenuation occurs, the longer the rise (fall) time.

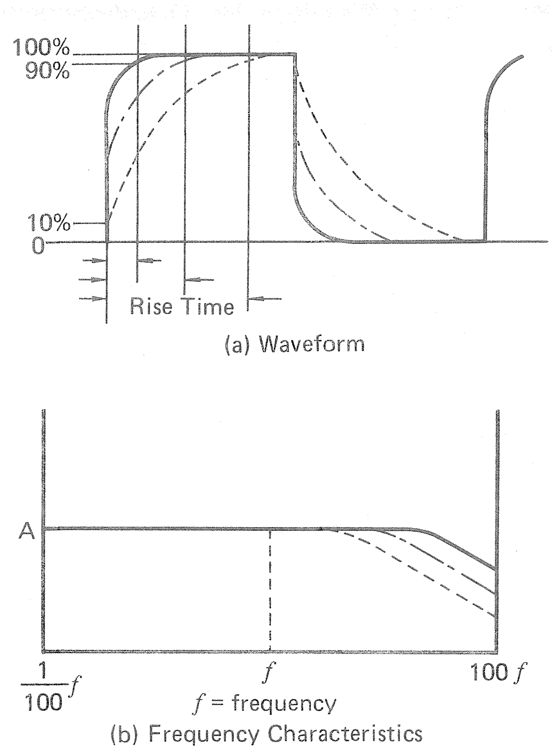
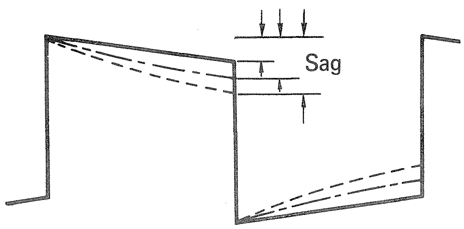



**Fig. 7 Output waveform rise time**

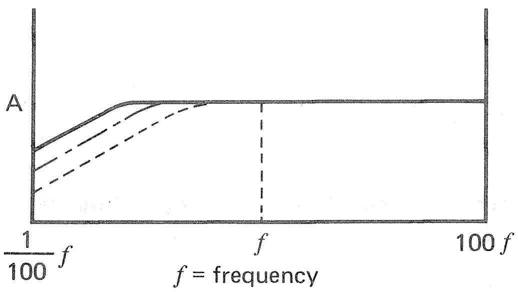
### 2-3 When Output Waveform Has Sags

Inclinations in a waveform (such as seen in Fig. 8, below) are called sags.

Such a waveform appears when there is attenuation in the low frequencies; the higher the frequency at which attenuation occurs, the larger the amount of sag.




(a) Waveform

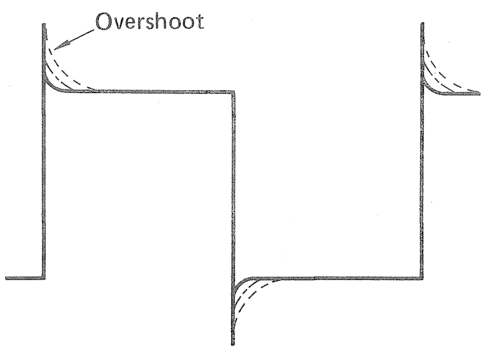



(b) Frequency Characteristics

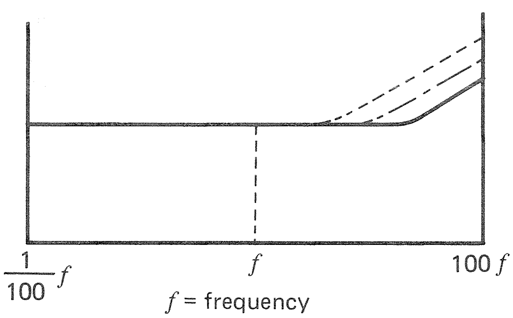
**Fig. 8 Output waveform with sags**

### 2-4 When Output Waveform Has Overshoot (Spikes)

Such a waveform appears when there is a rise in the high range of the high-frequency characteristics, as shown in Fig. 9, below:




(a) Waveform

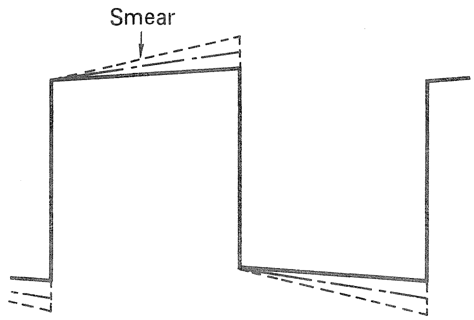



(b) Frequency Characteristics

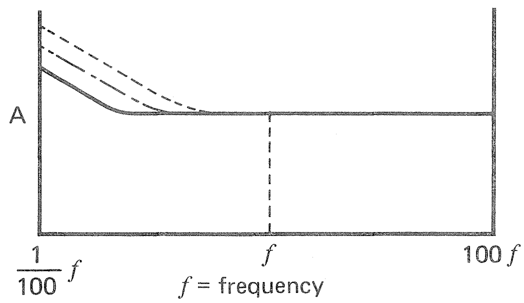
**Fig. 9 Output waveform with overshoot**

### 2-5 When Output Waveform Has Smears

This waveform appears when there is a rise in the low range of the frequency characteristics. The higher the frequency at which such a rise occurs, the larger the amount of smear.




(a) Waveform

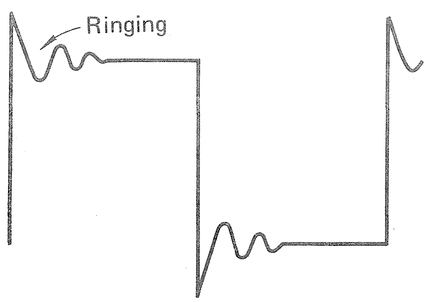



(b) Frequency Characteristics

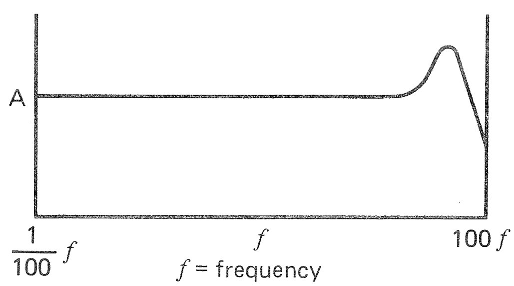
**Fig. 10 Output waveform with smears**

### 2-6 When Output Waveform Has Ringing

When there is a peak in a high range of the frequency characteristics, as shown in Fig. 11 (a), below, ringing will appear in the output of the 'scope. Ringing is a high-frequency damped oscillation caused when the subject circuit or amplifier's output is unstable and unable to follow a radical change in the input, such as a square-wave signal.




(a) Waveform



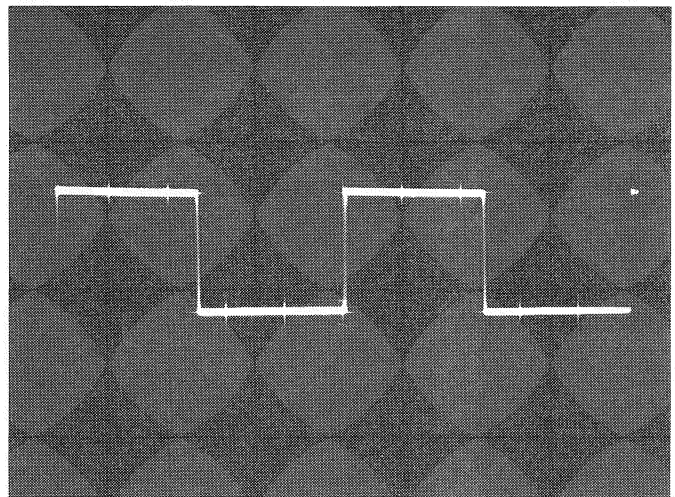

(b) Frequency Characteristics

**Fig. 11 Output waveform with ringing**

3. Square Wave Test

**(1) How to Check Frequency Characteristics:**

When servicing or repairing a piece of equipment, abnormal frequency response is easily observed in some sections, such as in the equalizer amp, the tone control, the power amp, the loudness circuit, filters, etc. The photo shows the output waveform in response to a square-wave input.



**(2) Stability Check of Power Amplifier**

Whatever type of speaker system used as the load on an amp—multi-way or full-range, etc.—the impedance characteristics will vary by frequency. Moreover, impedance is not always conductive, but changes to inductive or capacitive, depending on frequency. Given this, stability in amplifiers is a prime factor. Poor stability can cause deterioration in sound quality, and even oscillation of the amp in the worst case.

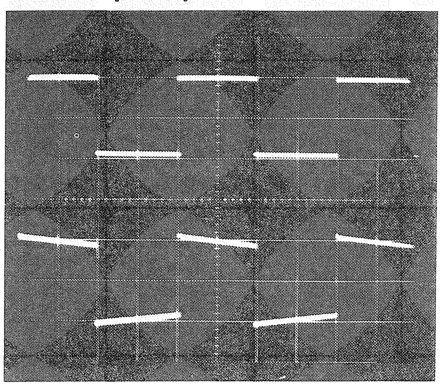
Confirming a power amplifier's stability is relatively easy; the input should be a square wave, and a capacitor (0.001–0.1$\mu$F) should be connected to the output. (In practice, a capacitor of 0.1$\mu$F is connected in parallel with an 8-ohm dummy resistor.)

In this test, the appearance of a small overshoot on the 'scope screen will not be a matter for concern. But, if ringing is indicated, trouble is likely to occur when the subject amplifier is applied in actual use. In general, amplifiers using excessive NFB (Negative Feed-Back) tend to have inferior stability.

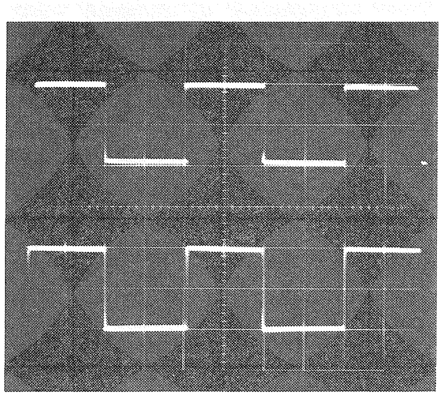
**4. Actual Output Waveforms**

For your reference we are including photographs of output waveforms under various conditions. Sample: SX-880.

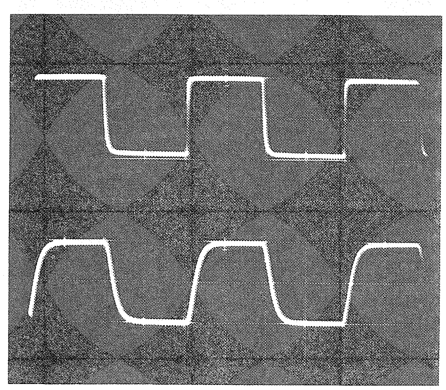
**4-1 Frequency Characteristics**



(1) 50Hz

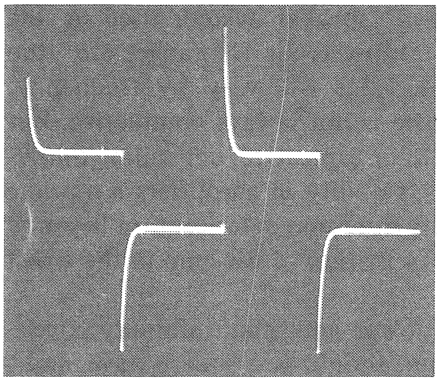


(2) 1kHz

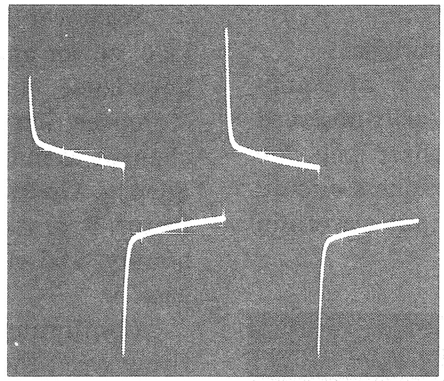


(3) 20kHz

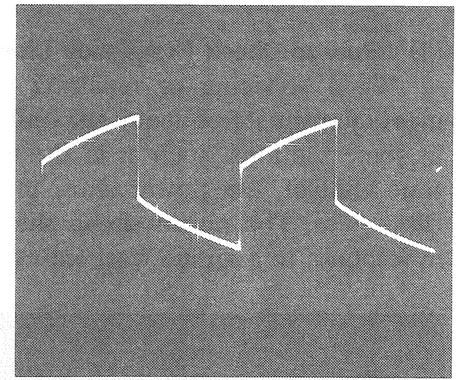
## 4-2 Tone Control



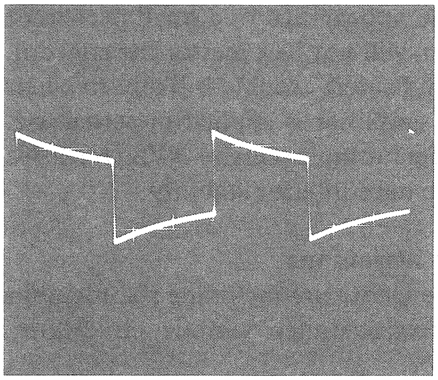
(1) Treble: Max.
Bass: Flat



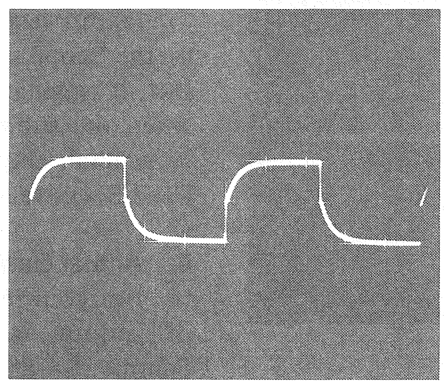
(2) Treble: Max.
Bass: Min.



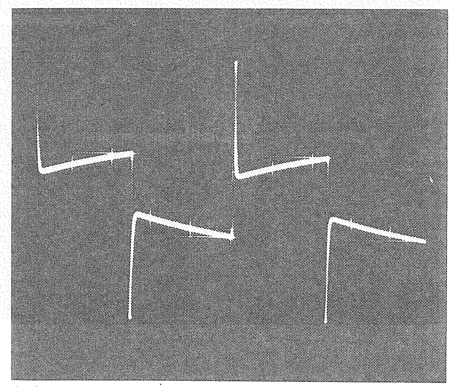
(3) Treble: Flat
Bass: Max.



(4) Treble: Flat
Bass: Min.

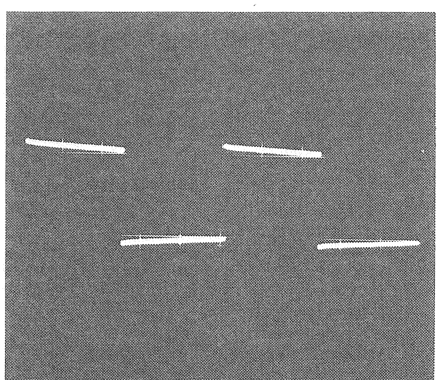


(5) Treble: Min.
Bass: Flat



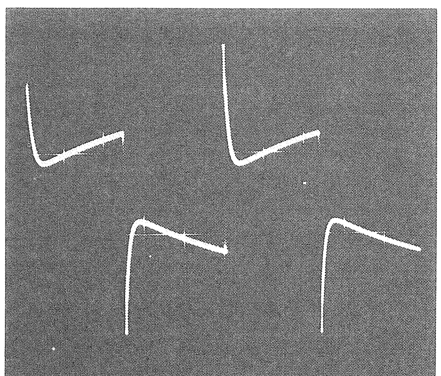
(6) Treble: Max.
Bass: Max.

## 4-3 Filter Characteristics



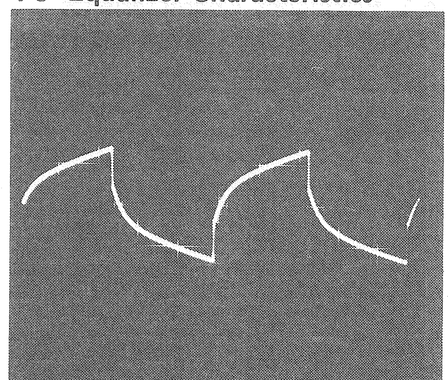
Low-cut filter: ON

## 4-4 Loudness Characteristics



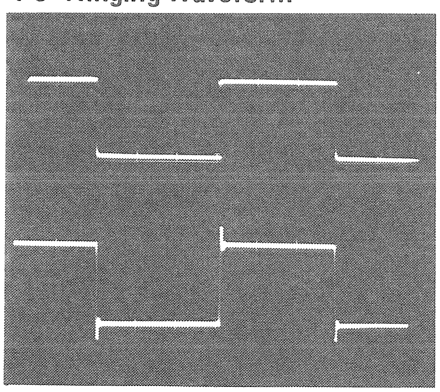
Loudness switch: ON
Tone controls: Flat

## 4-5 Equalizer Characteristics

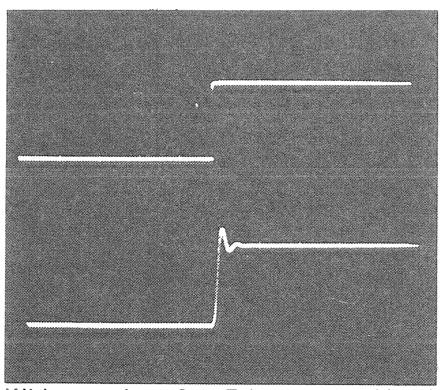


Phono equalizer output

## 4-6 Ringing Waveform



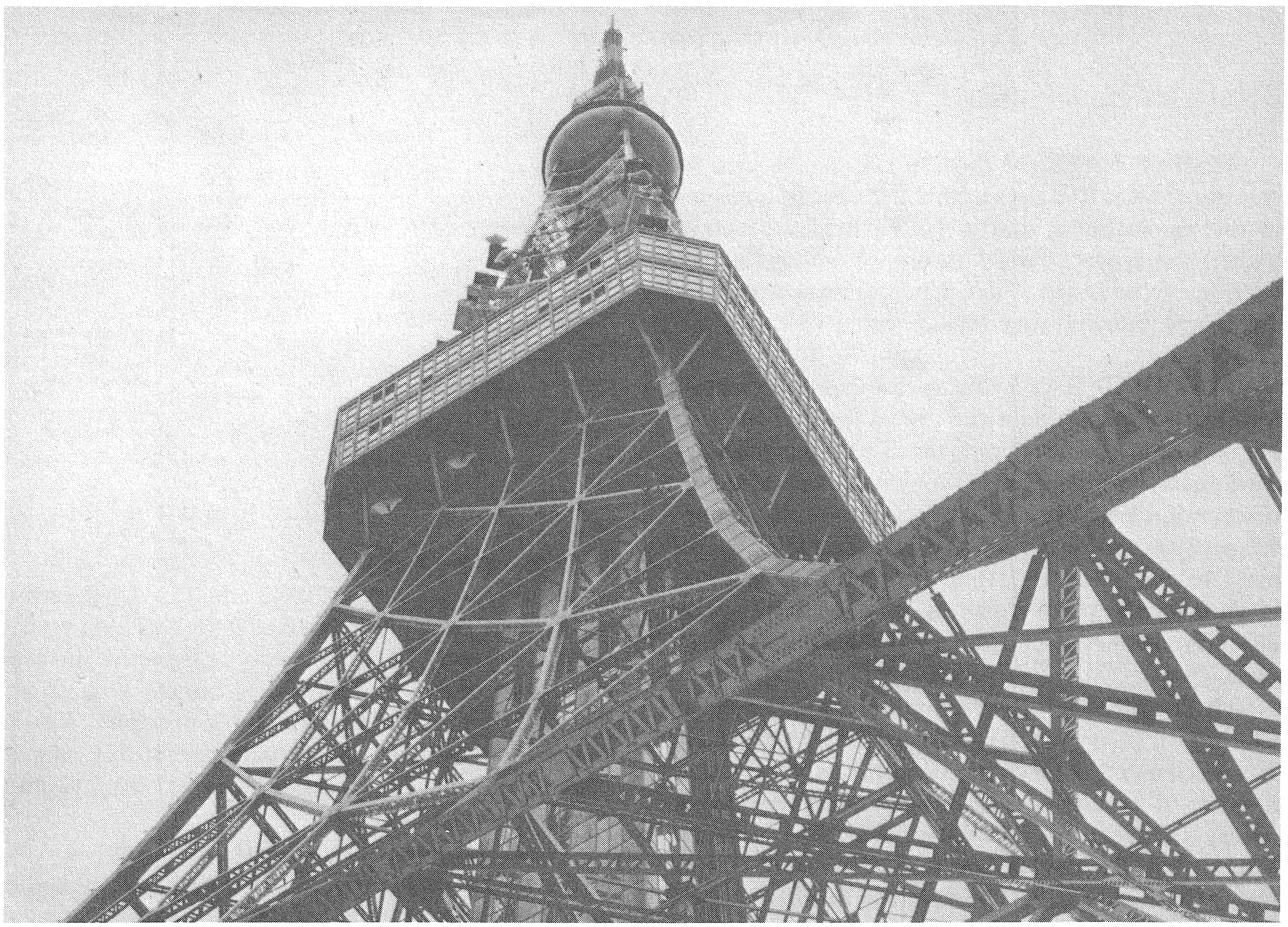
With capacitor, 0.1$\mu$F



With capacitor, 0.1$\mu$F (magnified: X 10)

# Understanding More About Radio Waves

## Wave Characteristics



In this issue of TUNING FORK we'll discuss how radio waves are transmitted. The antenna, where radio waves enter the radio receiver, will be covered in a later issue and here we'll concentrate on radio waves and how they travel.

## 1. Electromagnetic Waves

As shown in Table 1, electromagnetic radiation can be divided into six classifications:

| Name | Frequency (Hz) | Wavelength |
|---|---|---|
| Gamma Rays | $5x10^{19}$ Hz–$1x10^{21}$ Hz | $6x10^{-8}\mu$–$3x10^{-7}\mu$ |
| X-Rays | $1x10^{16}$ Hz–$1x10^{21}$ Hz | $0.03\mu$–$3x10^{-7}\mu$ |
| Ultraviolet | $8x10^{14}$ Hz–$1x10^{16}$ Hz | $0.4\mu$–$0.03\mu$ |
| Visible Rays | $4x10^{14}$ Hz–$8x10^{14}$ Hz | $0.7\mu$–$0.4\mu$ |
| Infrared | $1x10^{12}$ Hz–$4x10^{14}$ Hz | $300\mu$–$0.7\mu$ |
| Radio Waves | 10kHz–300GHz | 30km–0.1cm |

Table 1

VISIBLE RAYS are those which can be seen by the human eye. Red rays have the lowest frequencies in the visible range, and as the frequency becomes higher, the colors changes to orange, yellow, green, blue, indigo and then violet. When these seven colors are mixed equally, the light becomes "white," or "colorless."

INFRARED RAYS are, as the name indicates, lower in frequency than the lowest (red) of the visible spectrum. Infrared rays (such as from the sun) carry heat, and can cause ambient temperature to rise even on a cloudy day. They also have the strongest penetration powers of any rays, and their decrement is low. Therefore, they are used, for example, in photography when darkness, distance, rain, fog or etc. prevent the use of ordinary visible light frequencies.

ULTRAVIOLET RAYS, similarly, have frequencies higher than the fastest (highest) visible light waves (violet). Like infrared rays, ultraviolet rays are invisible to the human eye. Because they carry strong energy (as from the sun) they can cause sunburn. But as their frequencies are high, decrement is also high, and they are weakened considerably by such media as glass; this is why one cannot get a "tan" through a plate-glass window.

GAMMA and X-RAYS, the 1st and 2nd classifications, have very strong energy and are easily attenuated. They are used in the medical and engineering fields to study the internal structure of objects, etc.

RADIO WAVES, our major concern here, are the lowest (slowest) of all. They are classified into several categories, by frequencies. Table 2 is the classification system decided at the International Telecommunications Treaty Conference of 1947; Table 3 shows the classification traditionally used worldwide.

| Name | Symbol | Frequency | Abbreviation Means |
|---|---|---|---|
| Myriameter waves | VLF | less than 30kHz | Very Low Freq. |
| Kilometer waves | LF | 30k–300kHz | Low Frequency |
| Hectometer waves | MF | 300k–3MHz | Medium Frequency |
| Decameter waves | HF | 3M–30MHz | High Frequency |
| Meter waves | VHF | 30M–300MHz | Very High Freq. |
| Decimeter waves | UHF | 300MHz–3GHz | Ultra-High Freq. |
| Centimeter waves | SHF | 3G–30GHz | Super-High Freq. |
| Millimeter waves | EHF | 30G–300GHz | Extremely-High Frequency |

Table 2

| Name | Frequency | Wavelength | Use |
|---|---|---|---|
| Long waves | 10k–100kHz | 30km–3km | Long-distance communications |
| Medium waves | 100k–1500kHz | 3km–200m | Ships, aircraft & broadcasting |
| Medium short waves | 1500k–3MHz | 200m–100m | Mid-range communications |
| Short waves | 3M-30MHz | 100m–10m | Long-distance communications |
| Ultrashort Waves | 30M–300MHz | 10m–1m | Short-distance communications |
| Microwaves | 300M–30GHz | 1m–1cm | Multiplex communications & radar |

Table 3

## 2. Radio Wave Paths

A radio wave reaches its destination by describing a direct straight line between the emission point and the reception point, or along the ground surface by diffraction, or by reflection from the ground, or reflection and refraction from the ionosphere. Waves transmitted by these routes are respectively called "direct," "surface," "ground-reflected" and "ionosphere-reflected" waves.

Three of these are called "ground waves"–direct waves which reach the receiving point directly without reflection/refraction from the various media mentioned, those which are reflected by the earth, and those which travel along the surface of the earth.

The four paths shown in Fig. 1 are only the basic routes. Actually, the routes are far more complicated, due to scattering and reflection by buildings, mountains, surface of sea, etc.

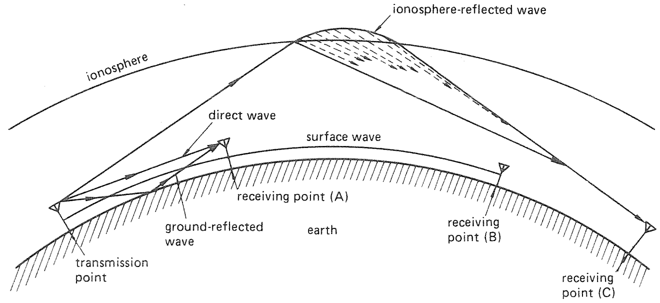



Fig. 1 Radio wave paths

3. **Surface Wave**

Direct and reflected waves can be easily understood, but a discussion of the surface wave is called for here.

As Fig. 1 shows, radio wave propagation to receiving Point (B), which cannot be seen from the transmission point, is possible by using the surface wave.

In this case, the waves describe a curved, not straight, path, helped by reflection/refraction from the ionosphere. The path created through reflection is affected by restrictions imposed by angle-of-incidence frequencies, as explained in our previous issue. These make it difficult to reflect a radio wave to a point relatively nearby; the wave will travel along its curved path to a point somewhere along the midle of that path.

Why does the path curve rather than being reflected or refracted? As shown in Fig. 2, a radio wave, like a light wave, is bent toward an obstacle as the wave passes by. This bending phenomenon is called "diffraction."

When a radio wave travels along the earth's surface, diffraction by the earth continuously bends the wave path. The resulting path is that of the surface wave.

As Fig. 2 shows, not all radio wave components are diffracted. As only some parts are bent, the wave becomes progressively weaker as it travels out from the transmission point and the curvature of the earth takes its toll of the wave's energy.

Moreover, as the radio wave travels along the surface, it is influenced by electromagnetic induction from the ground, and its energy weakens still further. Therefore, the propagation distance of a surface wave is limited.

As Fig. 3 shows, propagation is best over the sea; next best is a plain; worst is a city area.

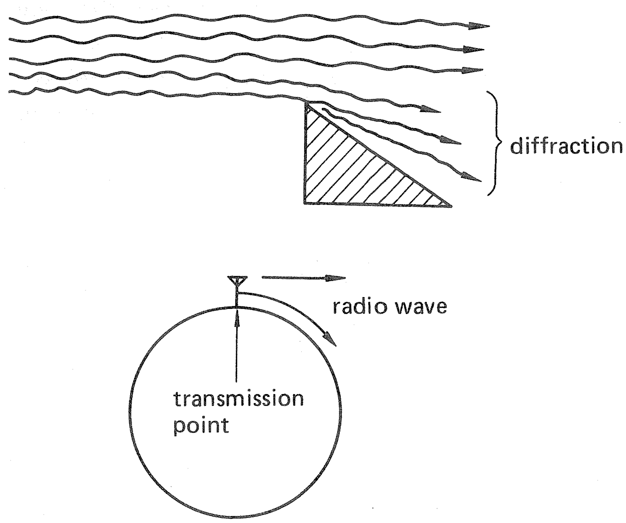



**Fig. 2 Surface wave**

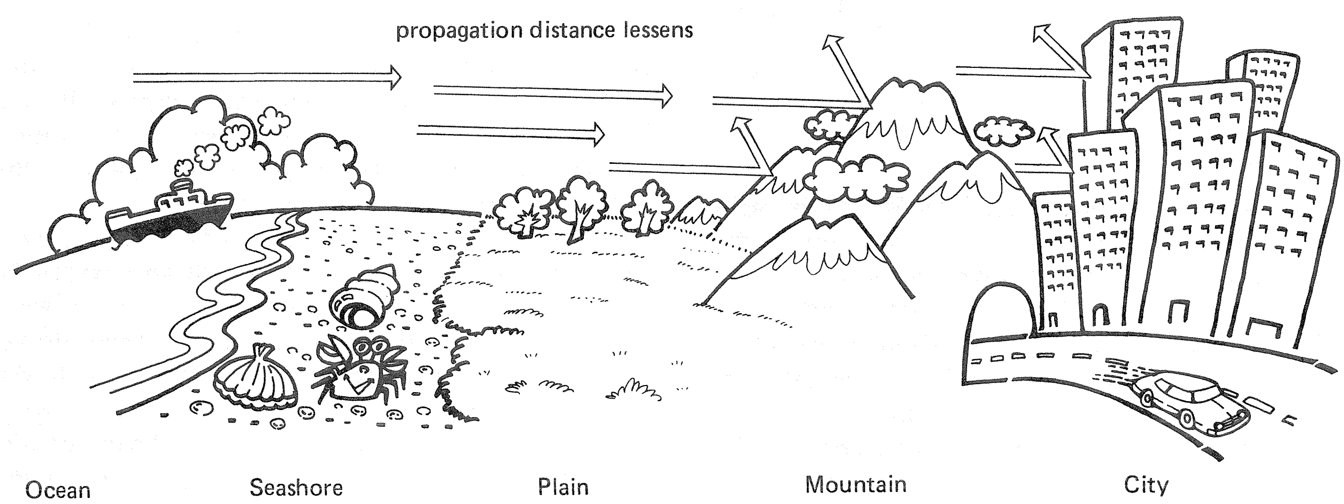



**Fig. 3 Propagation of waves**

The lower the frequency of the surface wave, the longer its range. Radio waves with long wavelengths are, for this reason, used in long-range communications, such as for maritime purposes.

Incidentally, the diffraction phenomenon is not limited to electromagnetic waves. When the wind is blowing, for instance, air will flow along the surface of an obstruction, such as a wall. Similar phenomena are observed in the behavior of animals and of man: as Fig. 4 shows, when a mouse enters a room in which there is cheese, it rarely crosses the room directly to reach it, but instead follows the walls. Similarly, when a man enters a department store, he rarely goes straight to a particular counter unless he has particular priorities in doing so. In most cases, the man will turn to his left; turning to the right, followed by going straight, are the next most often chosen directions.

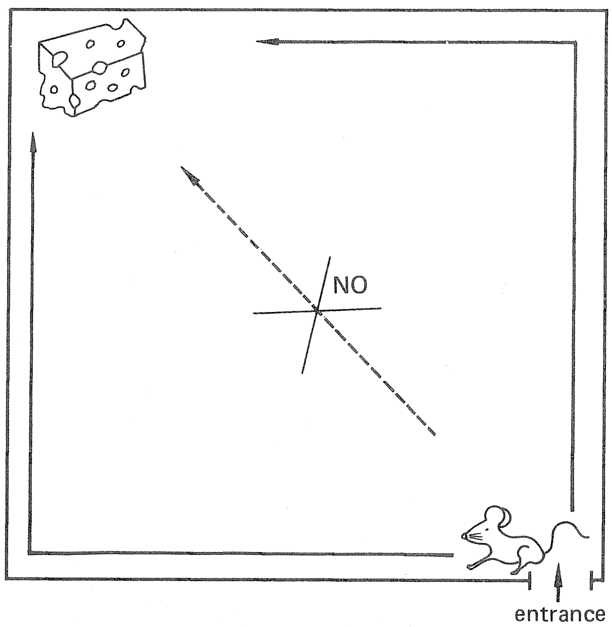


**Fig. 4 Mouse-and-cheese illustration**

## 4. Surface Wave Propagation Over Short Distances

When the reception point is in view, either the direct or the ground-reflected wave is used.

When the height of the transmitting antenna is short in comparison with the wavelength used–that is, when long or medium waves are used–surface wave transmission is possible. But, when the antenna's height necessarily exceeds the wavelength of the transmission wave, as shown in Fig. 5, the wave received is a composite of direct and ground-reflected waves.

The reflected wave which is emitted from Point A, reflected at Point C and received at Point B can be considered as identical to a direct wave coming straight from the imaginary Antenna A' through Point C, with the ground assumed to be acting as a reflector. This is true every time a radio wave encounters an obstacle and is reflected.

The image reflected inside the object as an imaginary point is called an "electric image," and can be used for solving various electrical problems.

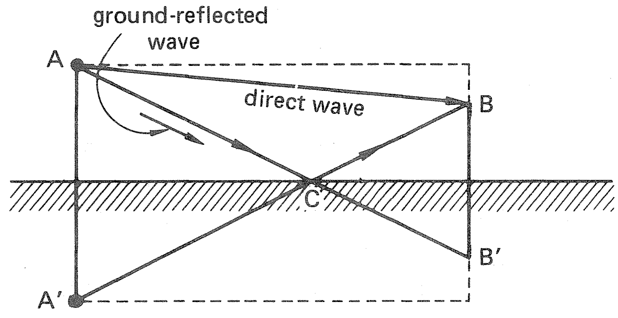


**Fig. 5 Composite wave**

## 5. Discovery of the Ionosphere

As we saw earlier, low-frequency (long) waves are used in long-distance communications; they are surface waves which take advantage of diffraction. When radio communications first became popular, the so-called "ham" radio field began to grow rapidly. Waves of the 7MHz frequency band (around 40m in wavelength) were reserved for the "hams." Those surface waves are short and cannot cover long distances as attenuation becomes a problem. Since "hams" used transmitters of relatively low power (only several watts), the wavelengths they were assigned were able to cover short distances only.

As time passed, however, "hams" reported achieving long-distance communications (such as between the U.S. and Great Britain, etc.) and scholars were perplexed as to how they did it, since the then-prevalent theory of radio wave propagation seemed to deny it.

Obviously, a new theory was called for, one which took into account the possibility of long-distance communications using short waves. Such a theory gained support from such persons as Hantaro Nagaoka of Japan, Arthur Edwin Kennelly of the U.S. and O. Heaviside of Great Britain.

The theory said: "When the surface wave is short in length, it will be soon attenuated and cannot be propagated over a long distance. But, when the wave is transmitted heavenward from the transmission point, it may be reflected from some point in the air, and return to the earth's surface at a more-distant point. In other words, some special layer (of air) which reflects radio waves might be surrounding the earth."

When scholars experimented with this, they found it to be true, and the so-called "ionosphere" was discovered and its existence confirmed by science.

As shown in Fig. 6, the ionosphere is divided into "E" and "F" layers (at different altitudes from earth). At an altitude of more than 100km above earth, the atmospheric pressure plunges from 760mm

(760mmHg in the height of a column of mercury) to less than 0.024mm (0.024mmHg), while the hydrogen content is some 99%. The average temperature at this altitude is –90°C.

As explained in our previous issue, the hydrogen electrolytically dissociated from the atmosphere by the sun's ultraviolet rays forms the $F_1$ layer, the lower part of the F layer existing some 200km above the earth's surface.

The $F_2$ layer, above $F_1$, is currently thought to be created by energy other than ultraviolet rays, though this is yet to be clarified.

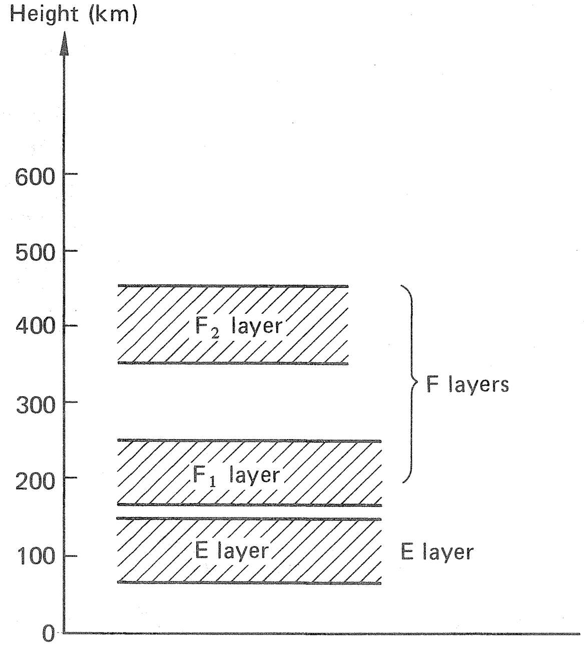



Fig. 6 "F" & "E" layers in earth's atmosphere

## 6. Relationship Between Ionosphere and Radio Waves

Radio waves behave differently inside the ionosphere, depending on their wavelengths. The longer the length, the bigger the influence of the ionosphere on the wave. As the wavelengths become shorter, the degree of refraction becomes smaller. Thus, an ultrashort wave is able to penetrate the ionosphere and travel into space.

Space communications are conducted on frequencies higher than those of the ultrashort lengths, chiefly to avoid the ionospheric influence, although there are other reasons as well.

While long and medium waves are reflected by the E layer and returned to earth, or suffer attenuation, short and ultra-short waves are refracted by the E layer and their paths are bent toward earth. However, the short and ultra-short types are not refracted fully, and tend to penetrate the E layer toward the F layers.

Short waves will be refracted by the F layers and turned toward earth (or will be attenuated). Ultra-short waves, which have frequencies higher than the critical frequency, will penetrate even the F layers to the limitless reaches of outer space.

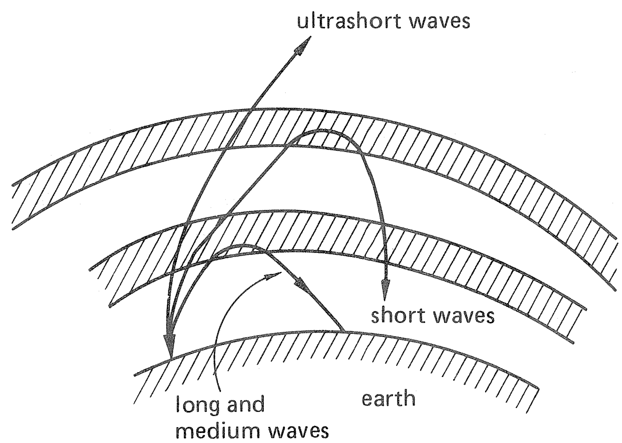



Fig. 7 Behavior of waves

[APPENDIX]

Speaking of space, let's touch briefly on analysis of signals reaching earth from that starry realm, that is, those radio waves used in communication between earth and spacecraft/satellites.

Recently, photographs of Jupiter and its moons (16 in all, so far) have been carried in the press; the photos have been of a quality far better than, for instance, those which we first received from the Apollo 11 mission to the surface of the moon. This vast improvement in quality is not entirely due to advances in communications but also to the very high technology being lavished on computerized photoreproduction, etc.

This involves what is called "correlative analysis." As in television broadcasting, an image is sliced in pieces from above; each slice is transmitted individually as a single signal (Fig. 8). On the receiving side, the many thin slices are joined, with the help of a sophisticated computer, to make up a single photograph.

Noise, that enemy of all kinds of audio and telecommunications activities, tends to exceed signal components in much of space communications. Pictures transmitted from spacecraft, therefore, are likely to be of poor quality, just as were those Apollo 11 photos we saw in newspapers on the day of the first moon landing. The "slicing" technique, mentioned above, is effective in removing such noise because, when one slice of the picture is compared with the next, the noise components in each will be different (Fig. 9). The "correlative analysis" technique disregards the noise components, therefore, and finds those components in the transmissions which are pure signal (Fig. 10). Repetition of this process eventually results in a clear image for reproduction as a photograph.

This method is also applicable to general communications. Through "correlative analysis," those components which are significant are isolated from massive amounts of data and the results are noise/distortion-free signals. Naturally, this technique is finding wider and wider applications in many fields, including those far beyond audio . . . . . all thanks to the "space age."

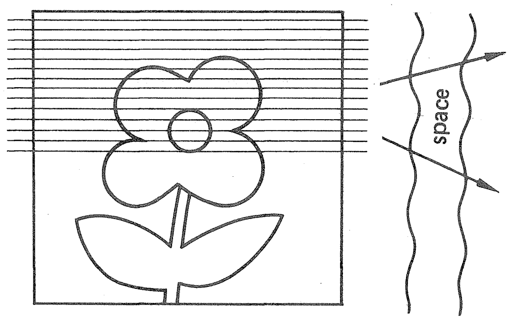



**Fig. 8 "Slicing" of Space-photo**

Photo is "sliced" into pieces for separate transmission to earth.

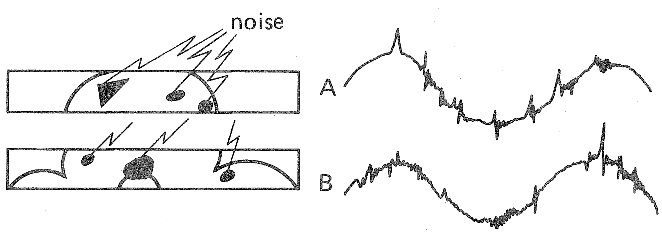



**Fig. 9 Noise content in slices A/B differs**

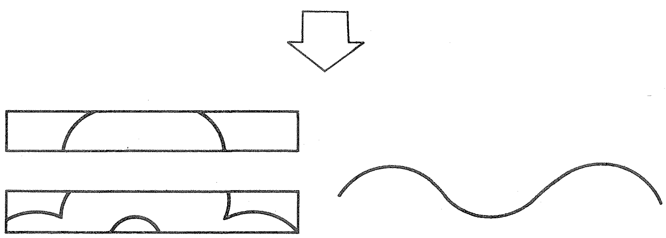
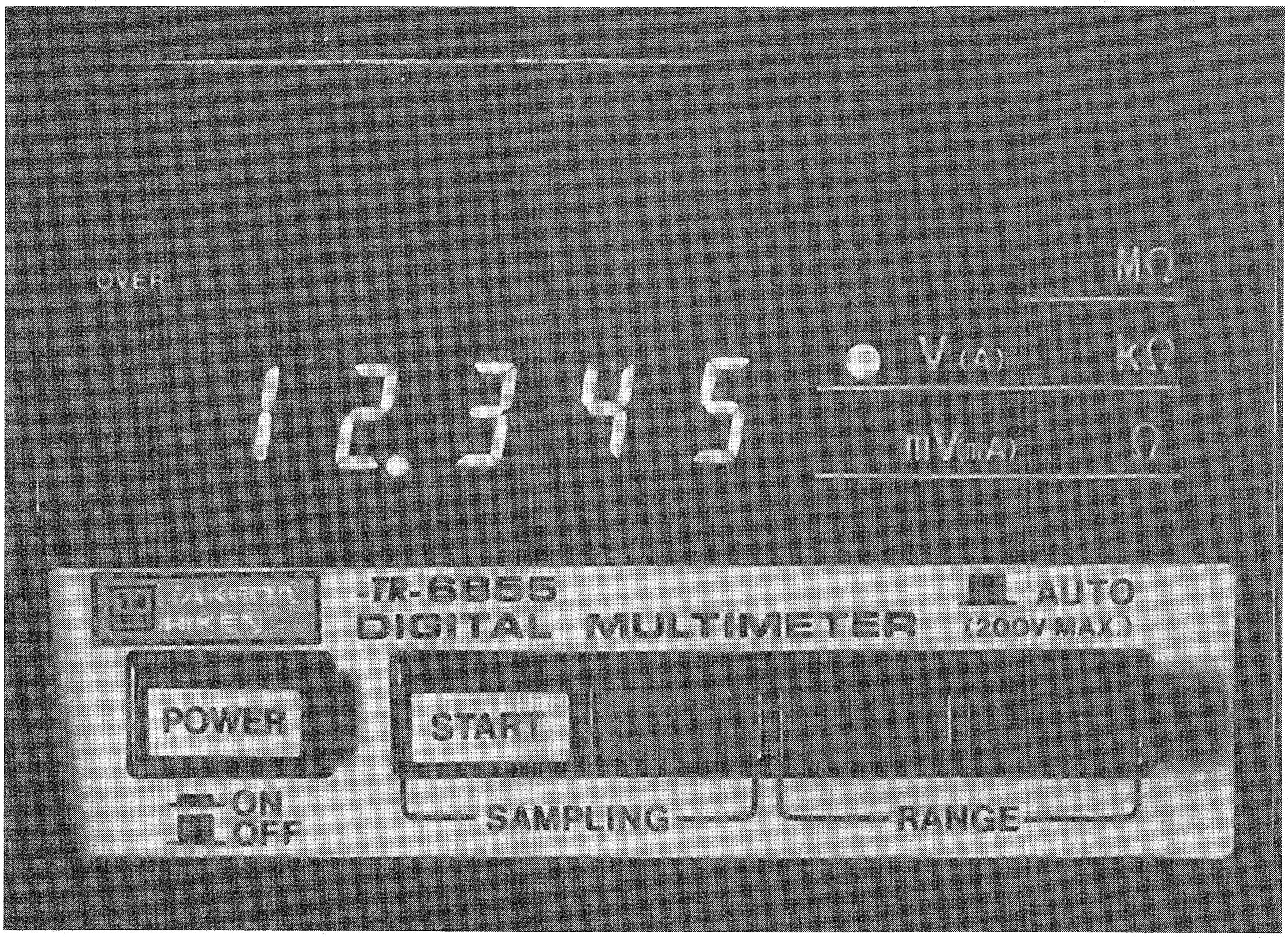


**Fig. 10 Correlative analysis of "slices"**

"Slices" A and B are compared, and noise components are ignored; only those parts of the signal relating to the photo itself are recognized and used in reproduction.

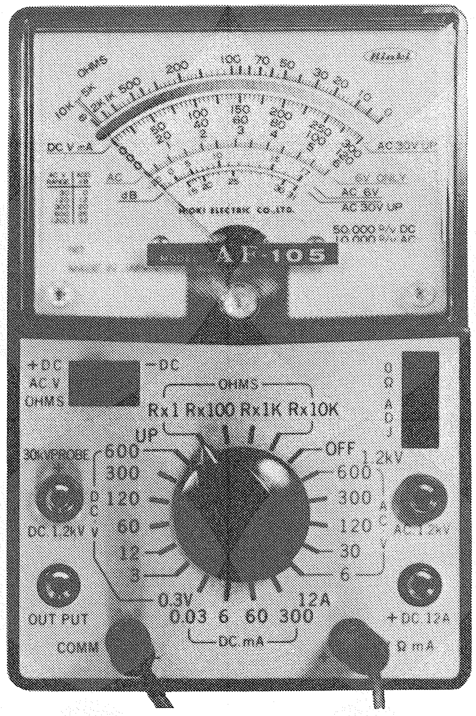
# Audio Memo

## Digital Multimeter

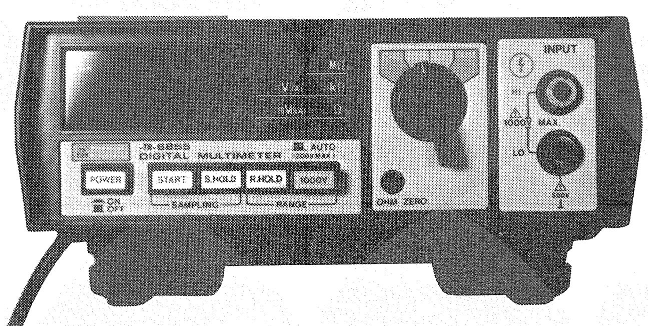



Smaller size, lower price, lower power consumption. These three advantages of the most recent digital multimeters are very much appreciated by those of us in the field of Pioneer servicing, and all three have come from new developments in IC and particularly LSI technology. In this issue of TUNING FORK we'll take a look at the new multimeters which take advantage of a new LSI which features high performance and low power consumption in the A-D (Analog-Digital) converter, the heart of the digital multimeter.

Photo 1 shows multimeters of the Analog and Digital types. In the following text we'll introduce a few of the characteristics, some of the theory, and some tips on the use of the digital multimeter.




(a) Analog Multimeter




(b) Digital Multimeter

**Photo 1 Multimeters**

## 1. Characteristics of the Multimeter

### 1-1 No-Error Reading

Because the output of the multimeter is displayed in digital figures, not on an analog scale, reading is easier and more accurate.

### 1-2 Easy Operation

Automatic operation is made possible by the new LSI. The following operations are available:

1) Automatic Polarity Switching and Display

Most digital models currently available have automatic polarity switching.When the polarity is reversed, the symbol "–" is displayed.

2) Range Switching

On digital multimeters, range is automatically changed to a higher scale when required. This feature is usually available on both the full-auto and semi-auto types.

Full-auto types feature automatic range change from low to high (four to six ranges in all), while the semi-auto types have a function switch to permit the user to change from the low to the high ranges at will. When the function switch is set to low, for example, the meter will automatically change from range to range within the lower scales (two or three ranges); set the switch to high and the same occurs within the higher scales (two or three ranges).

These automatic functions enable accurate measuring under proper conditions, and simplify operation considerably. Another advantage is that no adverse influence is passed on to the circuit being measured since the input impedance of such a meter is very high (normally approximately 10M ohms).

## 2. Theory of Digital Multimeters

The following covers the basic theory of the digital multimeter and the construction of its essential parts. Fig. 1 shows a block diagram of the meter:

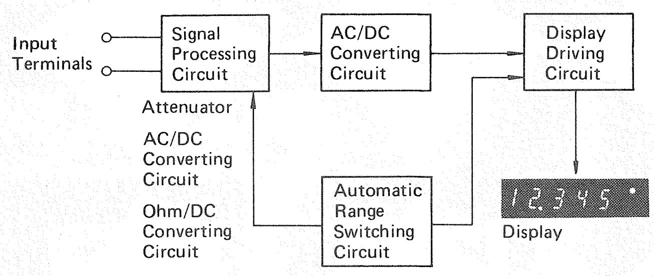



**Fig. 1 Block diagram of digital multimeter**

### 2-1 Signal Processing Circuit

The circuit structure depends on selection of the function switch on the panel, and includes an attenuator circuit which is necessary for range switching.

When DC voltage or current is measured, the signal will be fed into the A-D converter through the attenuator. However, an AC/DC converter is needed for measuring AC voltage, as AC must be first converted to DC. Such a converter is provided in the digital multimeter, along with an Ohm/DC converter for measuring resistance. The latter converts resistance value into DC voltage.

### 2-2 A-D Converter

This is for converting DC voltage (analog), sent from the signal processing circuit, into the digital signal needed for driving the display.

## 2-3 Automatic Range-Switching Circuit

This automatically switches the input attenuator in accordance with the input level to ensure that measurement is made in the most suitable range. It also sends a signal to the display drive to change indication accordingly.

## 2-4 Display Driving Circuit

This circuit permits the digital display to register the appropriate values sent from the A-D converter.

# 3. Tips on Digital Multimeter Use

## 3-1 Fluctuating Signals Cannot Be Measured

When the level of a subject signal is fluctuating it is practically impossible to measure on a digital multimeter. This is because the value indicated on the display constantly changes; use an analog multimeter if necessary and judge the value by observing the median point of the pointer's swing.

## 3-2 Inferior Frequency Characteristics

It must be noted that the frequency characteristics of the digital multimeter are not too good when measuring an AC voltage or current. In general, the measurable frequency ranges of a digital multimeter is from 40Hz to 1kHz. Accuracy is not guaranteed beyond this range. To accurately measure audio signals, for instance, an mV meter is the most suitable.

## 3-3 Smallest Figure Not Reliable

Another disadvantage in the digital multimeter is that you must not depend too much on the accuracy of its smallest reading in any given situation. For example, assuming that the meter has a four-figure indication, measurement of 0.001V (1mV) is not dependable.

In spite of these specified drawbacks, the digital multimeter has many practical uses and makes possible better servicing in less time, at less cost—all thanks to the introduction of sophisticated LSI technology.


**Photo 2 Use mV meter for audio signal measurement**

# IN THE NEXT ISSUE



# Editor's Note

Tuning Fork No. 4 is, at long last, completed and in your hands. We apologize for the delay and can offer only poor excuses for it, but we hope the wait proves worthwhile.

Since the publication of issue No. 3, the Tuning Fork editorial staff has been visiting Pioneer dealers and service stations all over the world. We found you and your fellow service engineers devoted to your daily work with much the same enthusiasm as we felt when we, ourselves, were in "your shoes." We like to think that we share your feelings, and we are always trying to consider what sort of useful information we would want to read in Tuning Fork if we were still on your side of the workbench.

The need for such information is all the more apparent today as we observe the remarkable advances and changes in audio–from circuit technology to the design of parts and beyond. Equally remarkable are the new developments in the applications of audio equipment and the fact that more complicated and highly advanced equipment is being influenced strongly by approaches from other fields, such as the fields of computers, optics and molecular physics.

Those of you who visited the recent 29th Japan Audio Fair held here in Tokyo in mid-October were no doubt amazed, as were we, to find not only many new products based on existing audio equipment but also several exciting new developments in the so-called "PCM" or "digital" field of both audio and video reproduction.

Pioneer is very active in this promising new field, as you may know. And the role that we are and will be playing in this bright, new era is, you may be sure, a leading one. To keep you informed of the developments, and to give you plentiful assistance in your preparations for that new era, we of the staff of Tuning Fork will continue to try to do our best.

See you (soon) in the next issue.

T. Taguchi
H. Koike
A. Kogirima
Y. Kojima

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