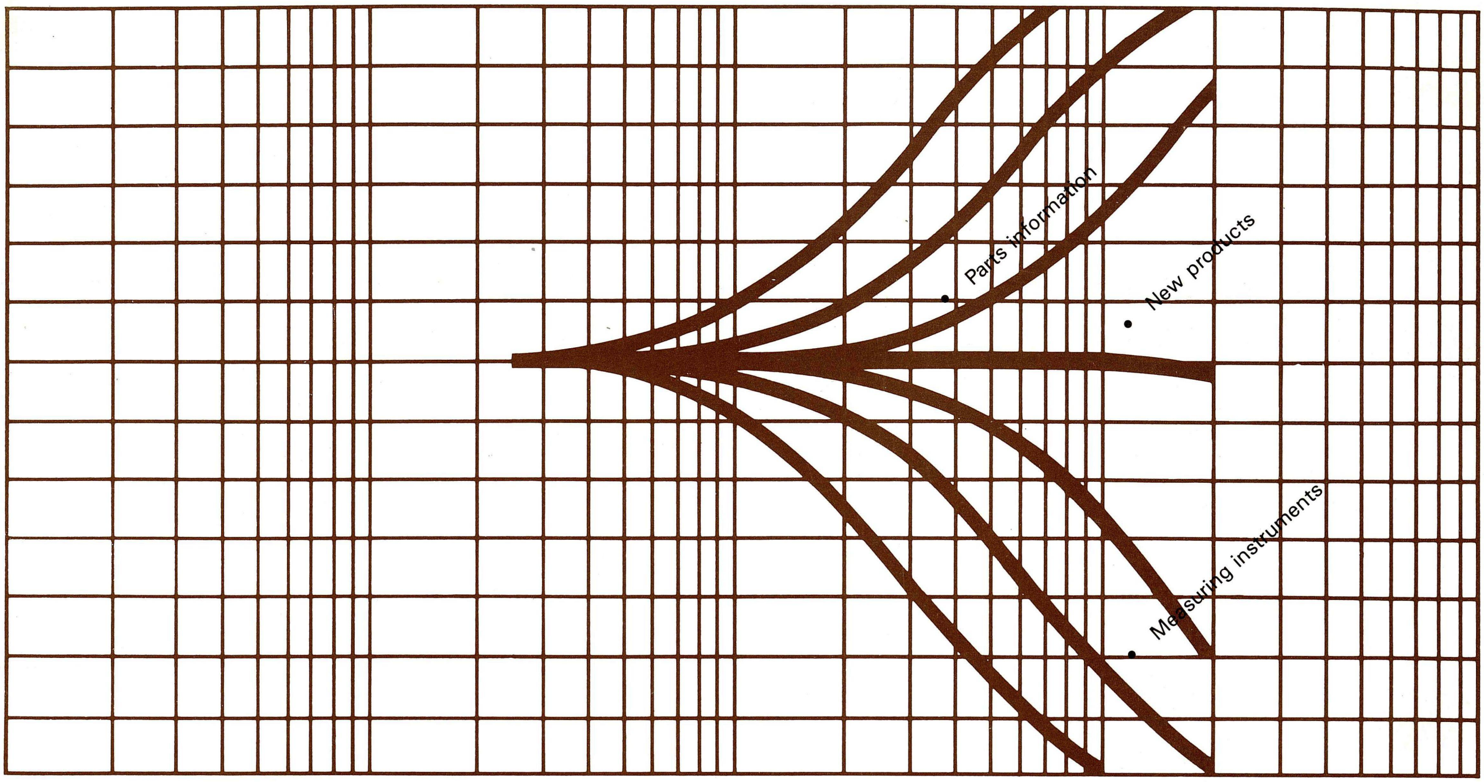
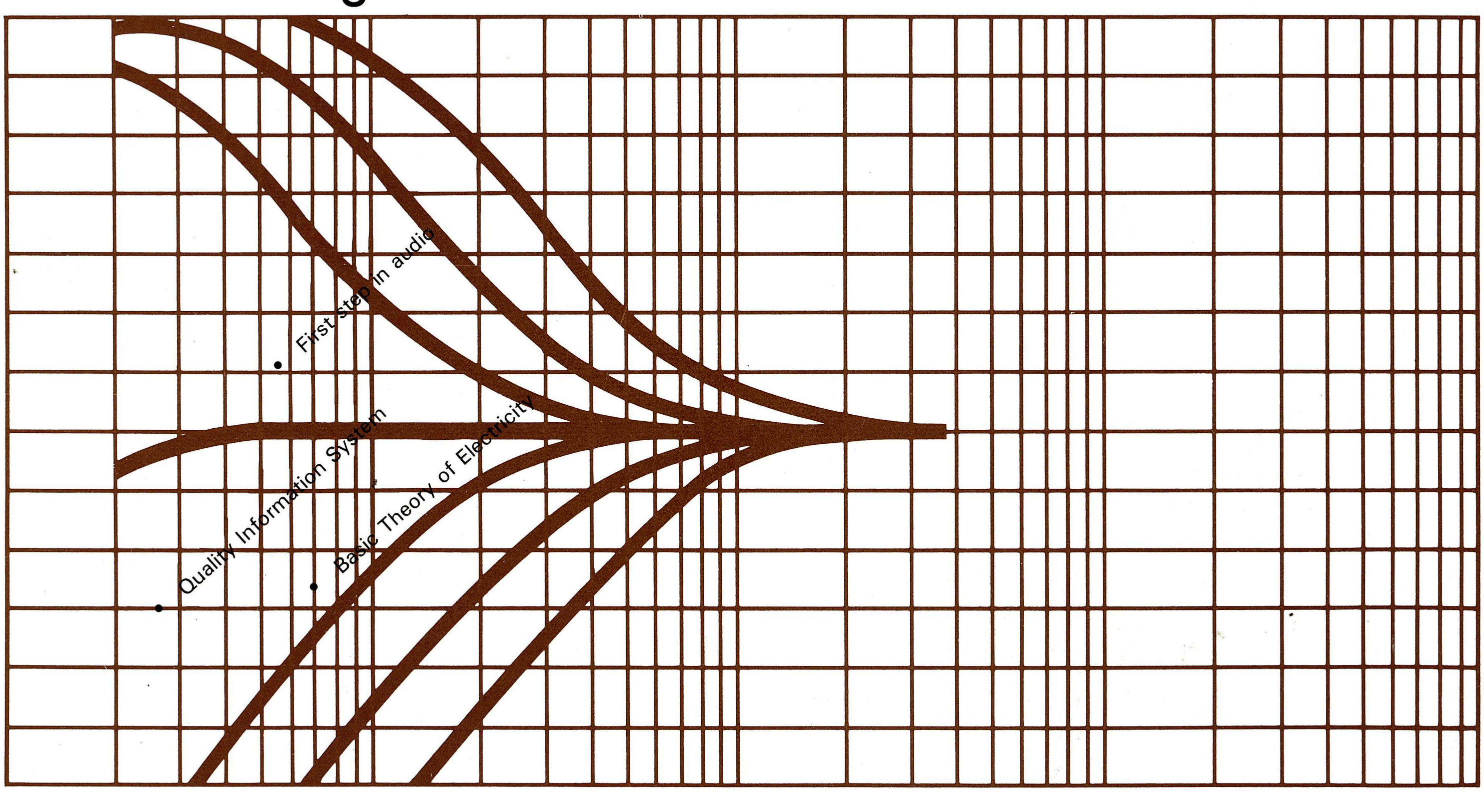


TUNING FORK

Audio service guide

No.6



PIONEER®

CONTENTS

Parts Information

New Resistors and Capacitors

The requirements of higher performance, quality, versatility and easy assembly by robots along with smaller dimensions for audio equipment have brought us new components. Therefore, although resistors and capacitors have already been discussed in ''Parts Information, No. 1 and No. 2, TUNING FORK (T.F.)'', its revision and some additional description on the newly employed components have become necessary.

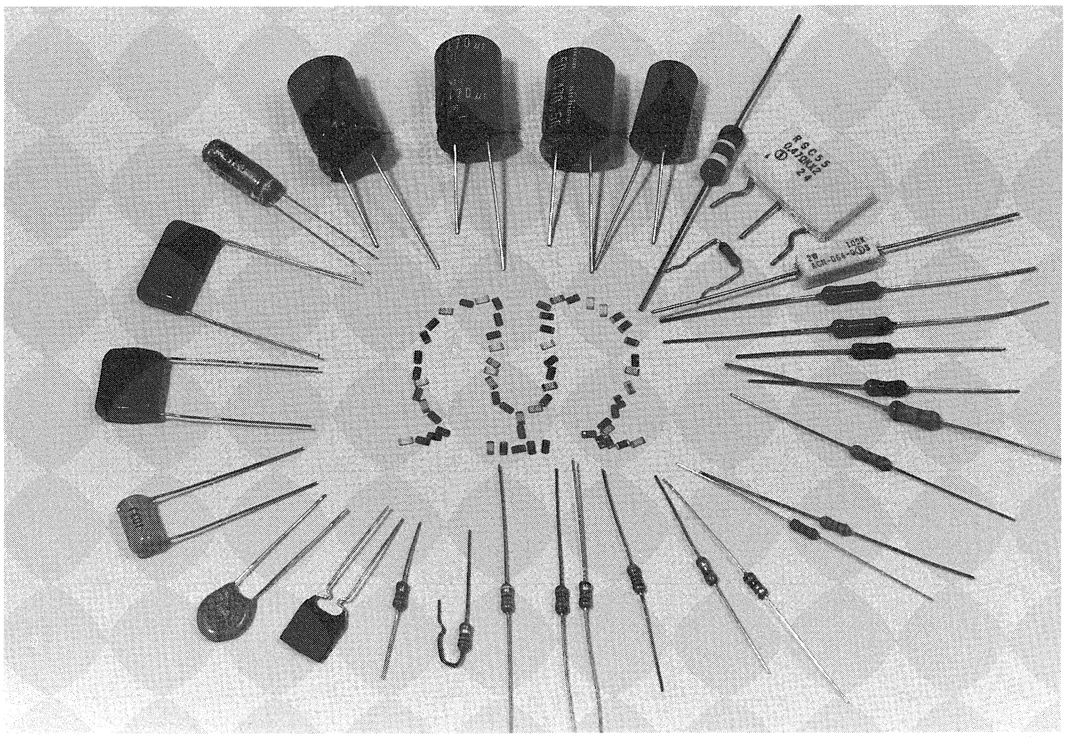


Photo 1 New resistors and capacitors

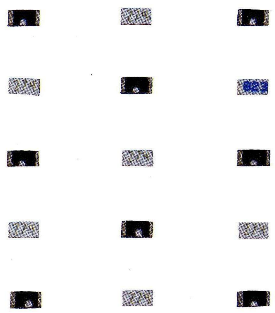


Photo 2 Chip type metal oxide film resistors

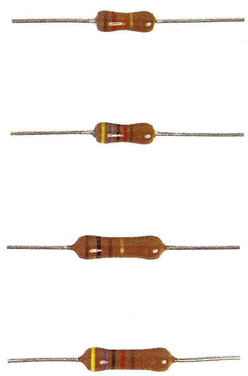


Photo 3 Carbon film resistors for audio equipment

Photo 4 Fusible resistors

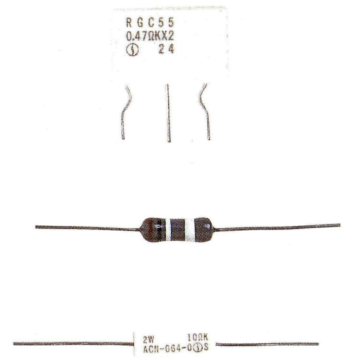


Photo 5 Special resistors

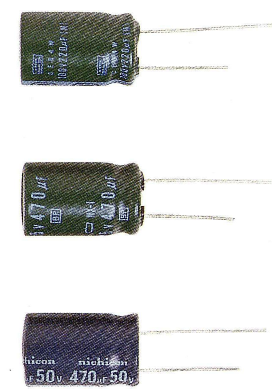


Photo 6 Aluminum electrolytic capacitors for audio equipment

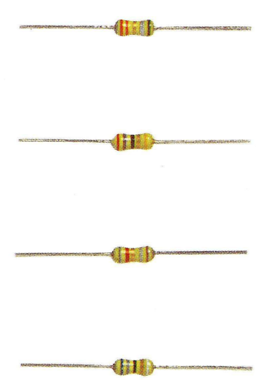


Photo 7 Axial leads type ceramic capacitors for thermal compensation

CKPYB221K50

CKPYX682N25

CKPYD122M50

CKPVYV152K50

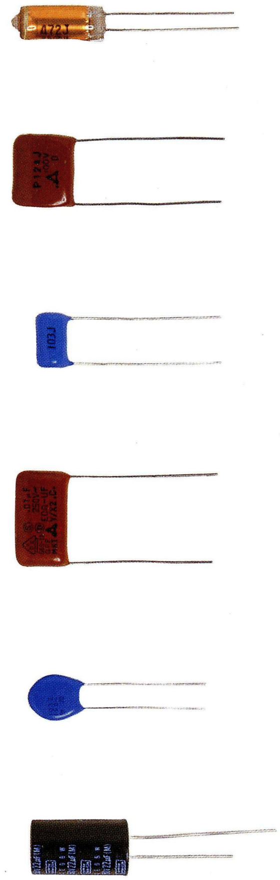
Photo 8 Axial leads type ceramic capacitors with high dielectric constant

Photo 9 Chip type ceramic capacitors

CMA121J500

CMA020D500

Phot 10 Mica capacitors for audio equipment



ACE-065

ACE-095

ACE-097

ACE-501

ACG-019

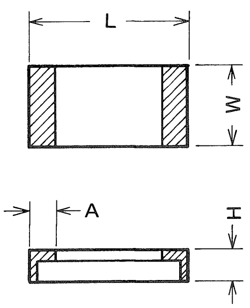
ACH-444

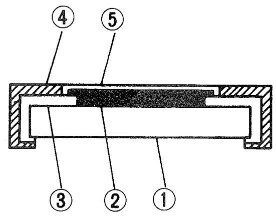
Photo 11 Special capacitors

1. Registors

1.1 Chip Type Metal Oxide Film Resistors (RS)

This type of resistor is popularly used in audio equipment which has limited space.
The description of this type is:





1. Base Board (Alumina, Al_2O_3)
2. Metal Oxide Film Resistor
3. Internal Electrode
4. Terminal Electrode
5. Protective coating

L	3.0 ~ 3.4
W	1.4 ~ 1.8
H	0.5 ~ 0.7
A	0.2 ~ 0.8

Unit: mm

Fig. 1 Dimensions and structure of chip type RS resistors.

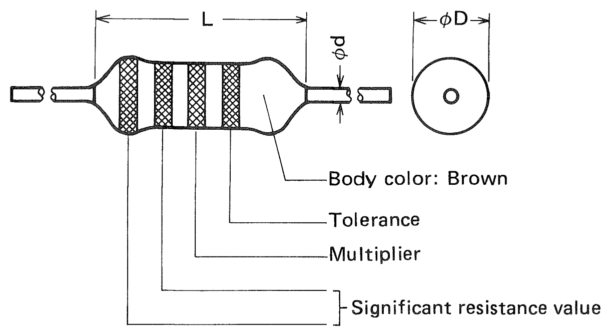
RS 1/8 S 123 J ....Example 1

(1) (2) (3) (4) (5)

(1) Type.
"RS" denotes metal oxide film resistor.
(2) Rated power (in watts).
Here it is 1/8 W. All resistors of this type now available is 1/8 W.
(3) Shape.
"S" denotes square chip (see Photo 2 and Fig.1)
(4) Resistance.
The first two digits indicate significant figures while the last digit indicates the power of 10 or the number of zeros following the significant figures. (See No. 1, T.F. for details). "123" denotes "12" and "000", that is, a resistance of 12kΩ.
Note that the significant figures in the resistance of this resistor adopts for the E-24 series. (Page 5. No.1, T.F.). The resistance range is 2.2Ω thru 3.3MΩ.
(5) Tolerance.
J: ±5% K: ±10%
Pioneer resistors are mainly in the rank of J (±5%).

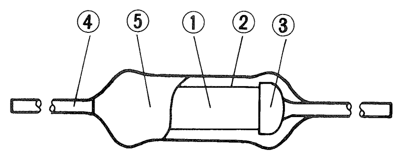
1.2 Carbon Film Resistors for Audio Equipment (RDH)

This type of resistor is a carbon film resistor specially designed for precision audio circuits such as equalizers (RIAA) and signal processors.
The structure is the same as that of the conventional carbon film resistors. The cap material, however, is brass instead of iron for eliminating magnetic distortion. Noise reduction has also been considered, resulting in the same characteristics as NL (low-noise) type resistors.



	1/8W	1/4W
L	10.5±2.0	13.5±2.0
φD	3.5±1.0	3.8±1.0
φd	0.6±0.05	0.7±0.05

Unit: mm



No.	Name	Material
1	Core	Mullite porceleaim
2	Resistor	Carbon Film
3	Caps	Tin-plated Brass
4	Lead wire	Solder-plated Copper
5	Coating	Epoxy-paint, Thick coating

Fig. 2 Dimensions and structure of RDH resistors.

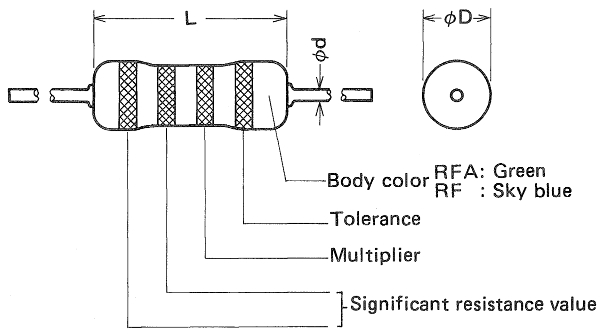
RDH 1/4 P 101 J............Example 2
(1) (2) (3) (4) (5)

(1) Type.
RDH denotes carbon film resistor for audio equipment to distinguish this from ordinary carbon film resistors.
(2) Rated power (in watts).
In addition to the 1/4 W type shown in Example 2 above, a 1/8 W type is also available.
(3) Shape.
"P" denotes pole (axial leads) type resistor (see Photo 3 and Fig. 2). All of this type have this shape.
(4) Resistance.
The resistance of carbon film resistors is indicated by either three or four digits. The resistor in Example 2 has a three-digit indicator, making the resistance 100Ω (the first two digits indicating the significant figures, and the last digit the number of zeros following the significant figures). Where four digits are used, the first three digits indicate the significant figures while the last digit indicates the number of zeros.
For example, 10R0 for 10Ω, 1000 for 100Ω, and 1001 for 1kΩ. Note that the E-24 series has three-digit, and the E-96 series has four-digit. The resistance range is from 5.6Ω to 2.7MΩ.
(5) Tolerance
J: ±5% F: ±1%
In J (±5%) resistors, the resistance is indicated in three digits, while in F (±1%) resistors, the resistance is indicated in four digits. And the resistance range of J resistors is from 5.6Ω to 2.7MΩ while that of F resistors is from 10Ω to 1MΩ.

1.3 Fusible Resistors (RF and RFA)

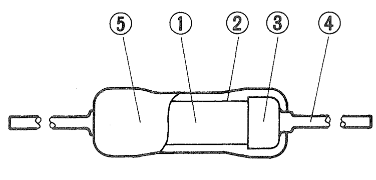
The resistor of this type ordinarily works as a resistor and when the current in the circuit becomes excessive, it works as a fuse. It is usually used in power amplifiers, DC stabilizers and other circuits which handle a large current. However, unlike ordinary fuses, its specification is based on its consumption power, not current.

Note: It is difficult to check this type visually because its surface color does not change even when the resistor is blown out. RD and RS nonflammable resistors, however, turn white.
The mark ⚠ found on some component parts indicates the importance of the safety factor of the part. Therefore, when replacing, be sure to use parts of identical designation.



	RFA1/4	RF1/4	RF1/2	RF1
L	6.5±1.0	$6.3^{+1.5}_{-1.0}$ or 7.5±1.0	$9^{+1.5}_{-1.0}$	$12^{+1.5}_{-1.0}$
φD	2.3±0.5	2.3±0.5	2.8±0.5 or 3±0.5	4±1.0
φd	0.55±0.05	0.6±0.1	0.6±0.1	0.8±0.05 or 0.7±1.0

Unit: mm



No.	Name	Material	
		RFA	RF
1	Core	Forsterite	Mullite
2	Resistor	Metal Film	Metal Film
3	Cap	Iron	Iron
4	Lead wire	Tin-plated Copper	Solder-plated Copper
5	Coating	Nonflammable paint	Nonflammable paint

Fig. 3 Dimensions and Structure of RF and RFA resistors.

RFA 1/4 PS 101 J......... Example 3
(1) (2) (3) (4) (5)

(1) Type.
RFA: Forsterite (MG_2SiO_4) porcelain based fusible resistor.
RF: Mullite ($3Al_2O_3 \cdot 2SiO_4$) porcelain based fusible resistor.

(2) Rated power (in watts).
The rated power depends on the type.
RFA: 1/4 W only.
RF: 1/4 W, 1/2 W, and 1 W
The relationship between the applied power versus fusing time is outlined in the following figure.

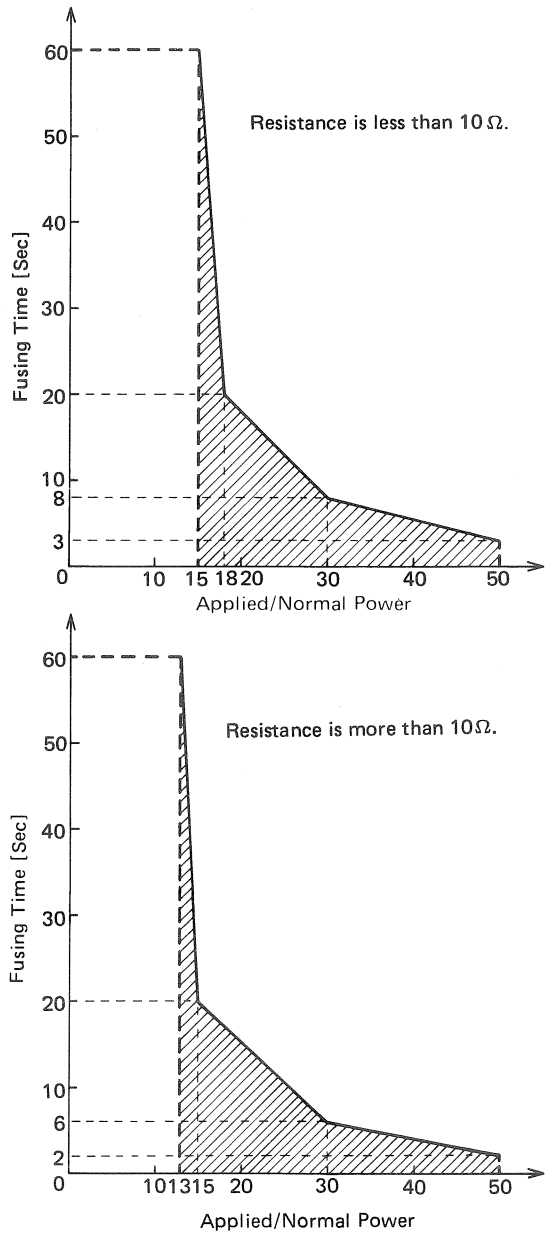


Fig. 4 Fusible characteristics

(3) Shape.
"PS" denotes pole (axial leads) shape.
"PL" denotes PS resistors with lead wires bent vertically to the same direction as shown in Photo 4. PL resistors are in RFA type. Although they are not used at present, they will be used in the near future.

(4) Resistance.
Resistance is indicated by three digits. The E-24 series is adopted for these resistors. The resistance range is 4.7Ω to 820Ω for RFA types, and 2Ω to 560Ω for RF types.

(5) Tolerance.
In this type, only J (±5%) rank resistors are available.

1.4 Special Resistors (□CN- □□□)

Most resistors are under the above standard. Some resistors of special specifications, however, are also used in sophisticated equipment. Those components remaining out of the standard are being numbered separately as below. Although the first letter of the part number differs according to the equipment category, the next two letters are always CN.

Amplifiers, tuners, and receivers :	ACN-
Tape decks :	RCN-
Turntables :	PCN-
Car stereos :	CCN-
Radio/cassettes :	HCN-
Laser disc units :	VCN-

Table 1 Resistor part numbers for each category

Features of Resistors in Photo 5

ACN-130 : Non-inductive type Cement Cased Resistor Encase 2 piece (0.47Ω, 5W)

ACN-079 : RDH resistor of 1/2W (Carbon Film Resistor for Audio Equipment) (1Ω, 1/2W)

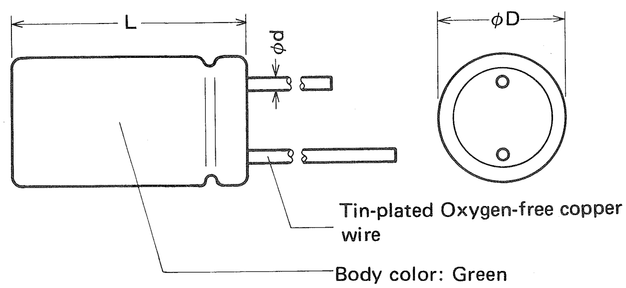
ACN-064 : Magnetic-Distortion Free type RT (Cement cased wire wound) resistor which employs brass caps. (10Ω, 2W)

2. Capacitors

2.1 Aluminum Electrolytic Capacitors for Audio Equipment (CEX and CEY)

These capacitors are used in circuits in high grade models. Although the basic structure is much the same as regular aluminum electrolytic capacitors (CE), special electrode foil and electrolytic solution are used. In addition, iron is no longer used in the lead wires, thereby minimizing the generation of magnetic distortion. The use of oxygen-free copper in these leads in the CEX type contributes to better sound quality.

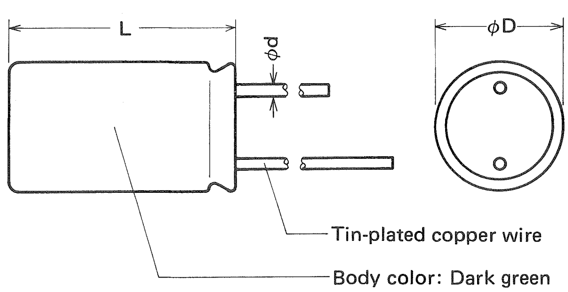
CEX



L	11 ~ 35.5 (11, 11.5, 12.5, 16, 20, 25, 31.5, 35.5)
φD	5 ~ 18 (5, 6.3, 8, 10, 12.5, 16, 18)
φd	0.6, 0.8

Unit: mm

CEY



L	11 ~ 40 (11, 11.5, 12.5, 16, 20, 25, 30.5, 34.5, 36.5, 40)
φD	5 ~ 18 (5, 6, 8, 10, 13, 16, 18)
φd	0.6, 0.8

Unit: mm

Fig. 5 Dimensions of CEX and CEY capacitors.

CEX A NP 330 M 25 .Example 4
(1) (2) (3) (4) (5) (6)

(1) Type.
"CEX" and "CEY" denote aluminum electrolytic capacitors for audio equipment to distinguish them from regular aluminum electrolytic capacitors (CE).

(2) Shape.
"A" denotes upright capacitors. (See No. 2, T.F.).This type of capacitor is always coded as A.

(3) Characteristics.
"NP" denotes non-polar type. Polar types have no specific indication. Only the CEX type is NP. There is no CEY NP type.

(4) Capacitance.
Like the three-digit indication for resistors, the first two digits denote the significant figures while the last digit denotes the number of zeros following the significant figures. The capacitance unit is always microfarad [μF]. A "330" indication denotes a capacitance of 33μF. ($33 \times 10^0 = 33 \times 1 = 33$)
The capacitance range is from 0.1μF to 470μF in CEXANP type, 0.1μF to 2200μF in CEXA type, and 0.1μF to 4700μF in CEYA type.

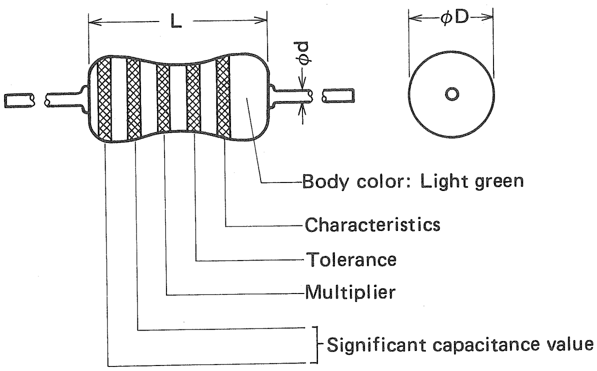
(5) Tolerance.
This type of capacitor is always M (±20%).

(6) Maximum working voltage (DC volt).

CEXANP	25 V and 50V
CEXA	16 V, 25 V, 50V and 100 V
CEYA	16 V, 25 V, 50 V and 100 V

2.2 Axial Leads Type Ceramic Capacitors for Thermal Compensation (CCP)

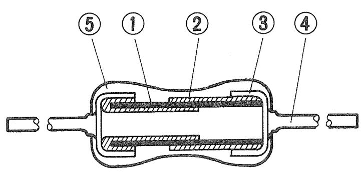
This type of capacitor has the same property as that of the conventional disc type ceramic capacitors.
The appearance is almost the same as that of the carbon film resistors (RD). For this reason, there has been a tendency for the capacitor to be mistaken for a resistor during repairs. The reason why this type of ceramic capacitor has been used is to minimize production costs. Today, most printed circuit board assembly has been automated. There is little advantage if disc type capacitors are used because robots (component inserters) are still too awkward to handle them. Therefore, to improve the efficiency of the automated assembly lines, capacitors shaped much the same as PM (PS) type carbon film resistors (RD) are commonly used. For example, the capacitors of this type are now commonly used in tuner stage assemblies.



L: 6.0 $^{+0.5}_{-0.3}$ mm

φD: 2.8mm (max.)

φd: 0.55 $^{+0.06}_{-0.05}$ mm



No.	Name	Material
1	Dielectric	Ceramic
2	Electrode	Silver
3	Cap	Iron
4	Lead wire	Solder-plated Copper
5	Coating	Epoxy-paint

Fig. 6 Dimensions and structure of CCP and CKP capacitors.

CC P CH 330 J 50 ....Example 5
(1) (2) (3) (4) (5) (6)

(1) Type.
"CC" denotes ceramic capacitors for thermal compensation.
(2) Shape.
"P" denotes pole (axial leads) type.
(3) Characteristics.
This capacitor has four types which are indicated by color codes.
CH: black, RH: yellow, UJ: purple, SL: white
(See the paragraph 3. Characteristics of ceramic capacitors.)
(4) Capacitance.
The indicating method is the same as that of resistors. "330" denotes a capacitance of 33pF. The capacitance ranges are listed below.
CH: 3.3pF to 47pF
RH: 3.3pF to 39pF
SL: 1pF to 120pF
UJ: 8.2pF to 82pF
(5) Tolerance.
The tolerance is divided into three levels according to the capacitance range.

		Color code
J (±5%)	: 10pF to 120pF	Gold
K (±10%)	: 2.2pF to 8.2pF	Silver
M (±20%)	: 1pF to 1.8pF	Black

(6) Maximum working voltage (DC Volt).
These capacitors are all rated 50V.
The voltage is indicated by the color of the body.
50V: Light green

2.3 Axial Leads Type Ceramic Capacitors with High Dielectric Constant (CKP)

Shape and structure are also identical to the CCP capacitor. See Fig. 6.

CK P YB 102 K 50 ....Example 6
(1) (2) (3) (4) (5) (6)

(1) Type.
"CK" denotes ceramic capacitors with high dielectric constant.

(2) Shape.
"P" denotes pole (axial leads) type. "PV" denotes an upright tubular type.

(3) Characteristics.
There are four types indicated by color codes.
YD: red, YB: silver, YV: gold, YK: grey
(See the paragraph 3. Characteristics of ceramic capacitors.)

(4) Capacitance.
The indication is the same as that of resistors. The capacitance ranges are listed below.
YB: 150pF to 1000pF (0.001μF)
YD: 1200pF (0.0012μF)
YV: 1500pF (0.0015μF) to 4700pF (0.0047μF)
YX: 1500pF (0.0015μF) to 22000pF (0.022μF)

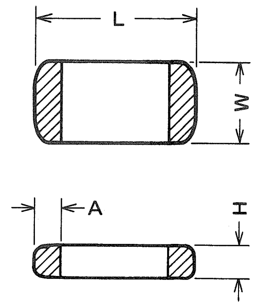
(5) Tolerance.
This is classified into three grades depending on capacitance.

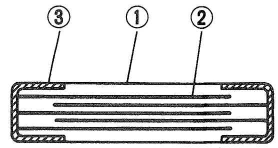
		Color code
K (±10%) :	YB and YV	Silver
M (±20%) :	YD	Black
N (±30%) :	YX	Grey

(6) Maximum working voltage (DC Volt)
This type of capacitor has two different voltage ratings (25V and 50V), each rating being indicated by the color code of the body.
25V: Light pink (6800pF to 22000pF narrower than YX)
50V: Light green
Capacitors in the range other than the above are of 50V.

2.4 Chip Type Ceramic Capacitors for Thermal Compensation (CCS)

Like the chip type resistor described earlier, this type is used to economize space.





1. Dielectric Ceramic
2. Internal Elactrode
3. Terminal Electrode

L	3.0 ~ 3.4
W	1.45 ~ 1.75
H	0.45 ~ 1.3
A	0.2 ~ 0.8

Unit: mm

Fig. 7 Dimensions and structure of CCS and CKS capacitors.

CC S CH 050 D 50 ....Example 7
(1) (2) (3) (4) (5) (6)

(1) Type.
"CC" denotes ceramic capacitor for thermal compensation.

(2) Shape.
"S" denotes a square chip.

(3) Characteristic (Thermal).
There are seven kinds:
CH, PH, RH, SH, TH, UJ, and SL.
(See the paragraph 3. Characteristics of ceramic capacitors.)

(4) Capacitance.
The unit is in picofarads [pF]. "050" indicates a capacitance of 5pF. The capacitance ranges are listed below.
CH: 1pF to 100pF
PH, RH, SH, TH, UJ: 3pF to 100pF
SL: 1pF to 470pF

(5) Tolerance.
The three tolerance levels rated for this type depend on capacitance, not percent.
C (±0.25pF) : 1pF to 5pF
D (±0.5pF) : 6pF to 10pF
K (±10%) : 12pF to 470pF

(6) Maximum working voltage (DC Volt)
These capacitors are all rated 50V.

2.5 Chip Type Ceramic Capacitors with High Dielectric Constant (CKS)

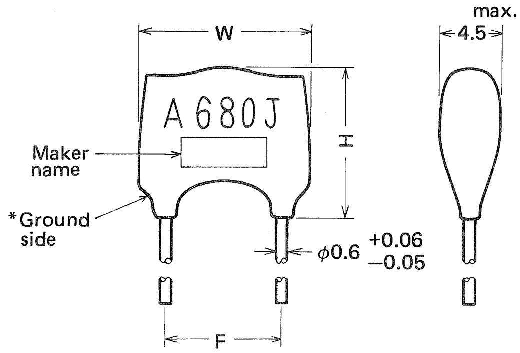
This type of capacitor is also used to save space. Shape and structure are also indentical to the CCS capacitor. See Fig. 7.

CK S YF 103 Z 50 ....Example 8
(1) (2) (3) (4) (5) (6)

(1) Type.
"CK" denotes ceramic capacitors with high dielectric constant.
(2) Shape.
"S" denotes a square chip.
(3) Characteristics
This capacitor is divided into two characteristics types YB and YF.
(See the paragraph 3. Characteristics of ceramic capacitors.)
(4) Capacitance.
The capacitance ranges are listed below.
YB: 560pF to 5600pF
YF: 4700pF to 47000pF (0.047μF)
(5) Tolerance.
Capacitors are classified in two:
K ($\pm$10%) : YB
Z ($^{+80\%}_{-20\%}$) : YF
(6) Maximum working voltage (DC Volt).
All capacitors of this type are rated 50V.

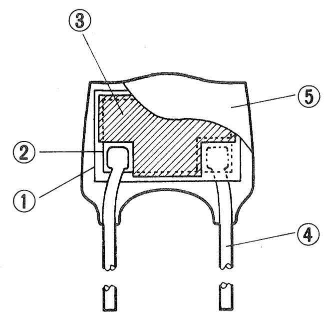
2.6 Mica Capacitors for Audio Equipment (CM)

This type of capacitor differs from the conventional type of mica capacitor. Oxygen-free copper lead wires have been used in it. This type of capacitor is used in circuits where sound quality is of prime importance such as the phase compensation in high grade audio equipment.



W	8.0 ~ 11.0 (8.0, 9.0, 11.0)
H	7.0 ~ 12.0 (7.0, 10.0, 12.0)
F	5.0, 7.5

*Generally, this kind capacitor is non-polar type but if the capacitor is used for high grade audio circuit, grounding side of the capacitor lead should be met to the grounding for the circuit.



No.	Name	Material
1	Dielectric	Natural Mica Film
2	Electrode	Silver
3	Coating	Glass
4	Lead wire	Oxygen-free Copper, solder-plated
5	Package	Phenol resin

Fig. 8 Dimensions and Structure of mica capacitors

CM A 680 J 500...............Example 9
(1) (2) (3) (4) (5)

(1) Type.
"CM" denotes mica capacitor for audio equipment.
(2) Shape.
"A" denotes upright type.
(3) Capacitance.
The unit is picofarad [pF]. "680" denotes a capacitance of 68pF. The capacitance of this type of capacitor lies between 1pF and 220pF.
(4) Tolerance:
This capacitor is rated at two different tolerance levels according to the capacitance.
D (±0.5pF) : 1pF to 10pF
J (±5%) : 11pF to 220pF
(5) Maximum working voltage (DC Volt).
All capacitors of this type are rated 500V.

2.7 Special Capacitors (□CG-□□□, □CE-□□□, □CH-□□□)

Like special resistors, special capacitors which cannot be coded on the basis of common specifications are given other identification numbers.
The first letter of the part number indicates the equipment category. The next two letters denote the following type of capacitor. (Note, however, that exceptions to the rule exist).

□CG- : Ceramic capacitors
□CE- : Film type capacitors
□CH- : Electrolytic capacitors

Features of capacitors in Photo 10

AEC-065: Polystyrene Film Capcitor (Copper foil). Employing oxygen-free copper wire as a leeds. (4700pF, 125V)
AEC-095: Non-inductive type Polypropylene Capacitor. (0.12 μF, 100V)
ACE-097: Non-inductive type Polystyrene Film Capacitor (Tin foil). (0.01 μF, 160V)
ACE-501: Metarized Maylay Film Capacitor for AC power supply circuit (0.01 μF, 150 V/AC)
ACG-019: Ceramic Capacitor for AC power supply circuit. (0.01 μF, 250 V/AC)
ACH-444: Electrolytic Capacitor encased a with glass-fiber plastic case. (22 μF/50V, Non-polar)

3. Characteristic of Ceramic Capacitors

3.1. Characteristics of CK-type Capacitors

The first letter of the code gives operating temperature range, while the second indicates capacitance variation within operating range as 20°C reference.
Operating temperature:
Y: −25° ~ +85°C
B: −30° ~ +85°C

Temp range	Code	Capacitance variation range	Tole-rance code	Indication (CKS: None) CKD (Letters)	CKP (Color code)
Y	A	Within −5 ~ +5%	J, K	A	–
Y	B	Within −10 ~ +10%	K	B	Silver
Y	D	Within −30 ~ +20%	M	D	Red
Y	F	Within −80 ~ +30%	Z	None	–
Y	V	Within −7.5 ~ +7.5%	K	–	Gold
Y	X	Within −15 ~ +15%	M, N	X or SR	Grey
B	C	Within −30 ~ +30%	M, Z	None	–

Table 2 Characteristic code for CK-type capacitors

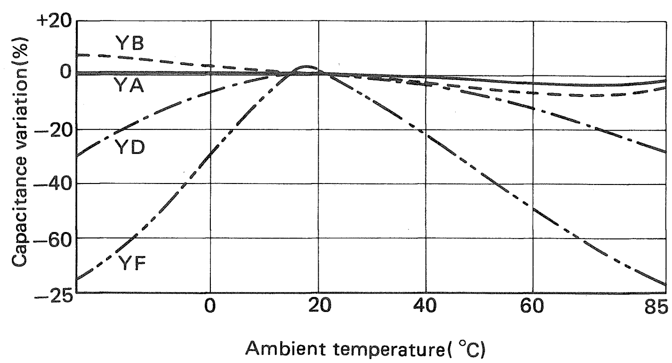


Fig. 9 Typical thermal characteristics curve for CK-type capacitors

3.2 Characteristics of CC-type Capacitors

The first letter of code gives temperature coefficient of nominal capacitance, while the second indicates the capacitance tolerance.

First code			
Code	Thermal coefficient PPM/°C	Indication: Color or letters	
C	±0	Black	NPO
H	−30	Brown	
L	−80	Red	N80
P	−150	Orange	N150
R	−220	Yellow	N220
S	−330	Green	N330
T	−470	Blue	N470
U	−750	Violet	N750
V	−1000		V or N1000
W	−1500		W
X	−2200		X
Z	−4700		Z
SL	−1000 ~ +350	No	

Second code	
Code	Thermal coefficient PPM/°C
G	±30
H	±60
J	±120
K	±250
L	±500
M	±1000

Table 3 Characteristic code for CC-type capacitors

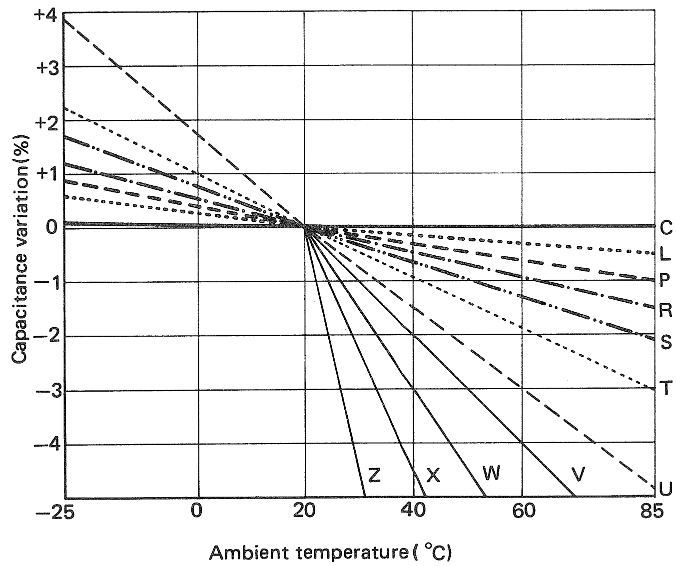


Fig. 10 Thermal characteristics curve for CC-type capacitors

Note: 1. PPM represents 10^{-6}

2. Code SL indicates an ordinary capacitor for which no thermal coefficient is rated (capacitance variation range +4.5 to −5% at −25 to +85°C).
3. Example UJ is for −750±120PPM/°C

1pF or less	CH, LH, PH, SL
2pF	CH, LH, PH, RH, SH, TH, SL
3pF, 4pF	CH, LH, PH, RH, SH, TH, UJ, WK, XL, SL
5pF	CH, LH, PH, RH, SH, TH, UJ, WK, XL, ZM, SL
6pF or more	CH, LH, PH, RH, SH, TH, UJ, VK, WK, XL, ZM, SL

Table 4 Pioneer's CC-type capacitors

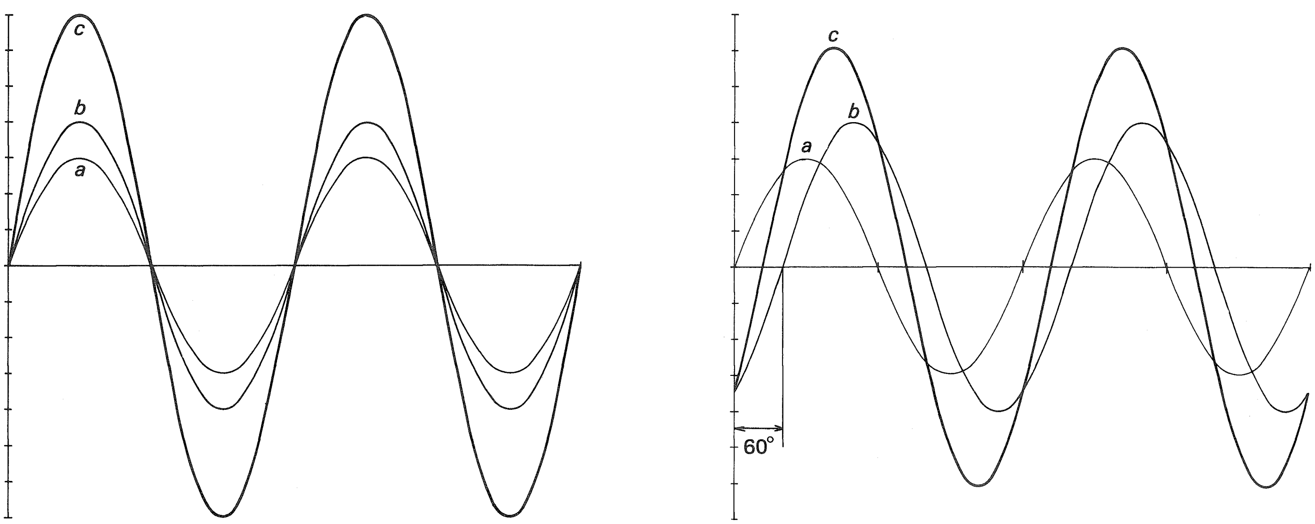
Basic Theory of Electricity

Ohm's Law for AC Circuits

1. Phase and Vector

We have discussed Ohm's Law for DC circuits in the No. 1 and 2 and the Fundamentals of AC in the No. 3 and 5, TUNING FORK. The law can also be applied to AC circuits which have coils and capacitors. In an AC circuit, the *phase of voltage and current becomes an important factor. As you can see in Fig. 1, the added result of two signals depends on their phase difference.

*Phase: One-dimensional relationship between two waves on the axis they travel. If the period of one cycle of a wave is represented by 360°, the fraction of the period elapsed from the time of fixed origin. Or, the angular relationship between current and voltage in AC circuits.



(a) $a + b = c$, **when the signals** a **and** b **are in-phase.**

(b) $a + b = c'$, **when the signals** a **and** b **are out of phase.**

Fig. 1 The added result of two signals.

Let's add a and b mathematically.
When a and b are in phase, it is simple.
(Fig. 1 (a)):

$$a = A \sin \omega t$$
$$b = B \sin \omega t$$
$$a + b = A \sin \omega t + B \sin \omega t = (A + B) \sin \omega t$$

When a and b have 60° phase difference.
(Fig. 1(b)):

$$a = A \sin \omega t$$
$$b = B \sin (\omega t - 60°)$$
$$\begin{aligned} a + b &= A \sin \omega t + B \sin (\omega t - 60°) \\ &= A \sin \omega t + B (\sin \omega t \cos 60° - \cos \omega t \sin 60°) \\ &= (A + B \cos 60°) \sin \omega t - B \sin 60° \cos \omega t \\ &= (A + 0.5B) \sin \omega t - 0.87B \cos \omega t \end{aligned}$$

$$= \sqrt{(A+0.5B)^2+(0.87B)^2}\left\{ \sin \omega t \frac{A+0.5B}{\sqrt{(A+0.5B)^2+(0.87B)^2}} - \cos \omega t \frac{0.87B}{\sqrt{(A+0.5B)^2+(0.87B)^2}} \right\}$$

$$= \sqrt{(A+0.5B)^2+(0.87B)^2}\left\{ \sin \omega t \cos \theta - \cos \omega t \sin \theta \right\}$$

$$= \sqrt{(A+0.5B)^2+(0.87B)^2} \sin(\omega t - \theta)$$

$$Here,\ \theta = \cos^{-1} \frac{A+0.5B}{\sqrt{(A+0.5B)^2+(0.87B)^2}}$$

You have seen how complicated the mathematical addition of sine waves is. Geometric composition using vectors, however, is very easy.

Vectors are useful for discussing AC circuits. It is not so difficult as you think. While scalar is a quantity that has no direction, it is a quantity that has both magnitude and direction and is commonly represented by an arrow with a length and an orientation which represent magnitude and direction respectively. ↗

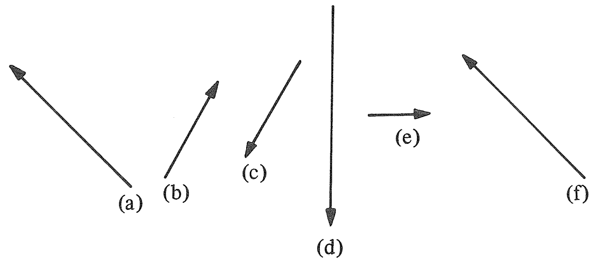


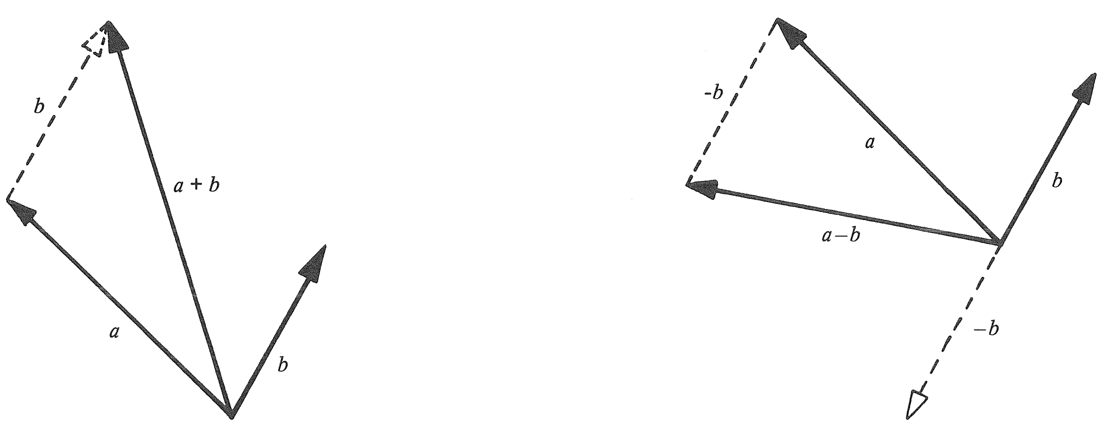
Fig. 2 Vectors

In Fig. 2, (a) and (f) are the same because they are parallel and equal in length: (a) = (f). (c) is called "inverse vector" of (b) because they are equal in length but opposite in direction: (b) = (−c).

2. Composing Vectors

The sum of two vectors is the center diagonal of the parallelogram that is formed when the two vectors are placed end-to-end and tip-to-end as shown in Fig. 3(a).

When subtracting one from the other, reverse the direction of a vector (inverse vector) and add them. Refer to Fig. 3(b).



(a) Adding vectors

(b) Subtracting vectors

Fig. 3 Composing vectors

The waves of Fig. 1 can be expressed by vectors as shown in Fig. 4.

The waves a and b of Fig. 1(a) can be converted and added in the same direction as in Fig. 4(a). Those of Fig. 1(b) have the phase difference of 60° and are composed as in Fig. 4(b).

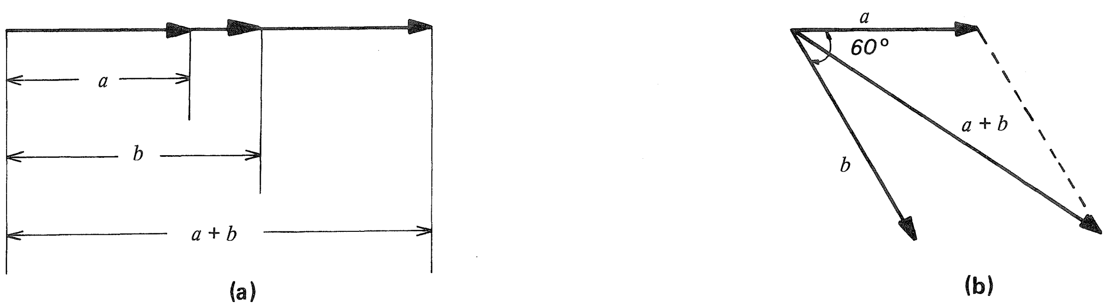


Fig. 4 Waves of Fig. 1 represented by vectors

3. RL Series Circuit

Let us see the output of a series circuit composed of a resistor R and a coil L when a signal of ($E = V \sin \omega t$) is applied to the circuit and its current is I [A]. (ω: $2\pi f$)

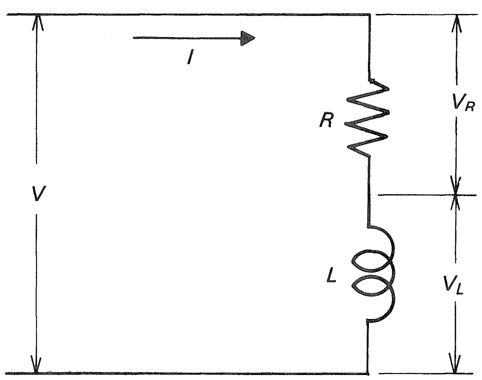


Fig. 5 RL series circuit

The current is equal at any point in the circuit. The voltage and phase across the R and L are as follows:

$V_R = RI$ [V] The voltage and current are in phase.

$V_L = X_L I$ [V] The phase of the volatge advances from that of the current by 90°. (No. 5, TUNING FORK)

As the phase is relative, a 90° advance of the voltage from the current means a 90° delay of the current from the voltage. X_L stands for the resistance of a coil against AC and is called "Reactance."

$$X_L = \omega L \ [\Omega]$$

The vectorial composition of V_R and V_L is shown in Fig. 6.

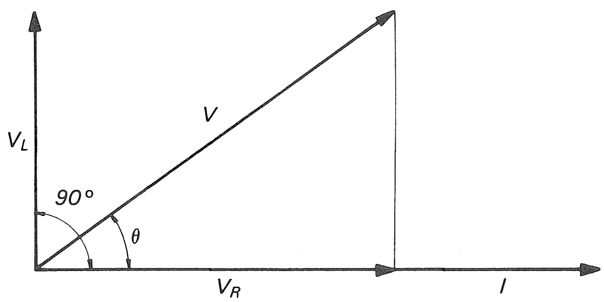


Fig. 6 Composing the vectors of V_R and V_L of RL series circuit with the vector of I set as the *reference.

*Reference vector: A common reference, usually drawn on the positive *x*-axis (horizontal), for drawing vectors. Generally, the magnitude and direction of a current is taken as the reference in a series circuit and those of a voltage are taken in a parallel circuit.

As the phase difference between V_R and V_L is 90°, the resultant voltage becomes the hypothenuse of a right angle triangle;

$$\sqrt{V_R^2 + V_L^2} \quad \text{(Pythagorean theorem)}$$

and its phase becomes θ in advance of the current phase.

$$V = \sqrt{V_R^2 + V_L^2} = \sqrt{(RI)^2 + (X_L\ I)^2}$$
$$= \sqrt{R^2 + X_L^2}\ I$$

Pythagorean theorem: The square of the hypotenuse of a right triangle is equal to the sum of each leg sqaured.

$$c^2 = a^2 + b^2$$

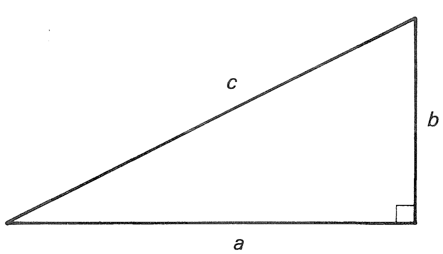


Fig. 7 Pythagorean theorem

In an AC circuit, the quotient of voltage/current *(V/I)* is called "impedance *Z*". The unit of *Z* is ohm. Thus, the combined impedance of the circut is $\sqrt{R^2 + X_L^2}$ [Ω]. The current value in the circuit can be obtained with the impedance *Z* and voltage *V* by applying the Ohm's law for AC circuits.

$$I = V/Z$$

4. *RC* Series Circuit

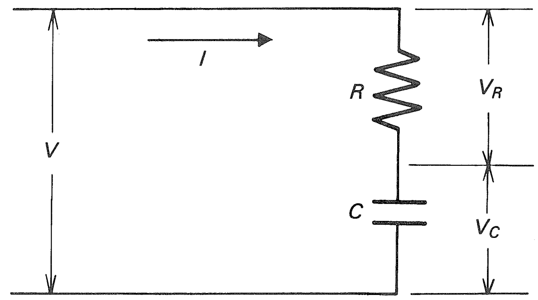


Fig. 8 RC series circuit

RC series circuit can be considered similar to the *RL* series circuit although the phase of the voltage across the *C* is delayed from that of the current by 90°. The reactance X_C of the *C* is:

$$\frac{1}{\omega C}\ [\Omega]$$

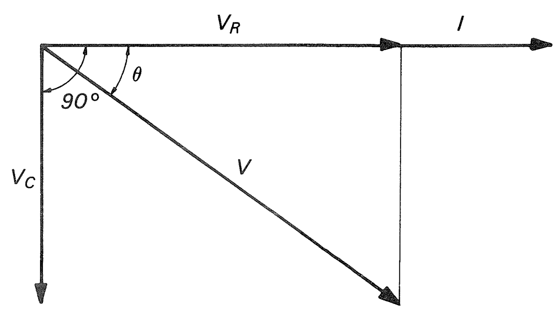


Fig. 9 Composing the vectors of V_R and V_C in the RC series circuit.

The resultant voltage can be obtained with:

$$V = \sqrt{V_R^2 + V_C^2}$$
$$= \sqrt{(RI)^2 + (X_C I)^2}$$
$$= \sqrt{R^2 + X_C^2}\, I$$

The resultant phase of the voltage is delayed from that of the current by θ. The impedance Z of this circuit is given by

$\sqrt{R^2 + X_C^2}$ [Ω].

5. *RLC* Series Circuit

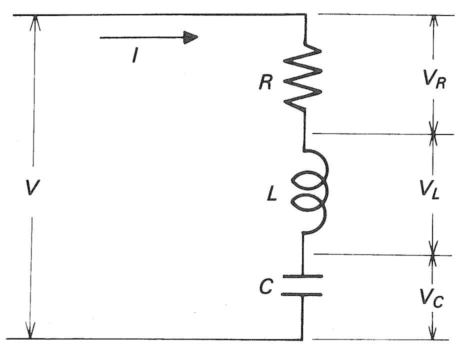
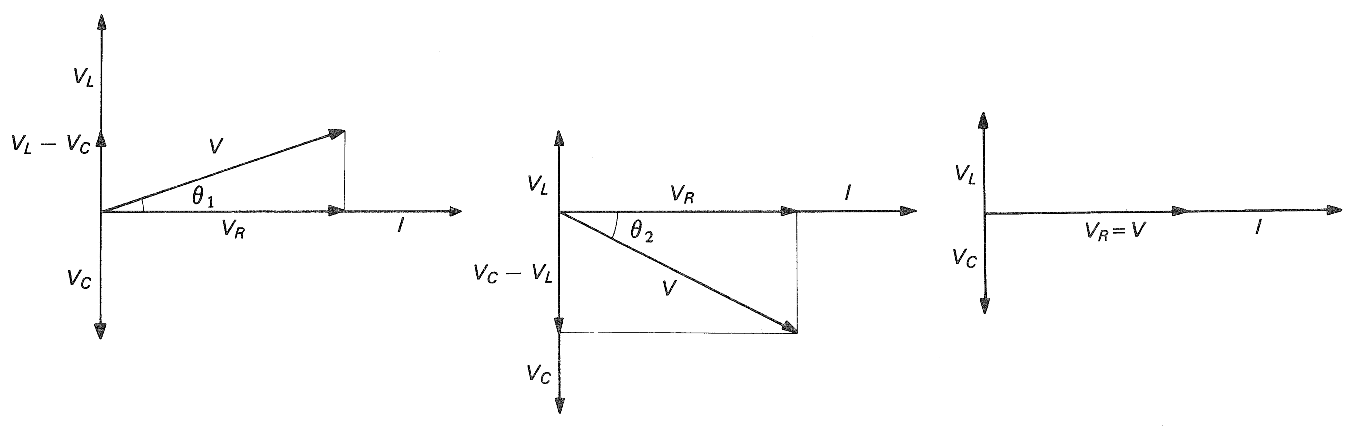


Fig. 10 RLC series circuit

Next, let us see the series circuit of R, L and C. Imagine that a current I [A] flows when a voltage V [V] of f [Hz] is applied to the circuit. The voltage across each component is:

$V_R = RI$	The voltage and current are in phase.
$V_L = X_L I$	The phase of the voltage advances from that of the current by 90°.
$V_C = X_C I$	The phase of the voltage is delayed from that of the current by 90°.

The composite voltage can be obtained by setting the current vector as the reference. The resultant voltage and its phase varies in accordance with the difference between X_L and X_C. The typical three types of resultant vectors are shown in Fig. 11.



(a) When $X_L > X_C$ (b) When $X_L < X_C$ (c) When $X_L = X_C$

Fig. 11 The relation of vectors

When X_L is larger than X_C (Fig. 11(a)),

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

The phase of the voltage advances from that of the current by θ_1. When X_C is larger than X_L (Fig. 11(b)),

$$V = \sqrt{V_R^2 + (V_C - V_L)^2}$$

The phase of the voltage is delayed from that of the current by θ_2.

When X_L and X_C become equal Fig. 11.(c), V becomes V_R, the voltage and current become in phase, the combined impedance is minimized and the current suddenly becomes maximum. Here, you may be surprised to find that the circuit is equivalent to the one with only a resistor. Under this condition, X_L and X_C cancel each other and the circuit becomes series-resonant. The frequency where X_L becomes equal to X_C is called the "Resonant Frequency". It is given by the following equation which is useful for finding tuning frequencies.

$$X_L = X_C$$

$$2\pi fL = \frac{1}{2\pi fc}$$

$$4\pi f^2 L = \frac{1}{C}$$

$$f^2 = \frac{1}{4\pi^2 LC}$$

$$\sqrt{f^2} = \sqrt{\frac{1}{4\pi^2 LC}}$$

$$f = \frac{1}{2\pi\sqrt{LC}} \text{ [Hz]}$$

It should be noted that a slight frequency deviation varies X_L and X_C. When the frequency increases, the phase of the resultant voltage advances as shown in Fig. 11 (a), and when it decreases, it is delayed as shown in Fig. 11 (b). The equations for the three phase conditions can be combined as follows:

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$= \sqrt{R^2 I^2 + (X_L - X_C)^2 I^2}$$

$$= \sqrt{R^2 + (X_L - X_C)^2}\, I$$

The mathematical sign of $(X_L - X_C)$, whether it is positive or negative, does not affect the result and only the absolute value has a meaning because $(X_L - X_C)$ is squared. But, we can see the phase relation with the signe as follows:

$(X_L - X_C) > 0$: The phase of the voltage advances from the current. The combined impedance becomes inductive.

$(X_L - X_C) < 0$: The phase of the voltage is delayed from the current. The combined impedance becomes capacitive.

$(X_L - X_C) = 0$: The phase of the voltage is in phase with the current.

The impedance of this circuit becomes

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

When calculating the impedance of RC or RL series circuit with the above equation, X_L or X_C is made 0. This equation is important.

6. *RLC* Parallel Circuit

We have been learning about series circuits. Now, let's look at a *RLC* parallel circuit.

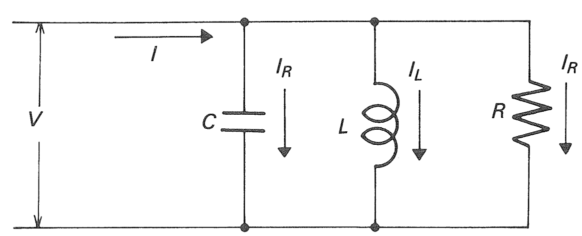


Fig. 12 RLC parallel circuit

The RL and RC parallel circuits can be understood by assuming that the impedance of C or L (X_C or X_L), is infinite. The AC current and its phase in the parallel circuit of R, C and L are as follows:

$I_R = V/R$	The current and voltage are in phase.
$I_L = V/X_L$ $= V/\omega L$	The phase of the current delays from that of the voltage.
$I_C = V/X_C$ $= \omega CV$	The phase of the current advances from that of the voltage.

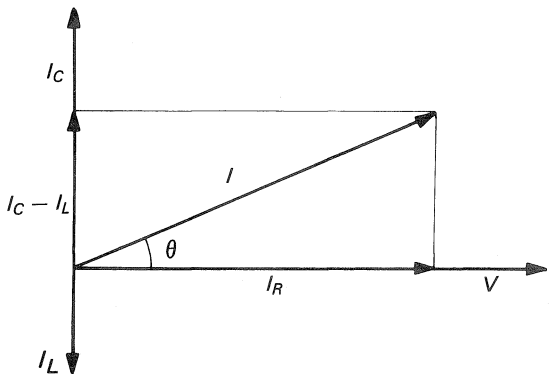


Fig. 13 Composing vectors when $I_C > I_L$

In Fig. 13, voltage has been taken as the reference. The resultant current can be obtained with:

$$I = \sqrt{I_R^2 + (I_C - I_L)^2}$$

$$= \sqrt{\left(\frac{V}{R}\right)^2 + \left(\frac{V}{X_C} + \frac{V}{X_L}\right)^2}$$

$$= \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2}\ V$$

The impedance $Z = V/I$

$$= \frac{1}{\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2}}$$

The phase appears in the two quadrants depending on the sign of $(1/X_C - 1/X_L)$ as in Fig. 11.

When $(1/X_C - 1/X_L) > 0$:

the phase of the current advances from that of the voltage. The combined impedance becomes capacitive.

When $(1/X_C - 1/X_L) < 0$:

the phase of the current delays from that of the voltage. The combined impedance becomes inductive.

When $(1/X_C - 1/X_L) = 0$:

the current and voltage are in phase.

When $(1/X_C - 1/X_L)$ is 0 in the parallel circuit, the combined impedance becomes R and the circuit is in the state of parallel-resonance. The phenomena is similar to that of series resonance. The resonant frequency can be obtained with the same equation as that of the Series-resonant Circuit:

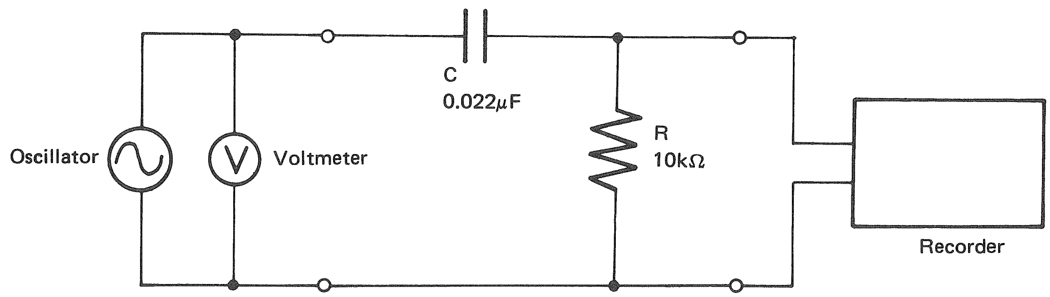
$$f = \frac{1}{2\pi\sqrt{LC}}\ [\text{Hz}]$$

7. Filter

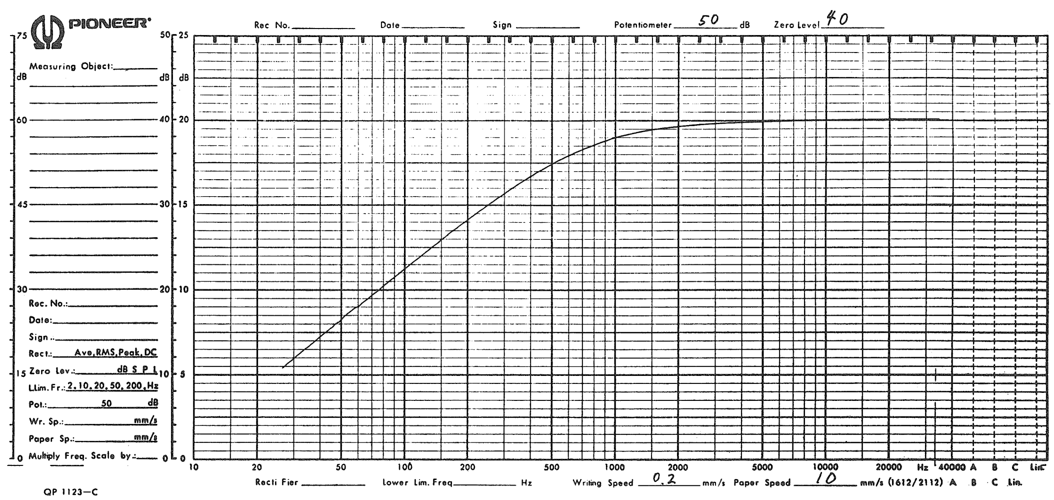
We have learned the characteristics of R, C and L in the No. 1 and 2 of *T.F.* The reactance of a coil increases and that of a capacitor decreases when the current frequency increases and it varies conversely when the frequency decreases. The frequency does not affect the resistance of resistors. Using these characteristics, various circuits can be designed. One of them is the filter.

7-1 High-pass Filter (HPF)

Fig. 14(b) shows the frequency/output-voltage characteristic measured with a frequency characteristic recorder by applying the sine wave signal of constant voltage 0 [dB] in the frequency range from 20 [Hz] to 30 [kHz] to the input.



(a) Circuit diagram



(b) Characteristics

Fig 14 High-pass filter

The circuit of Fig. 14(a) is called a "high-pass filter (HPF)" which passes high frequency components. The characteristic can be understood with the Ohm's law. When the input frequency becomes 0 [Hz] or the input current becomes DC, the capacitor opens and no output voltage appears. The current in the C increases as the input signal frequency increases and when the frequency becomes extremely high, the reactance of the C becomes negligibly low and a voltage equal to the input appears at the output. The relationship can be expressed as follows:

V_O: Output voltage

$$V_O = V_R = RI = RV_I/Z$$

V_I: Input voltage

$$\omega = 2\pi f$$

$$Z = \sqrt{R^2 + X_C^2}$$

$$V_O = \frac{R}{\sqrt{R^2 + X_C^2}} V_I \qquad X_C = \frac{1}{\omega C}$$

Fig. 14(b) can be obtained with the above equation.

Here, when $X_C = R$,
$$V_O = \frac{R}{\sqrt{R^2 + R^2}} V_I = \frac{R}{\sqrt{2R^2}} V_I = \frac{1}{\sqrt{2}} V_I$$

The frequency at which the output voltage becomes $1/\sqrt{2}$ of the input voltage or 3 [dB] below the input is called the "cut-off frequency *(fc)*". *fc* is given by:

$$R = X_C$$

$$R = \frac{1}{2\pi f_C C}$$

$$fc = \frac{1}{2\pi RC} \text{ [Hz]}$$

It is not easy to make a graph of frequency vs. output voltage characteristics with:

$$V_O = \frac{R}{\sqrt{R^2 + X_C^2}} V_I$$

The approximate value of *fc*, however, is easily obtained with *1/(2πRC)*. The slope is 6 [dB/octave], or the voltage increases by 6 [dB] when the frequency is doubled. This approximation is used by most designers and service technicians.

Let us draw the curve of the characteristic of a high-pass filter composed of a 10 [kΩ] resistor and a 0.022 [μF] capacitor.

a) Calculate the *fc* and plot the point (1) at $x = fc$, $y =$ input level.

$$fc = \frac{1}{2\pi RC} \qquad \text{input level} = 0\text{[dB]}$$

$$= \frac{1}{2\pi \text{x}(10\text{x}10^3)\text{x}(0.022\text{x}10^{-6})} = 723 \text{ [Hz]}$$

b) As the slope of the characteristic of single staged filter is 6 [dB/oct], plot the point (2) at $x = 723/2$ [Hz], $y = -6$ [dB] and connect the points (1) and (2).

c) Draw a line parallel to the x axis from (1).

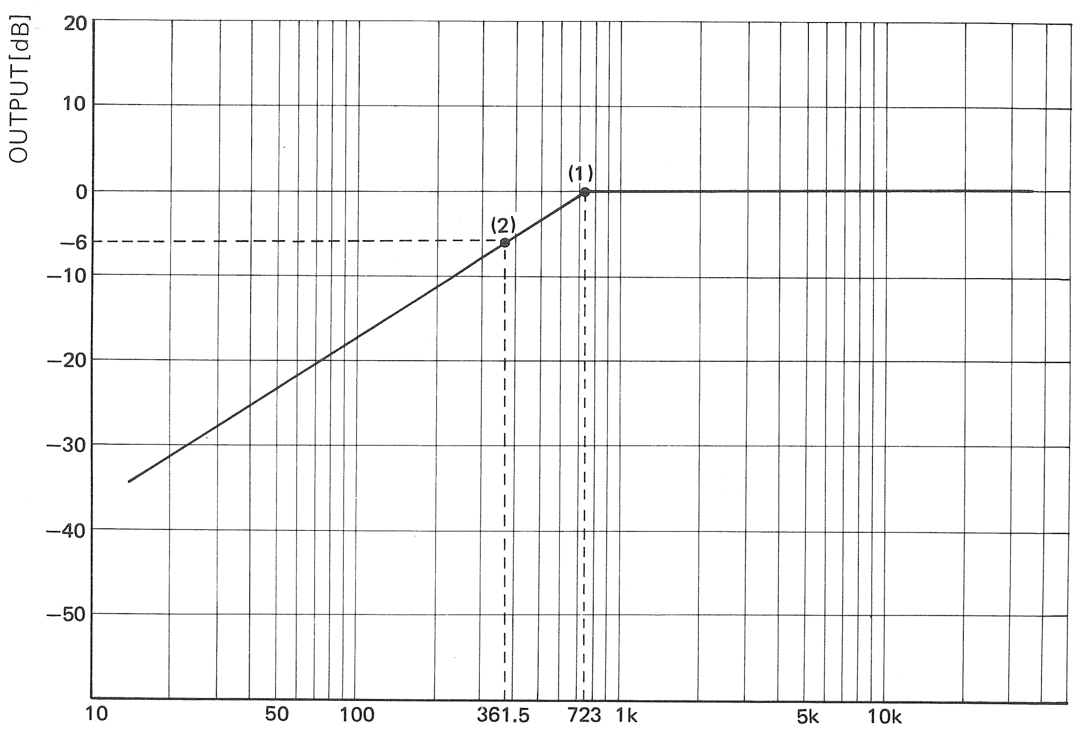
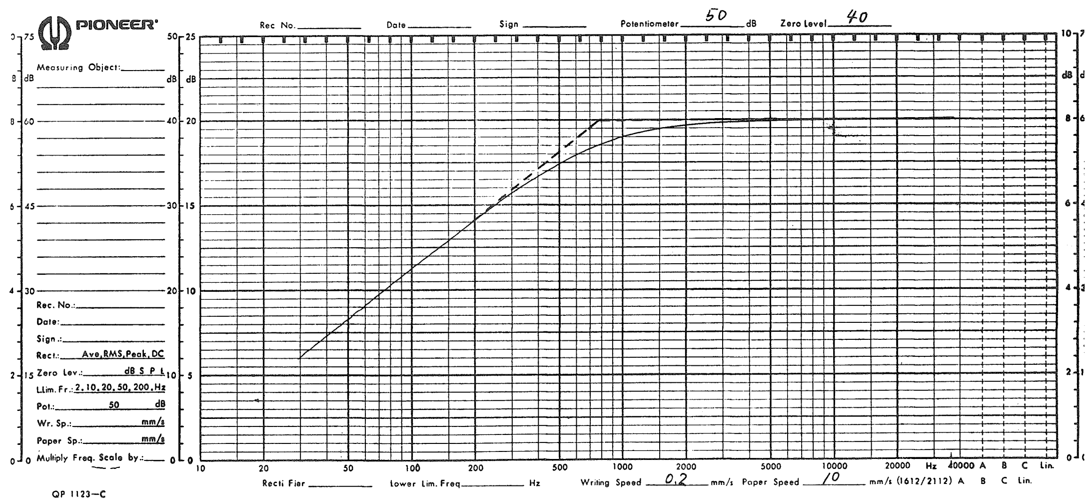


Fig. 15 Approximate graph of the HPF (R: 10[k Ω] C: 0.022[μF])



a solid line : Fig. 14
a dotted line : Fig. 15

Fig. 16 Superimposed graph of Fig. 15 to Fig. 14

7-2 Low-pass Filter (LPF)

Now let's examine the output across the *C* instead of the *R* of the HPF.

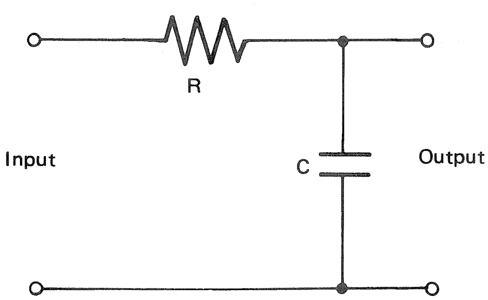


Fig. 17 Low-pass filter

In the circuit of Fig. 17, when the input signal frequency is 0 [Hz] the *C* becomes open, the current stops, the voltage drop across the *R* becomes 0 [V] and thus the voltage equal to that of the input appears at the output. When the frequency increases, the current in the circuit increases and the output voltage across the *C* decreases. When the frequency becomes extremely high, the reactance of the *C* becomes extremely low making the output 0. Then, the low frequency components are passed to the next stage and the high frequency components are blocked. Such a circuit is called "low-pass filter". The characteristic of this circuit is the opposite of a HPF.

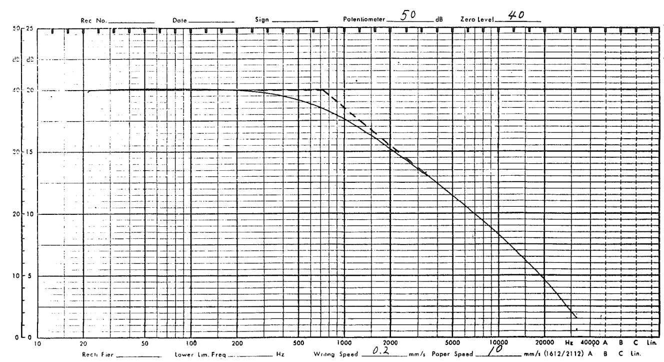


Fig. 18 Characteristics of LPF

The output Vo is given by:

$$V_O = V_C = X_C I = X_C (V_I / Z) = \frac{X_C}{\sqrt{R^2 + X_C^2}} V_I$$

V_I : Input voltage

$$X_C = \frac{1}{2\pi fc}$$

The cut-off frequency *(fc)* of this circuit is given by $1/(2\pi RC)$ [Hz]. Approximating the characteristic of a LPF can be done in the same way as that of HPF (Fig. 18). It is interesting to see various characteristics of these circuits. The circuits and characteristics of various filters are shown in Fig. 19.

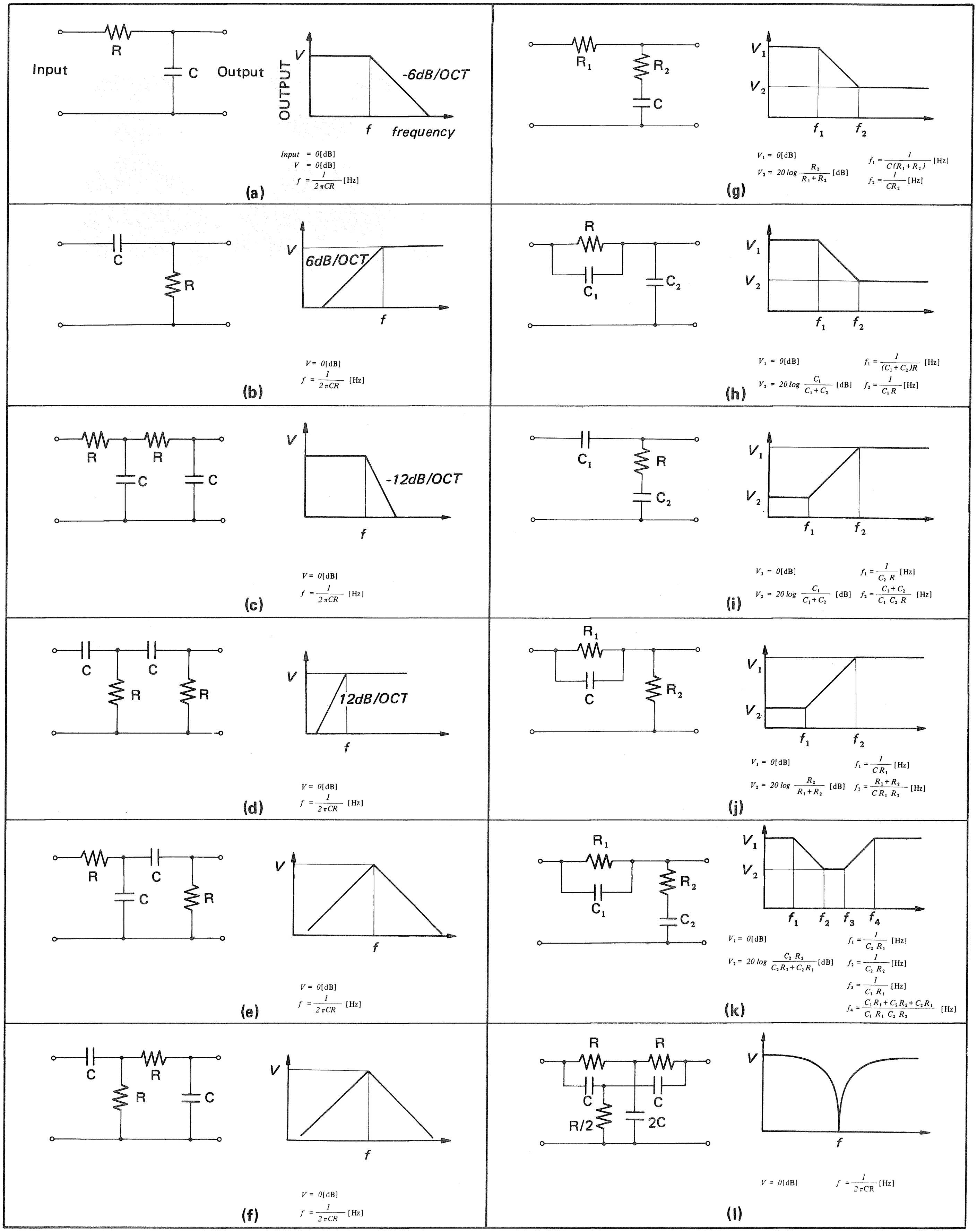
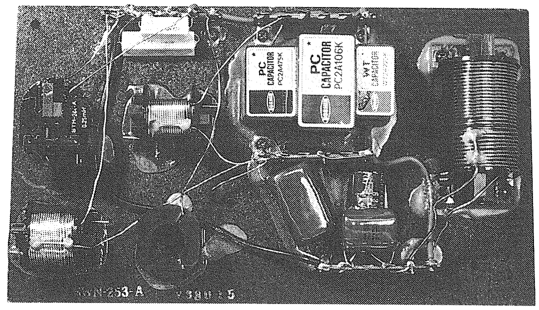


Fig. 19 Various filters and their f-v characteristic

Filters which pass signals of a particular frequency band such as (e) and (f) are called a "band-pass filter (BPF)". Filters of opposite characteristics to BPF such as (k) and (l) are called a "band-elimination filter (BEF)".



We have been discussing *RC* filters. The same characteristic is available with *RL* or *LC* filters. *LC* filters have no resistor which consumes power. They are popularly employed in speaker systems and power supply blocks to save power. Fortunately, the slope of the characteristics of *LC* filters is more rapid than that of *RC* or *RL*. Fig. 20 shows *LC* filters employed in speaker networks. Try to guess their type, HPF, LPF, BPF or BEF.

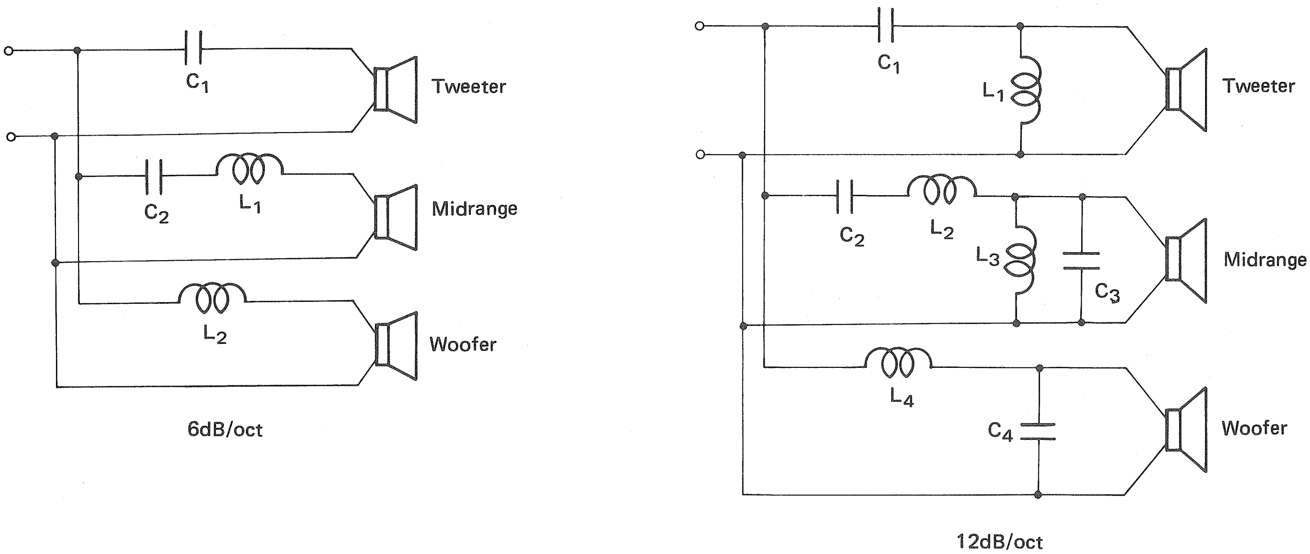


Fig. 20 LC filters employed in speaker networks

First Step in Audio

Specifications

(SPEC) SPEAKER

The speakers are the most important audio components in determining sound coloration and quality. The sound produced by the speakers is subject to many influences by the speaker components themselves, the enclosure, and the listening room, etc. before it reaches our ears. But as yet, there is no standard measuring method which takes all of these factors into account. And because of considerable differences in individual tone color preferences, it is hard to judge speaker quality on the basis of catalog specifications alone.
This does not mean, however, that there is no point in being familiar with speaker performances. There is no disputing the fact that the better the performance of a speaker, the better the quality of sound that it reproduces. If the performance of the speaker systems is high, you can change the sound quality to your preference by changing attenuators and the conditions of listening room. If the performance is low, the possibility is limited.
The purpose of the discussion here is to describe basic speaker specifications. There are many parameters available for expressing speaker performance. Apart from the fairly technical items required for design purposes, the specifications described here are limited to those appearing in catalogs and instruction manuals.

SPECIFICATIONS

Enclosure	Floor style, Passive Radiator type
System	3-way, 3-speaker system
Loudspeakers:	
Woofer	26 cm (10-1/4 in) PG cone type
Mid-range	6.6 cm (2-1/2 in) PG cone type
Tweeter	Horn-loaded Ribbon type
Passive-radiator	36 cm (14 in) PG cone type
Nominal Impedance	6.3 ohms
Frequency Range	28 to 50,000 Hz
Sensitivity	92.5 dB/W at 1 m distance
Maximum Music Power	240 W
Rated Power	80 W
Crossover Frequencies	1,500 Hz, 6,000 Hz
Dimensions	465(W) × 928(H) × 341(D) mm 18-5/16(W) × 36-9/16(H) × 13-7/16(D) in
Weight	37.5 kg/82 lb 10 oz
Accessory Parts	Operating Guide x 1 Speaker Cords x 1

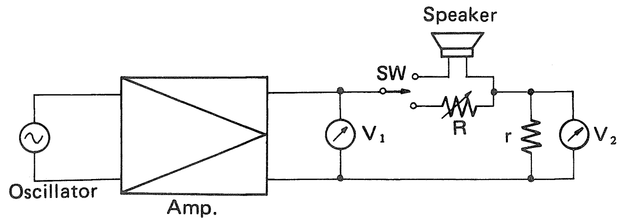
NOTE:
Specifications and design subject to possible modification without notice, due to improvements.

1. Lowest Resonant Frequency and Nominal Impedance

If the adjustment of the variable resistor R in the measuring circuit shown in Fig. 1 results in R = Ra, and equal currents flow through the speaker and the resistor, the electrical impedance in respect to the voice coil terminal can be expressed as Zs = Ra. The curve obtained by repeating this measurement at different frequencies is called the electrical impedance characteristics curve indicating how the electrical impedance varies at different frequencies.

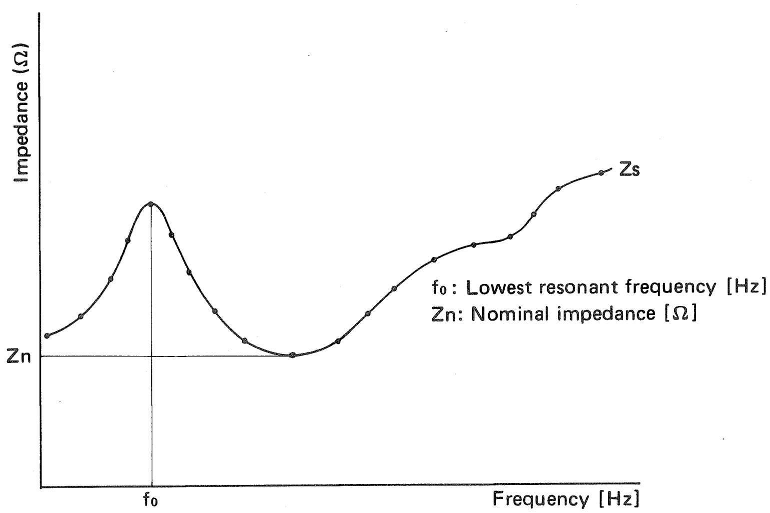
An electrical impedance characteristic curve is shown in Fig. 2. Generally, there are some undulations, the curves differ greatly from those of the input impedance of amplifiers and transformers.

The first peak appearing in the curve shown in Fig. 2(a) is at what is called the "lowest reasonant frequency" (f_0). The lowest impedance above the lowest resonant frequency is called the "nominal impedance," or "impedance."

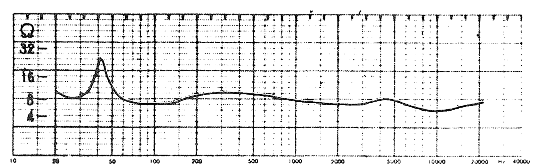


V1: AC Voltmeter (for input monitoring)
V2: AC Voltmeter (for measuing admittance)
R: Variable resistor
r: Low resistance resistor (about 0.1Ω)

Fig. 1 Electrical impedance characteristics measuring circuit (Resistor replacement method)



(a) Lowest resonant frequency and nominal impedance



(b) Examples of electrical impedance characteristics

Fig. 2 Electrical Impedance Characteristics

2. Sensitivity (Output Sound Pressure Level)

Sensitivity indicates the efficiency of the speaker. Sensitivity is measured in an anechoic room under specified conditions as shown in Fig. 3. The microphone is placed at a distance of one meter on-axis from the speaker enclosure. The input voltage applied to the speaker is 1W, adjusted for the rated impedance of the speaker.

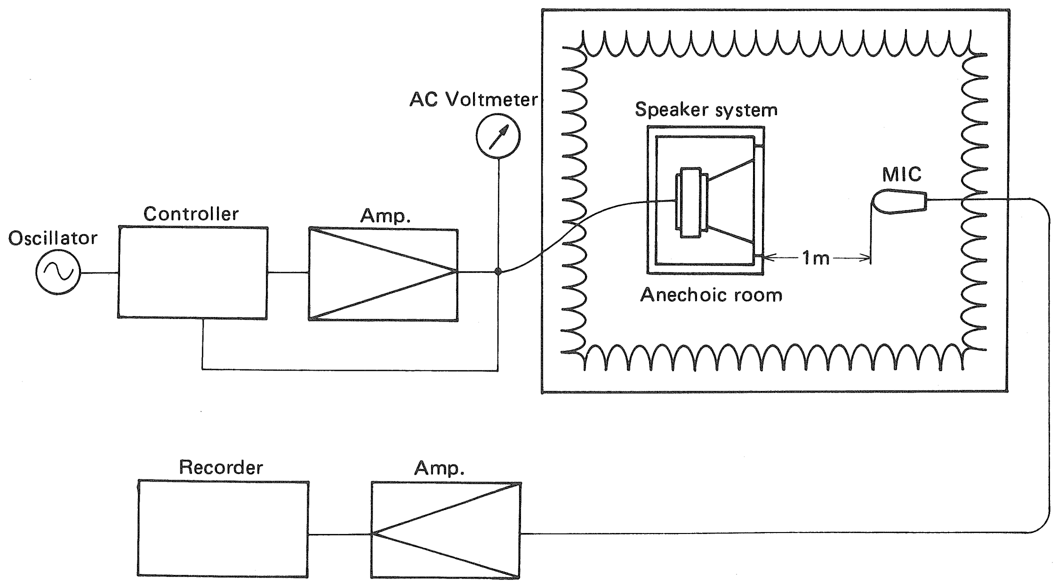


Fig. 3 The measurement of speaker system

Under the conditions shown in Fig. 3, the sound pressure levels measured at 1 meter from the speaker are recorded with continuously varying frequencies (see Fig. 4).
The sound pressure is measured and expressed in dB, with a 0dB reference point being 0.0002μbar.
Therefore:

$$S = 20 \log \frac{P}{0.0002\mu bar}$$

S: Sensitivity [dB]
P: Sound pressure [μbar = dyne/cm^2]

This 0dB standard of 0.0002μbar is considered to be the minimum sound pressure level that is audible, and so has been adopted as the increment of measurement.
From the chart showing frequency characteristics of output sound pressure measured using the process just described, we take measurements at four prescribed frequencies, average them, and then take the result for the published sensitivity specification.

Therefore:

$$S_o = \frac{S_1 + S_2 + S_3 + S_4}{4}$$

S_o: Rated sensitivity [dB]
$S_1 \sim S_4$: Rated sensitivity [dB] at 4 fixed-point frequencies]

The four fixed frequencies are usually 300Hz, 400Hz, 500Hz, and 600Hz (but if there is a peak or dip in frequency response at one or more of these points, they may be shifted a little to get a more uniform reading).

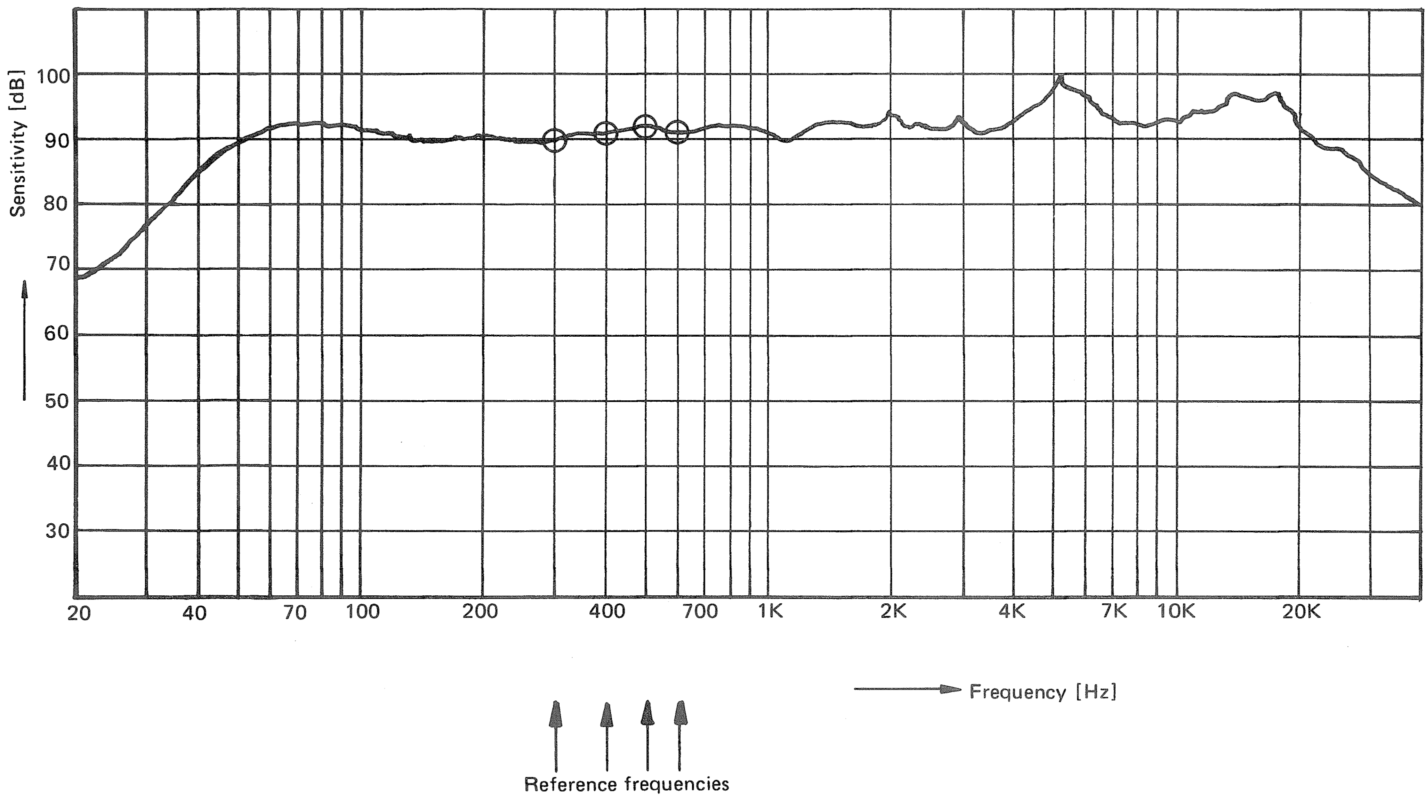


Fig. 4 Calculation of output sound pressure level

3. Frequency Range

As seen in Figs. 4 and 5, the sound level reproduced by a speaker decreases gradually at the high and low ends of the frequency range. It is necessary to define the lowest level to be measured. The lowest resonant frequency (fo) is taken as the low frequency limit and the high frequency where the sound level decreases from the rated sensitivity by 10dB is taken as the high frequency limit.

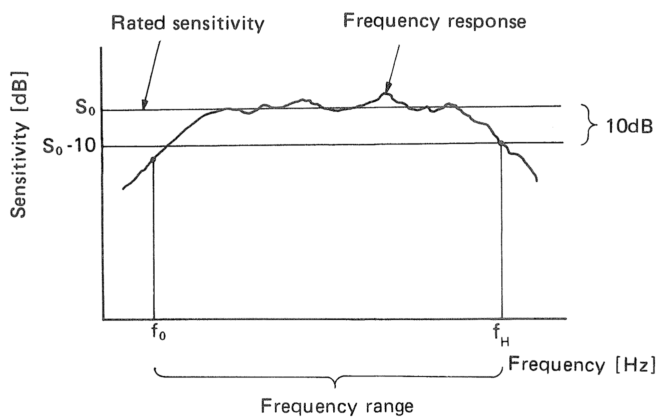


Fig. 5 Definition of the playback frequency band

4. Directional Frequency Characteristics

The directional characteristics are obtained by measuring sound pressure level at various points with various angles off the reference axis of the speaker keeping a prescribed distance from the sound source, usually 30° or 60°. Note that the characteristic can be known in relative to the characteristics measured at $\theta = 0°$.

It indicates the relative degree of decrease or increase in sound pressure level by angle variation.

These characteristics can also be indicated by polar coordinates. This method gives a better idea of how the acoustic power is distributed radially when the frequency is kept constant. This method involves many measuring points (for example, in 15° steps) and a constant frequency. Special measuring equipment which enables direct recording onto polar coordinate recording paper is available. In this case, the speaker or microphone is rotated. Examples of recorded results are given in Figs. 6 and 7.

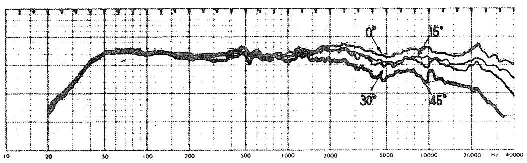


Fig. 6 Rated sensitivity directional characteristics

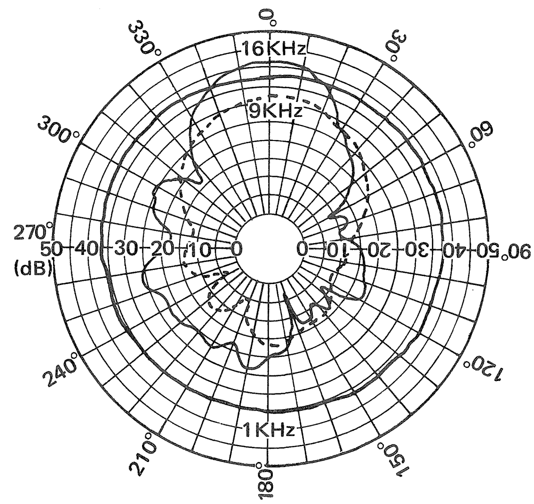


Fig. 7 Rated sensitivity directional characteristics (using polar coordinates)

5. Rated Input

The rated input is the highest input which ensures continuous operation of the speaker without letting it generate abnormal noises.

Tests, using white noise whose energy distribution has been compensated, are stipulated by JIS (Japan Industrial Standards.) The compensation is in accordance with the curve recommended by IEC (International Electro-Technical Commission).

The time constant of the compensator, which is a 2-stage ladder RC circuit, has been determined at 250μs to obtain the mean characteristic curve between those curves of music and voice to simulate the same energy distribution of the actual sound. This curve is believed to be ideal for this type of testing.

The attenuation slope of the curve is 6dB/octave with the cut-off frequency (−3dB) set at the lowest resonant frequency. Unless otherwise specified, a 3.2ms ladder type RC high-pass filter, whose low cut-off frequency is 50Hz, is used. The compensation characteristics, compensation filter and the block diagram of the testing system are outlined in Fig. 8. In case a full-range speaker or a woofer is tested, the signal is directly and continuously applied to the component speaker for 96 hours bypassing the dividing network. With a speaker such as a mid-range or a tweeter whose frequency range is limited, a −6dB/oct dividing network with a specified cut-off frequency is inserted in the circuit to ensure that only signals in the specified frequency range are applied to the speaker. The signal outside the specified frequency range is dissipated in a dummy load. And although the testing of a midrange or a tweeter is also conducted for 96 hours, it must be noted that the rated input in this case is actually the power consumption of the overall system including a network and not the power consumption of the speaker alone. This point must be borne in mind when checking spec values. In other words, even if, say, 15W is given to a tweeter as the rated input, the continuous application of a 15W input to it will damage it.

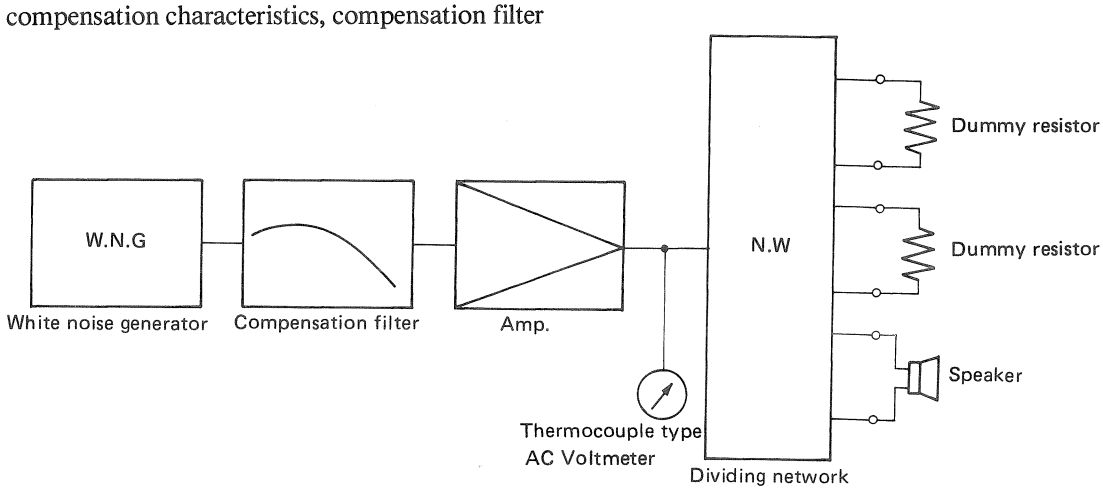


Fig. 8 The block diagram of rated input testing system

6. Maximum Input

The maximum input power is the maximum power applicable to the speaker in a short period. The general testing method employs ordinary program signals. The power is calculated with the rated impedance and the peak value of the program signal.
The testing method and frequency range are the same as those for testing the rated input. In place of the white noise generator and the compensation filter, however, program signal sources of radio or endless tape are used. And in place of the voltmeter, an oscilloscope capable of measuring and monitoring peak values is employed. (See Fig. 9).
This completes the discussion on rated and maximum input measuring methods. As far as general speakers are concerned, it would seem that the maximum input voltage tends to be 1.5 times to twice the rated input. This relationship, however, varies considerably according to application and operating conditions, making it difficult to relate the two factors.

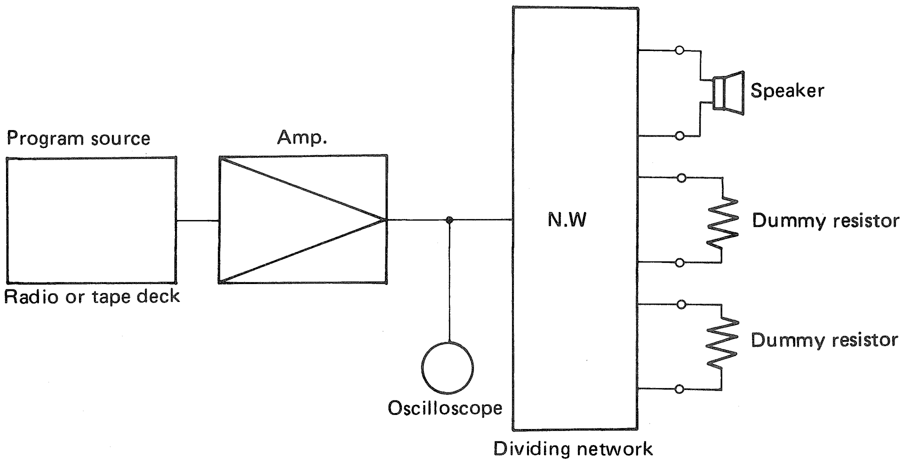


Fig. 9 Measuring maximum input power

7. Conclusion

The reflected sound from the walls, and other surfaces greatly affects the Sound Pressure Level frequency response and directional frequency characteristics. The measured results depend on the measured point and the conditions of the room. To overcome this drawback, an anechoic room where all reflection is eliminated must be used. When measuring the electrical impedance characteristics, the lowest resonant frequency, rated input and maximum input power, however, the effect of the reflection is not so great. A room where sound reflections have been minimized by sound absorbing materials is adequate to enable these parameters to be measured with sufficient accuracy.
When measuring at home, use a dead room which has soft walls and floors. Concrete walls should be avoided.

Measuring Instrument

AUDIO FREQUENCY GENERATOR (RC OSCILLATOR)

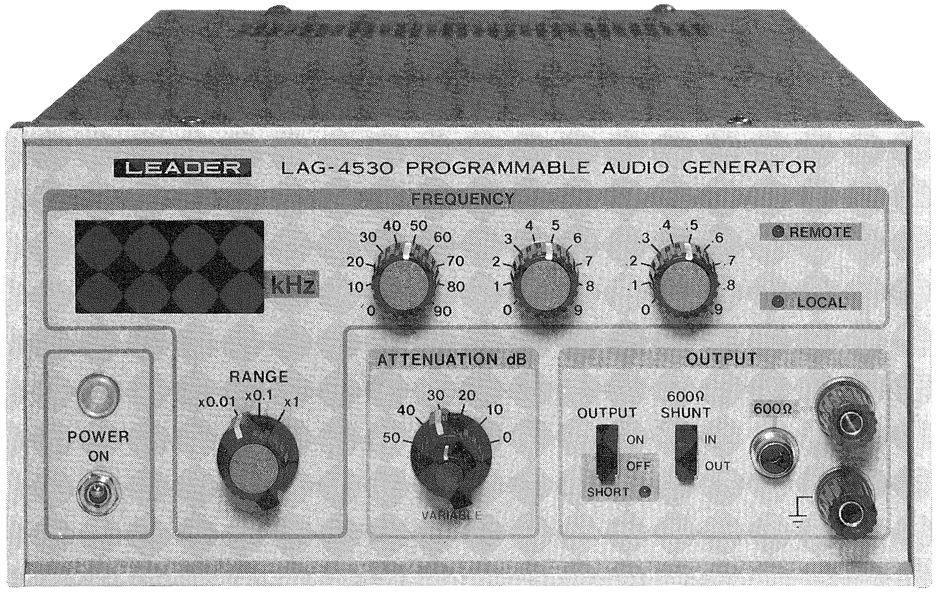


Photo 1 Programmable audio generator

Audio frequency generators are used to produce an audio signal source for measuring the performance and characteristics of audio equipment such as amplifiers, and also for locating failures. Whereas the frequency range of the conventional generators is limited to the audible range (about 20Hz to 20kHz), new generators are designed to cover a range from several hertz to several 100kHz due to the advances in today's amplifiers. And in addition to sine waves, square waves, delta waves, and sawtooth waves can also be obtained.

1. Principles

Since most generators mainly generate sine wave and square wave signals, the discussion here will be limited to these two types of signals.
The AMPl shown in Fig. 1 is the circuit generating sine waves. The voltage between A and B becomes in phase to that between A and C when the $R_1 = 1/\omega C_1$ and $R_2 = 1/\omega C_2$ conditions are met. Here, if the input and output of AMP1 are in phase, AMP1 will oscillate at a particular frequency due to the positive feedback. The oscillating frequency can be changed by varying R_1 and R_2 together, or by varying C_1 and C_2 together.
In actual circuits, C_1 and C_2 are ganged, and frequency ranges are shifted by switching R_1 and R_2. With this method, a wide frequency range is available. The oscillator stage in Fig. 1 employs a Wien's bridge oscillator circuit which is the most popular type due to its high stability.
Phase shifter and tuning-fork oscillators are also available, but there is little room to discuss them here. Square waves are formed by the Schmitt trigger circuit in Fig. 1. When the switch is set to the square wave position, sine waves from the oscillator stage are (clipped, or clamped) by the Schmitt trigger to from square waves. In this case, the sine wave is amplified sufficiently before being clipped. Some generators, for example, include an amplifier stage between oscillator stage and the Schmitt trigger.
The AMP2 circuit is a buffer amplifier whose purpose is to reduce the high output impedance, and to minimize the effects of the following low impedance stage such as an attenuator.
Many generators employ an emitter-follower circuit for this buffer stage and with a 600Ω attenuator, signals of 600Ω output impedance are available at the output.

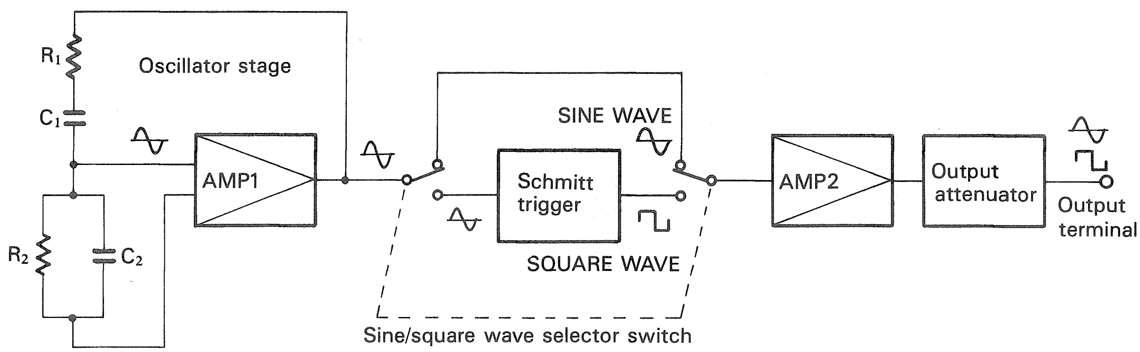


Fig.1 Block diagram of audio frequency generator

The most popular RC audio frequency signal generator of positive feedback type is explained here. In Fig. 2, a port of the output voltage of the amplifier G, which has a sufficient gain, is fed positively back to its in put via BPF(band-pass filter). The feedback signal is made inphase to the original and the loop gain is made 1.

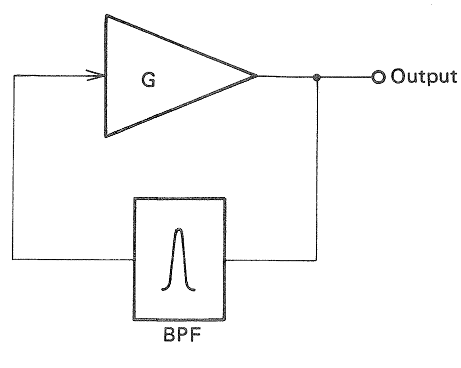


Fig. 2 Simplified diagram of a positive feedback oscillator

In this method, if the bandwidth of the amplifier is wide enough, the oscillating frequency can easily be changed by varying the filtering frequency of BPF.
As a passive BPF, the Wien Bridge circuit is widely employed in the positive feedback loop of RC oscillators. The oscillating frequency (fo) is determined by the resistance-capacitance elements of BPF.

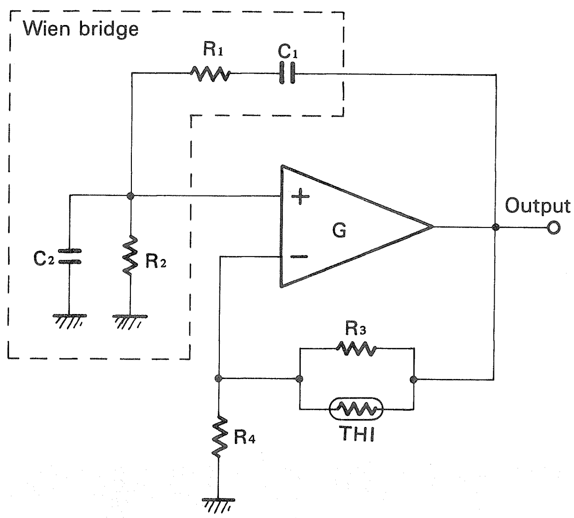


Fig. 3 Wien bridge oscillator circuit

The necessary gain for amplifier G in the Wien-bridge oscillator is equal to the reciprocal of the Wien-bridge's attenuation K. where K is expressed by the following

$$K = \frac{1}{1 + \frac{R_1}{R_2} + \frac{C_2}{C_1}}$$

If $R_1 = R_2$, and $C_1 = C_2$, the closed loop gain will be about 3.1 to 3.2.

In Fig. 3, the gain is determined by R_4, R_3 and TH_1. TH_1 is an amplitude stabilizer thermistor designed to maintain a constant output voltage by varying the negative feedback in response to changes in the output voltage. This thermistor is thus indispensable in RC oscillator. Some generators employ a CdS photocoupler or an FET instead of the thermistor's.

2. Devices in the Generator

Several devices are employed in the generator for easy operation.

1) Frequency selector
Generally, the output frequency of a generator is required to be variable. Frequencywise, there are three types of generators; Continuously variable type (Photo 3), Spot type (Photo 4) and Digitally variable type (Photo 5), C_1 and C_2 or R_1 and R_2 in Fig. 3 are varied for adjusting the frequency.

FREQ. RANGE SETTING (Multiplier)	OUTPUT FREQUENCY RANGE
x10	10 – 100Hz
x100	100 – 1000Hz (1kHz)
x1K	1 – 10kHz
x10K	10 – 100kHz
x100K	100 – 1000kHz (1MHz)

Table 1 The output frequency is set with the frequency dial and the FREQ RANGE switches.

2) Output voltage selector
The output voltage is also required to be variable. Since output voltage adjustment is difficult in the oscillator circuit, a variable resistor is connected to the output line. Some generators have a built-in attenuator instead of the simple variable resistor to achieve accurate attenuation.

3) Square wave generator
The generators described above are all sine wave generators. The generation of square waves which are widely used for measuring purposes can be achieved by incorporating a Schmitt trigger circuit or similar circuit to convert sine waves into square waves.

4) Others
In addition to the above features, a number of generators also incorporate the following type of features to cope with different applications.

- Burst oscillator circuit
- Sync terminals (to obtain low-distortion signals at precise frequencies synchronized with a crystal oscillator etc.)

The generator shown in Photo 2 is capable of varying the oscillator frequency from 10Hz to 1MHz, and equips with an output ATT and sync terminals. The block diagram is given in Fig. 4.

Other generators are given in Photos 3, 4 and 5. Photo 3 is a low-distortion generator which suppresses sine wave distortion. This type includes a burst oscillator stage.

The one in Photo 4 features push-button frequency switching (spot generator) designed to improve efficiency on production lines and during maintenance servicing operations. The Photo 5 shows a programmable generator. In addition to digital setting of the oscillator frequency, this generator also enables remote control.

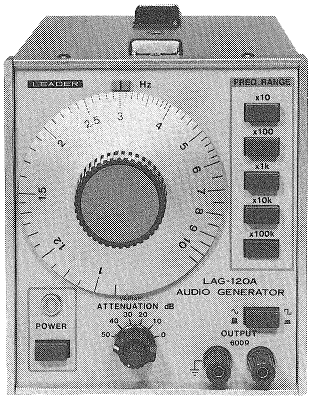


Photo 2

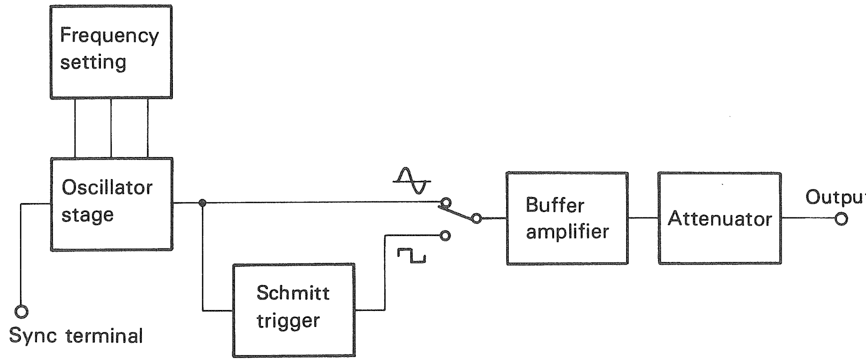


Fig. 4 Block diagram of typical audio generator

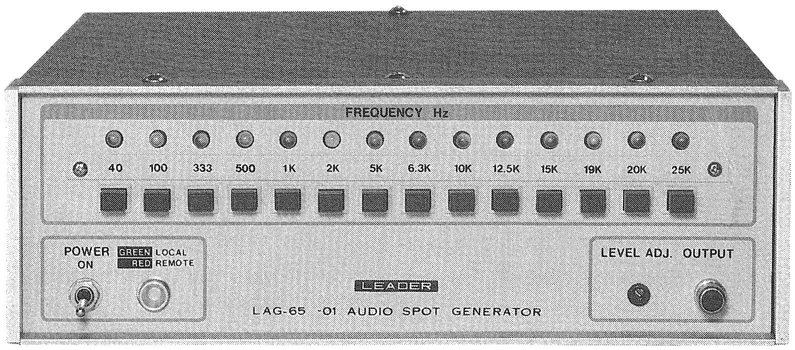


Photo 4 Spot generator

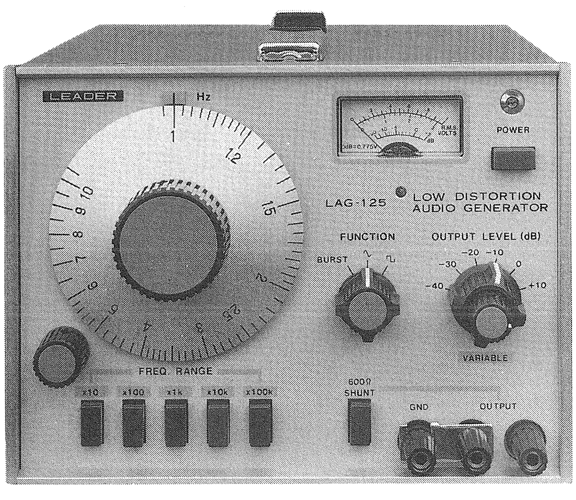


Photo 3 Low distortion generator

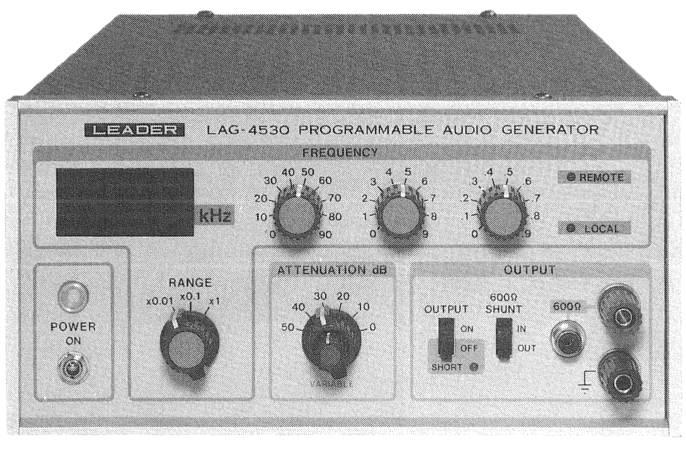


Photo 5 Programmable generator

3. Operating Precautions

More attention should be paid to the following precautions than in general Hi-Fi audio equipment to get proper performance.

1. The voltage of the AC mains used by the generator must be within the range rated for the generator. (See Table 2)

2. The generator specifications must comply with the requirements of the applications.

Example: To measure the distortion of a 0.1% distortion amplifier, the generator distortion specification must be less than 0.1%.

3. Carefully read the operation manual.

Standard voltage	Usable voltage range
100V	90V–110V
117V	106V–128V
220V	196V–238V
240V	211V–257V

Table 2 Voltage and usable voltage range

4. Applications

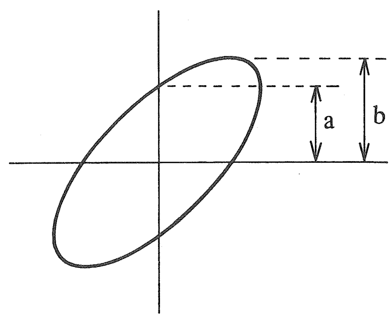
The audio generator is a basic measuring instrument used in a wide range of measuring applications. A number of examples of measuring audio equipment are outlined below.

4.1 Phase Characteristics

The measuring system is connected as shown in Fig. 5(b). When there is no phase difference between the input and output, the Lissajous figure becomes a slant straight line with its right end up. The figure becomes elliptic and fatter as the oscillating frequency is varied and the phase difference becomes larege. (see Fig. 5(a)) The degree of phase difference can be expressed by the phase angle (θ) given by the following equation.

$$\theta = \sin^{-1}\frac{b}{a}$$

The straight line bends when the input voltage is excessive and the output signal is distorted.



$\text{Sin}\ \theta = \frac{b}{a}$

θ : Phase angle

Fig. 5(a)

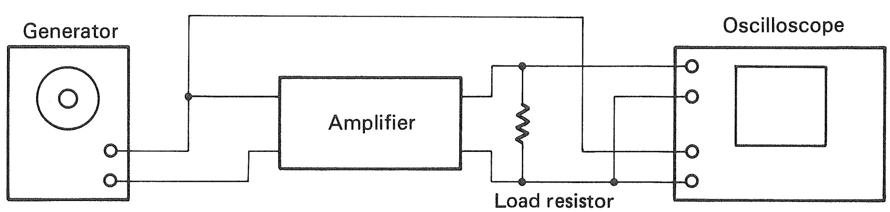


Fig. 5(b) Phase characteristics measurement

4.2 Sine Waves

The use of sine waves is shown in measurement of various amplifier characteristics.

a) Measurement of input/output characteristics
Adjust the generator controls to the following positions.

FUNCTION		Sine wave
FREQ RANGE	x100	1kHz
Dial position	10	
OUTPUT LEVEL (Output attenuator)	−40dB (Maximum attenuation)	

When the measuring instruments are set up as shown in Fig. 6, and the generator's variable OUTPUT LEVEL control is turned clockwise to increase the amplifier's input voltage, the amplifier's output voltage is increased proportionally.

Once the amplifier is saturated, there is no further increase in the output voltage, and the waveform shown in the oscilloscope will show signs of distortion. The amplifier's input-output characteristics are thus obtained by recording these input and output voltages. This data is important in ensuring that the amplifier is not operated in the saturated region. The amplifier voltage gain is obtained from the following equation.

$$\text{Voltage gain (dB)} = 20 \log \frac{\text{Output voltage (V)}}{\text{Input voltage (V)}}$$

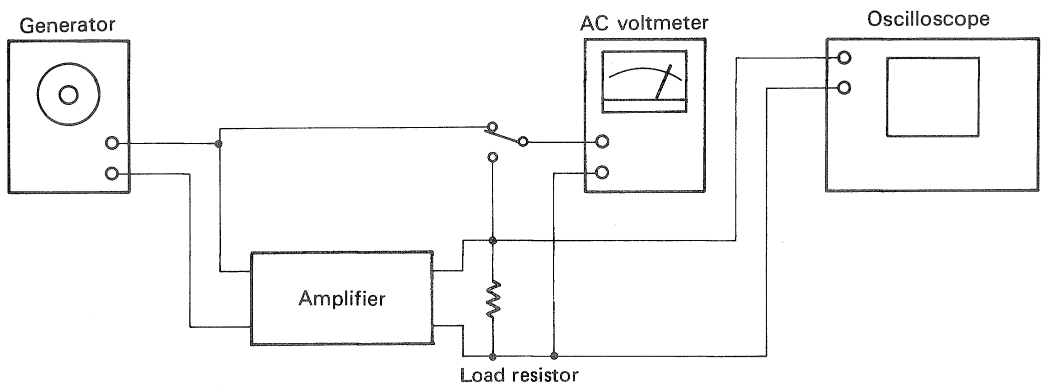


Fig. 6 Measurement of input/output characteristics, maximum output power and frequency response

b) Measurement of maximum output power
First determine the maximum output voltage free from distortion with the input-output characteristic data obtained in a) above, then calculate the maximum output power by using the following equation.

$$\text{Output power (W)} = \frac{(\text{Output voltage})^2}{\text{Load resistance } (\Omega)}$$

c) Measurement of frequency response
Adjust the OUTPUT LEVEL control to a range free from amplifier distortion. The amplifier's input voltage is kept at a constant level during this measurement. Next vary the frequency by FREQ RANGE and dial, recording the amplifier output voltage at each frequency on single-axis logarithmic graph paper. This plot forms the amplifier frequency response curve. If there is any output deviation in respect to generator frequencies, the amplifier input voltage will have to be adjusted up to a reference level at each frequency during the measurement.

d) Distortion measurement

The measuring circuit is outlined in Fig. 7. Adjust the generator's frequency and its OUTPUT LEVEL. Refer to No.2, TUNING FORK. Measure the distortion in accordance with the method prescribed for the distortion meter.

If the distortion meter's MONITOR output is monitored by oscilloscope, the distortion components and noise can be observed. Lissajous figures with the fundamental wave on the V axis and the distortion wave on the H axis are shown in Fig. 8.

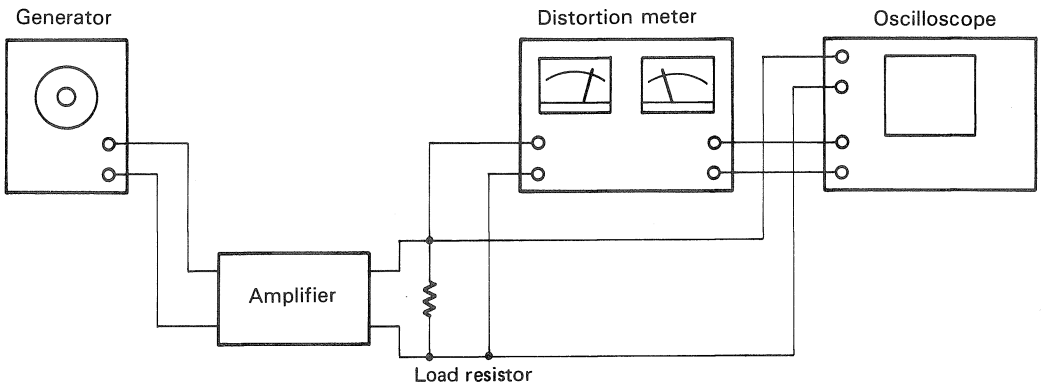


Fig. 7 Distortion measurement

Precautions in measuring distortion

The distortion generated in the distortion meter is called residual distortion, and this should be taken into account when measuring the distortion of amplifiers etc. Measure this residual distortion first before proceeding to measure the amplifier distortion. And if the value is, for example, 0.02%, and the distortion value obtained when measuring the amplifier is 0.07%, the actual amplifier distortion is not obtained by taking the difference, but by using the following equation:

$$\text{Amplifier distortion} = \sqrt{(0.07)^2 - (0.02)^2} = 0.067[\%]$$

Actually, however, the residual distortion and the measured amplifier distortion affect each other according to a complicated phase relationship, resulting in considerable variation in the distortion readings.

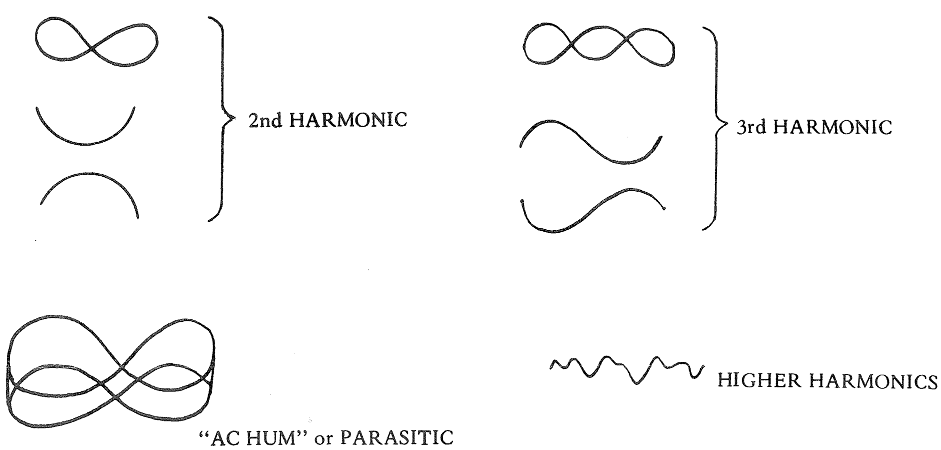


Fig. 8 The various Lissajous figures

4.3 Square Waves

Using the same measuring circuit as outlined in Fig. 6, switch FUNCTION to the (square) position, and apply square waves to the amplifier. Various amplifier characteristics can thus be checked by monitoring the output waveforms by oscilloscope. Please refer to Nos. 4 & 5, T.F.

When using square waves, first monitor the input waveform with an oscilloscope before observing and measuring the output waveform. Next, some of the special functions such as the burst wave and the sync will be considered.

Waveshape	Amplifier Response	Condition
RECTANGULAR	FLAT	SATISFACTORY
SAG	DEFICIENT LOW FREQUENCIES	LOW PRIMARY INDUCTANCE IN OUTPUT TRANSFORMER: INCORRECT VALUES OF THE COUPLING ELEMENTS
ROUNDING	DEFICIENT HIGH FREQUENCIES	HIGH LEAKAGE INDUCTANCE IN OUTPUT TRANSFORMER OR HIGH DISTRIBUTED CAPACITANCE IN CIRCUIT
RINGING	RINGING AT HIGH FREQUENCY	MALADJUSTMENT IN THE NEGATIVE FEEDBACK CIRCUIT; INCORRECT CONSTANTS; INSTABILITY

Table 3 Application of square wave

4.4 Burst Wave

The burst wave is generated intermittently and since a step is formed at each transient point, this kind of signal is ideal for measuring transient characteristics.

This type of signal is used as the signal source for measuring a circuit which has a time constant and for measuring all kinds of equipment relating to sound such as microphone, amplifiers, speakers, and even listening rooms. The BURST wave output voltage is about 1/5th of the SINE wave output voltage when the output attenuatór is in the VARIABLE position.

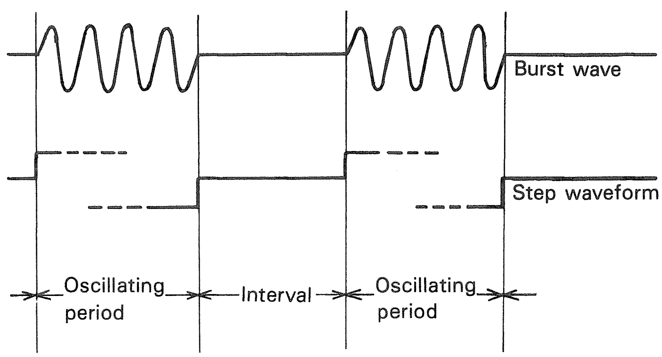


Fig. 9 Burst wave

a) Speaker transient response test
Connect as shown in Fig. 10, set the FUNCTION switch to the BURST position, and then select the desired burst wave by rear panel switch.
Using a dual-trace oscilloscope, monitor the generator output waveform in CH-1 and the mic amplifier output in CH-2 (that is, simultaneous display).

The mic amplifier output differs according to a number of factors such as speaker frequency response and the suspending method of speaker's cone paper. The output waveform is also affected by the relationship between the amplifier's output impedance and speaker impedance. For example, if a speaker is driven by an amplifier of high output impedance, the poor damping factor results in residual waves left in the zero voltage interval.

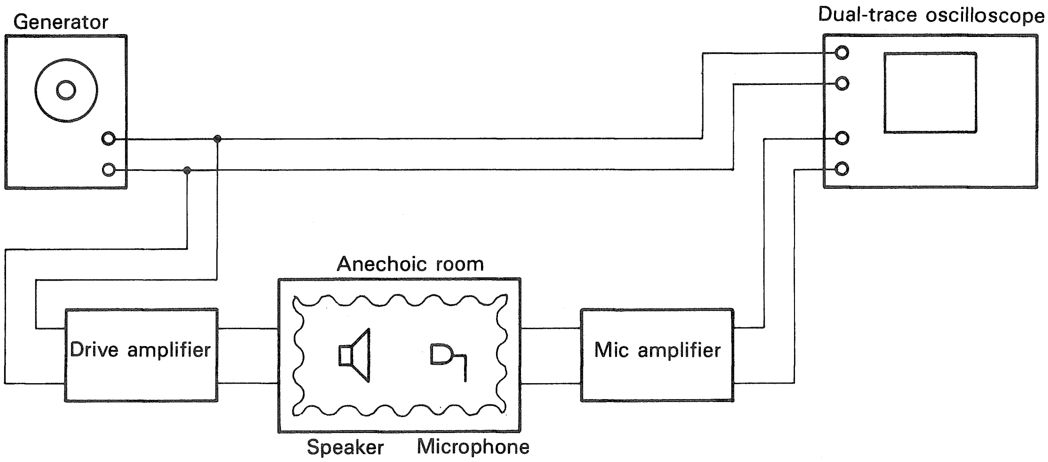


Fig. 10 Speaker transient response test

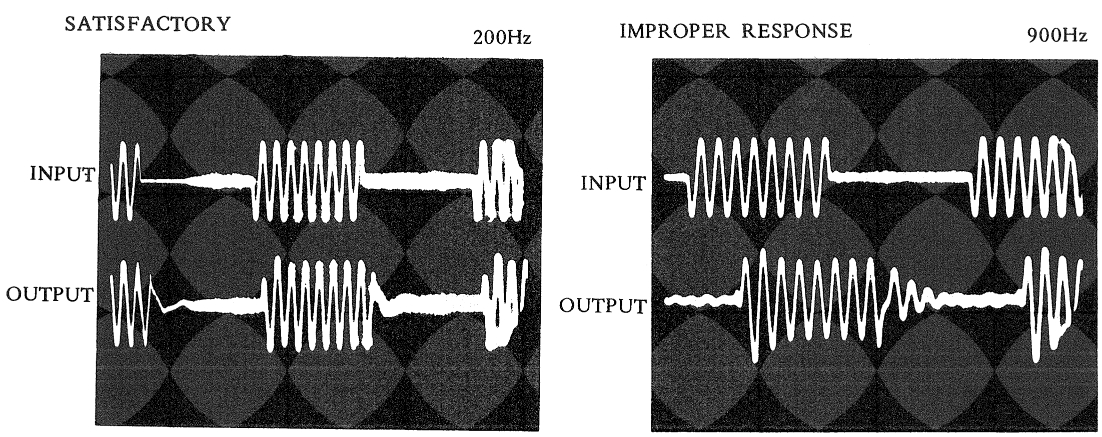


Photo 6 Examples of oscilloscope monitoring

b) Amplifier transient response test

Connect as shown in Fig. 11. The measurement is conducted by using a dual-trace oscilloscope in the same way as during the speaker transient response test described above. Since the transient response is much better in an amplifier than in a speaker system, no remarkable differences can be observed. However, the characteristics of an amplifier can be deducted from the output waveform.

The interval (OFF period) and the oscillating ON period can be varied. When the burst wave is used as a signal source for testing a circuit which has a time constant, its characteristics can be known with the waveform. The second waveform is obtained when the phase is delayed by an integrator while the third waveform is obtained when phase is advanced by a differentiator.

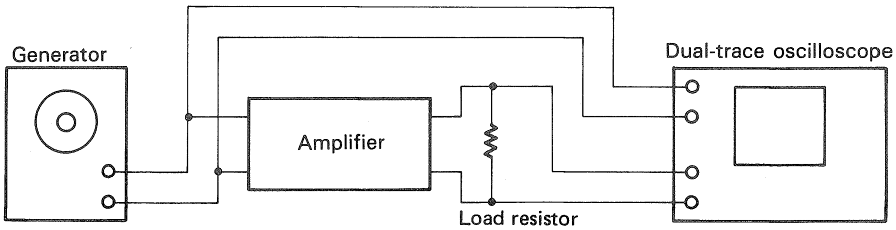


Fig. 11 Amplifier transient response test

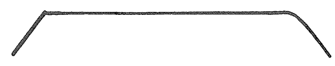
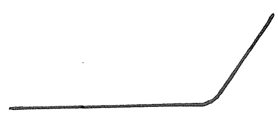
WAVESHAPE	CONDITION	RESPONSE
(1) 	The frequency response appears to be quite flat.	
(2) 	The low end of the frequency response appears to be attenuated.	
(3) 	The high end of the frequency response appears to be boosted.	

Table 4 Amplifier transient response waveform

Quality Information System (3)

Calculation of Field Failure Rate

Pioneer product repair reports are forwarded to Tokyo (PEC) from all parts of the world every month. These reports are passed on to the Quality Assurance departments of each relevant factory where they are subject to statistical analysis.
From these analyses, field failure rates are calculated for each model and each category, thereby providing important information in forecasting trends in the number of product failures, and in checking reliability. This information is also used in estimating the demand for servicing parts, and in estimating servicing costs. Although there are various methods available for analyzing the tabulated data, methods relevant to the way components are used are most common.
This time we will discuss the terminology and analytical methods employed in the use of this data.

1. Percent Defective and Failure Rate

All products are divided into "good" and "defective", and the proportion of defective products expressed as "percent defective" or "fraction defective ".
The "failure rate", on the other hand, refers to the proportion of failures in respect to the period or frequency of use as described in section 2 below. A clear distinction must be made between percent defective and failure rate.
Product quality after shipment from the factory can be expressed in the following two ways.

*Percent defective ...... the proportion of unused products which are already defective when the product is first used (includes "incoming inspection" defects).

*Failure rate .... the proportion of used products which failed in a certain period (including failure rate based on repair date).

However, regular repair data includes both of the above products and even those faulty products caused by misuse or tampering. The ratio which includes this kind of failure, is referred to as the "repair ratio" and is to be clearly distinguished from "failure rate". The failure rate (and repair rate) is expressed in "%" and period. The unit of field failure rate, for example, is "%/month".

2. The Meaning of "Failure Rate"

Failure rate can be defined as the "probability that a product which has operated up to a certain time will fail within a certain period".

Example: The mortality rate (failure rate) at 70 years of age is the probability that persons who have reached the age of 70 will die (fail) within the next year.

The failure rate of a relatively complex item varies as it grows old as shown below. This kind of curve (see Fig. 1) is called a "bath tub" curve.

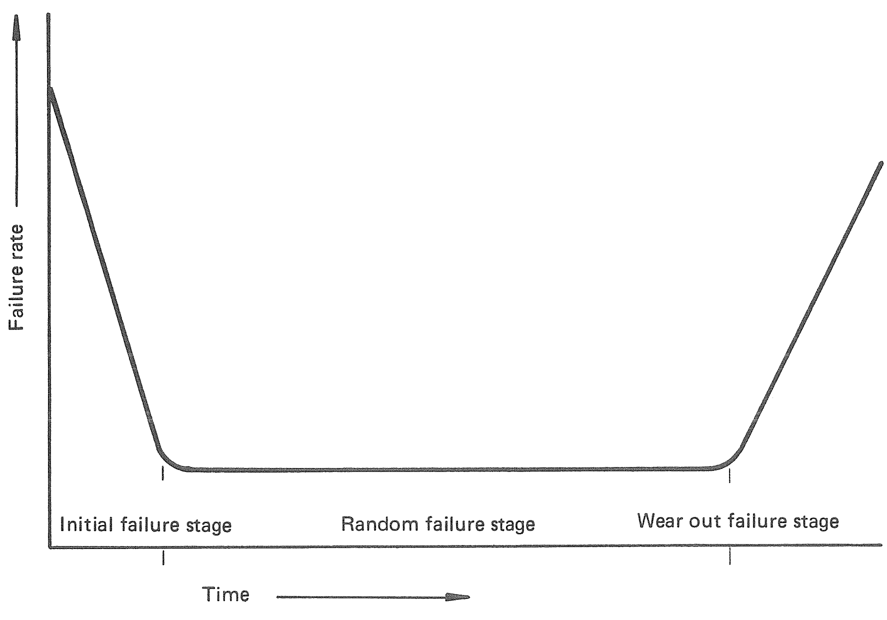
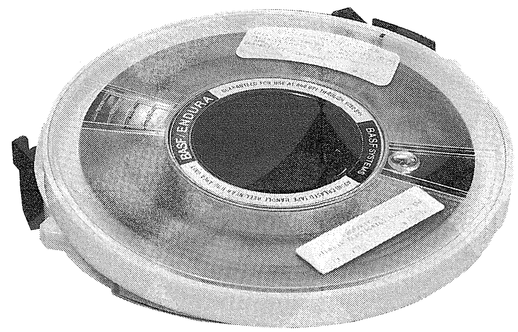


Fig. 1 Bath tub curve

3. Field Failure Rate Analysis (Part 1 — Production Quantity Base)

3.1 Failure data tabulation

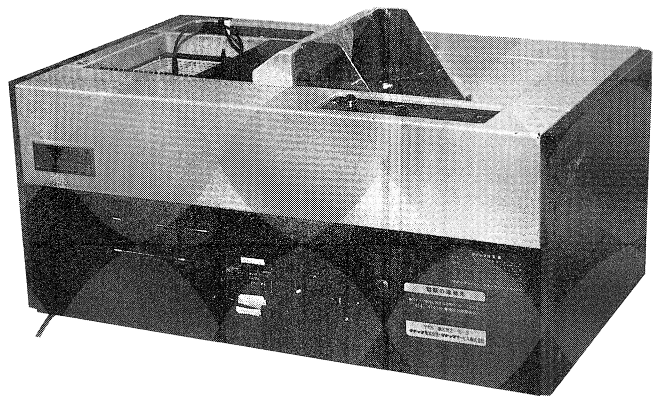
The failure data up to September 1982 for the new product YZ-999 which have been manufactured since April 1982 is tabulated, for example, as shown in Table 1 below. This data serves as the basis for various analyses.



Field repair raw data (MT) from PA

Month / Date of manufacture	Quantity manufactured	No. of failures					
		April 1982	May	June	July	August	Sept.
Apr. '82	2,000	4	7	8	16	11	14
May	3,000		5	10	14	12	18
June	4,000			6	12	22	25
July	4,000				1	3	4
August	3,000					0	2
Sept.	3,000						1

Table 1 Failure data for new product YZ-999



Statistic Card Analyzer

3.2 The field failure rate of September '82 (production quantity base)

Failure data for September can be sampled to obtain the following information (see Table 2). According to this table, the September failure rate for products manufactured in April is 0.7%/month. The corresponding figure for products manufactured in May is 0.6%/month,

for June : 0.63%/month,
for July : 0.1%/month,
for August : 0.067%/month,
and for September : 0.033%/month.

The mean failure rate for September is 0.34%/month. The unit "%/month" denotes that the figure refers to the failure rate for the one month period of September. The mean failure rate is calculated from the following equation.

(Mean September) failure rate

$$= \frac{\text{Number of failures in one month (September)}}{\text{Accumulative number of products}} \cdots\cdots\cdots (1)$$

Month / Date of manufacture	Quantity manufactured	No. of failures in September	Failure rate
Apr. '82	2,000	14	0.7 (%/month)
May	3,000	18	0.6
June	4,000	25	0.63
July	4,000	4	0.1
August	3,000	2	0.067
Sept.	3,000	1	0.033
	Total: 19,000	Total: 64	Mean: 0.34 (%/month)

Table 2 September failure data

3.3 Confirming the results of design modification

Assume that the YZ-999 design was modified from the July production lots to improve quality. How can the effect of the modified design be assessed? Rearranging Table 1 according to the number of months after manufacture results in Table 3.

If Table 3 is expressed in graphical form, any change in failure rate for any manufacturing month (lot) will be apparent, and will indicate if the modified design has been effective. However, since the graph is rather complex, the data for products prior to the change (April to June) and products after the change (July to September) is arranged separately as shown in Table 4.

Failure rates are determined from Table 4 and summarized in Table 5.

Month (Date of manufacture)	Quantity manufactured	No. of failures (Failure rate: %/month)					
		One month	Two months	Three months	Four months	Five months	Six months
Apr. '82	2,000	4 (0.2)	7 (0.35)	8 (0.4)	16 (0.8)	1 (0.55)	14 (0.7)
May	3,000	5 (0.17)	10 (0.33)	14 (0.47)	12 (0.4)	18 (0.6)	
June	4,000	6 (0.15)	12 (0.3)	22 (0.55)	25 (0.63)		
July	4,000	1 (0.03)	3 (0.05)	4 (0.1)			
August	3,000	0 (0)	2 (0.07)				
Sept.	3,000	1 (0.03)					

Table 3 Failure data arranged according to the number of months after manufacture

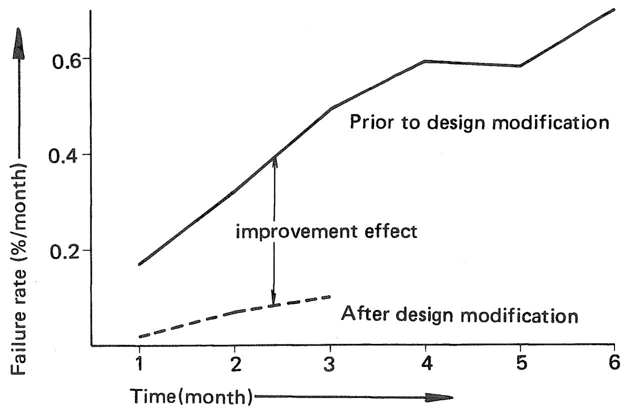


Fig. 2 Change in failure rate before and after design modification

	Month	One month	Two months	Three months	Four months	Five months	Six months
Prior to modification	No. of failures	15	29	44	53	29	14
(April, May, and June production lots 1982)	No. of manufactured products	9,000	9,000	9,000	9,000	5,000	2,000
After modification	No. of failures	2	5	4			
(July, August, and September production lots 1982)	No. of manufactured products	10,000	7,000	4,000			

Table 4 Failure data before production lots 1982

Month	One month	Two months	Three months	Four months	Five months	Six months
Prior to modification (April, May, June)	0.17	0.32	0.49	0.59	0.58	0.7
After modification (July, August, September)	0.02	0.07	0.1			

Table 5 Failure rates before and after design modification (%/month)

3.4 Advantages and disadvantages of this analytical method

Although the above type of analysis is desirable in checking quality differences between manufactured lots and the effects of quality improvement measures, one of the major problems with this method is the length of time between manufacture and sales. Because of this time lag, the failure rate will appear to be lower in the first months. In Fig. 2,the failure rate appears to increase steadily at first. But this is not actually so. The more or less steady figures obtained after four to six months represent the actual failure rate.

As was mentioned in section 1, the failure rate is defined in terms of unit operating time. Problems arise, however, if this time also includes nonoperating times.

4. Field Failure Rate (Part 2 — Sales Quantity Base)

4.1 Field failure rate based on the number of products sold

On the premise that "sold products are operating products", the field failure rate is also determined on the basis of the number of products sold. At Pioneer, the "field failure rate" usually refers to the failure rate based on the number of products sold.

4.2 Tabulation of failure data

The number of YZ-999 components sold each month from April to September 1982 is listed in Table 6 together with the corresponding number of failures. The number of failures agrees with the totals obtained from Table 1.

Month	April 1982	May	June	July	August	Sept.
No. sold	600	1,300	2,000	2,500	3,200	3,000
No. of failures	4	12	24	43	48	64

Table 6 The number of YZ-999 components sold and the number of failures

4.3 September field failure rate (sales quantity base)

To calculate the September failure rate from Table 6 by using the figures 64/3000 = 2.1 (%/month) is incorrect. The 64 failures during September do not only cover products sold during September, but also include random failures occurring in products sold in April thru September. The failure rate in this case can be calculated from the following equation.

(Mean September) failure rate

$$= \frac{\text{No. of failures in one month (September)}}{\text{Accumulative number of products sold}} \cdots\cdots \quad (2)$$

Both equations (1) and (2) are very similar, the sonly difference being in the denominator — the number manufactured, or the number sold. If values from Table 6 are substituted in equation (2), the following result is obtained.

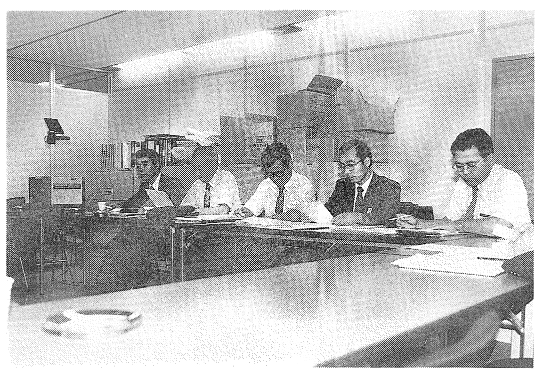
$$\text{Mean September failure rate} = \frac{64}{600 + 1300 + \ldots\ldots + 3000}$$

$$= \frac{64}{12600} = 0.51\ (\%/\text{month})$$

At Pioneer, the "field failure rate" usually refers to this result.

4.4 Advantages and disadvantages of this analytical method

The value obtained by this method is by and large fairly representative of the actual mean failure rate. Hence, it is safe to say that the YZ-999 field failure rate is about 0.51%/month. On the other hand, this method does not give any indication of the quality differences between manufactured lots, nor enable the effects of quality improvement measures to be checked. If the design of a new product is modified several times soon after the beginning of sales, it is necessary to combine this analytical method with the method described in section 2.



Snapshot of monthly Quality meeting

New Products

LaserDisc System

The dream of recording picture information in addition to sound information into a handy disc has been realized. Consisting of discs and a player, videodisc system is similar to the conventional record player system. Its principle and materials, however, are quite different from the conventional system. As the signal frequency is very high, very high density recording is required.

Since 1960's, several videodisc systems have been developed. In 1979, we introduced LaserDisc or laser optical videodisc system to the market under PHILIPS/MCA standards.

The NTSC version will mainly be discussed here.

The main signal of the videodisc system is the same as television (TV) signal. The principle of TV has been omitted here because there are many books of TV available on the market. Circuit description and adjustment have also been omitted here. Refer to service manuals for details.

1. Three videodisc systems

Now, there are three videodisc systems on the market, laser-optical system (LASER VISION or LaserDisc) and two capacitive systems; Capacitance Electronic Disc (CED) and Video High Density (VHD) systems. The laser-optical system reads information with a laser pickup without making physical contact to the disc surface. The CED system reads information by sliding a stylus on a grooved disc surface while the VHD system does it on a flat disc surface. Having a non-contact pickup, LaserDisc (LD) system provides you with quick random access and a still picture or a frozen frame for many hours. Further, it reproduces clear pictures with the horizontal resolution of 350-line equal to that of broadcasting stations.

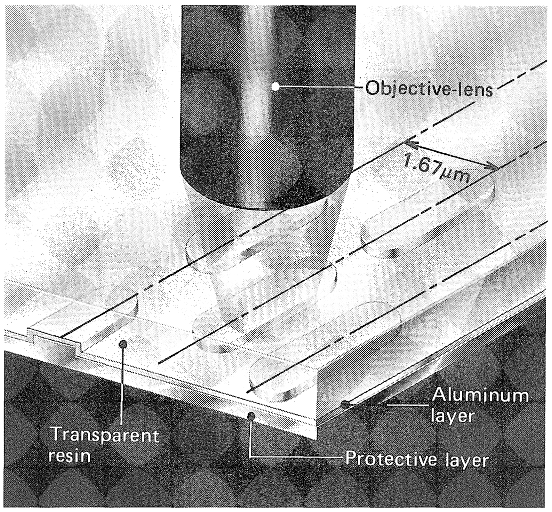


Fig. 1 LaserDisc (LD) pickup system

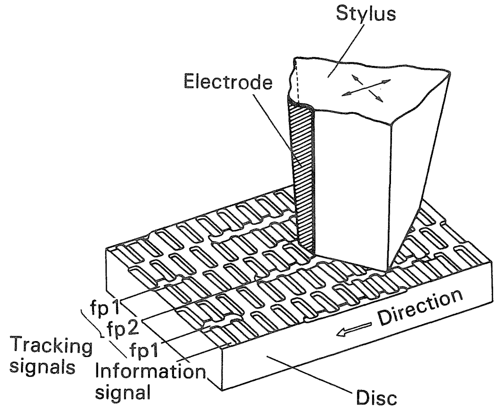


Fig. 2(a) VHD pickup system

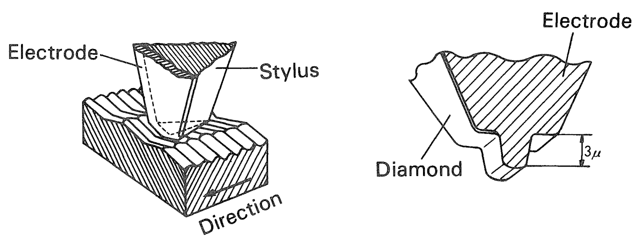


Fig. 2(b) CED pickup system

	LaserDisc	CED	VHD
System	Non-contact laser-optical system	Stylus capacitance system (grooved)	Stylus capacitance system (grooveless)
Pickup	Non-contact laser beam	Diamond stylus	Diamond stylus
Playing time (Minimum on 1 side)	60 min NTSC 60 min PAL(CLV) 30 min NTSC 36 min PAL(CAV)	60 min	60 min
Disc Rotation (rpm)	1,800–600 NTSC (CLV) 1,500–570 PAL 1,800 NTSC (CAV) 1,500 PAL	450	900
No. of Play	Virtually unlimited	–	Same as audio disc (over 500)
Quality Degradation	None	Yes	Yes
Still Display	Virtually unlimited	Limited	Limited
Life of Pickup	Over 7,500H	–	Same as VCR head

Table 1 LaserDisc and other videodisc systems

2. Difference from video cassette recorder.

LD is free from wearing and print-through which are inevitable for VCR. Table 2 shows the features of LD and VCR.

LaserDisc & Video Cassettes

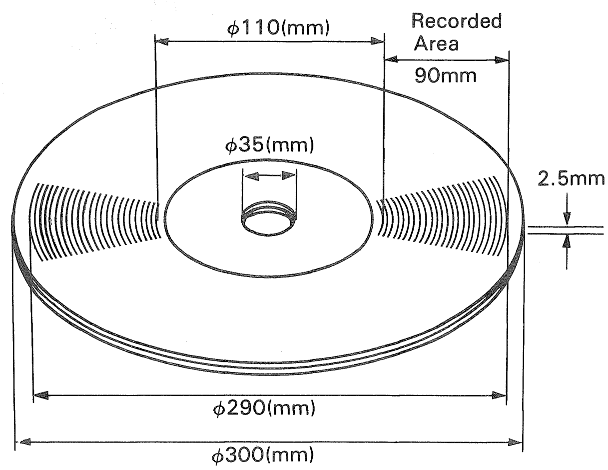
	LaserDisc	VCR
Recording Medium	Laser-optical disc of hard acrylic plastic	1/2 in. polyester based magnetic tape
Basic Function	Playback only	Recording/Playback
Picture Quality	350-line resolution	240-line resolution
Sound Quality	40Hz-20kHz Wide dynamic range	50Hz-7kHz (Beta III & VHS Extended Play)
Function	Instant Random Access and additional special functions. No time limit on still-picture display	No random access: limited special functions. Still display over a few minutes cancelled automatically.
Durability	Non-contact optical system ensures retention of original quality virtually forever.	Wear on tape and player can lead to some degradation in audio video quality.
Prices of "Softwear"	LaserVision discs are easily mass-produced and compare in cost to audio discs, considering the added video content.	Blank VCR tape is relatively costly; tape rental, etc. notwithstanding, prerecorded video-cassettes are generally more costly.
Use	LaserDisc is a kind of "Video Turntable" with the added ability to provide interactive functions.	Direct recording using a video camera is, of course, a strong feature of VCR systems.

Table 2 LaserDisc and video cassette recorder

3. LaserDisc (LD) system

LD system is composed of laser optical video discs (software) and a player (hard ware). It is combined with a TV set or a TV monitor and an audio system. The disc of ϕ30cm has encoded video, audio and control information on both sides. There are two kinds of discs, Constant Angular Velocity (CAV) disc and Constant Linear Velocity (CLV) disc which will be discussed later.

The information has been recorded by a laser beam in the form of a spirally aligned row of microscopic indentations or pits starting from the inner track. The player reads the pitted information (present/absent information) optically and converts it to video and audio signals.



Diameter	300mm
Thickness	2.5mm
Revolution (CAV)	1800rpm
Linear velocity (CLV)	About 11m/sec
Track pitch	1.67μm
Up/down fluttering	$\pm$1.025mm max
Fluttering acceleration	10G max
Eccentricity	80μm max
Track meandering	2G max

Fig. 3 Specifications of LD

The disc provides you with clear pictures and stereo sound semipermanently because it is free from wearing under the non-physical-contact pickup system. Very thin laser beam has made the high density recording of video and audio composite signal possible; 140 billion pits per one side (CAV disc). The recorded disc has protective layers on both sides. The reflected beam is not affected by small scratches and thin fingerprints on the surface because the beam converges on the pitted reflective aluminum surface which lies 1.2mm below the disc surface. The area of the shadow of a scratch or dust on the disc surface is reduced to 1/250,000 on the signal plane and, therefore, the effect of the shadow to the power of the reflected beam is greatly reduced.

Thick fingerprints and dust can be wiped off by gently scrubbing the disc surface with a piece of soft cloth, which has been dipped in plane lukewarm water and wringed, in the way as if you are drawing small circles.

Every sheet of the CED and VHD discs is cased in a caddy and is untouchable because its information has been recorded on its surface.

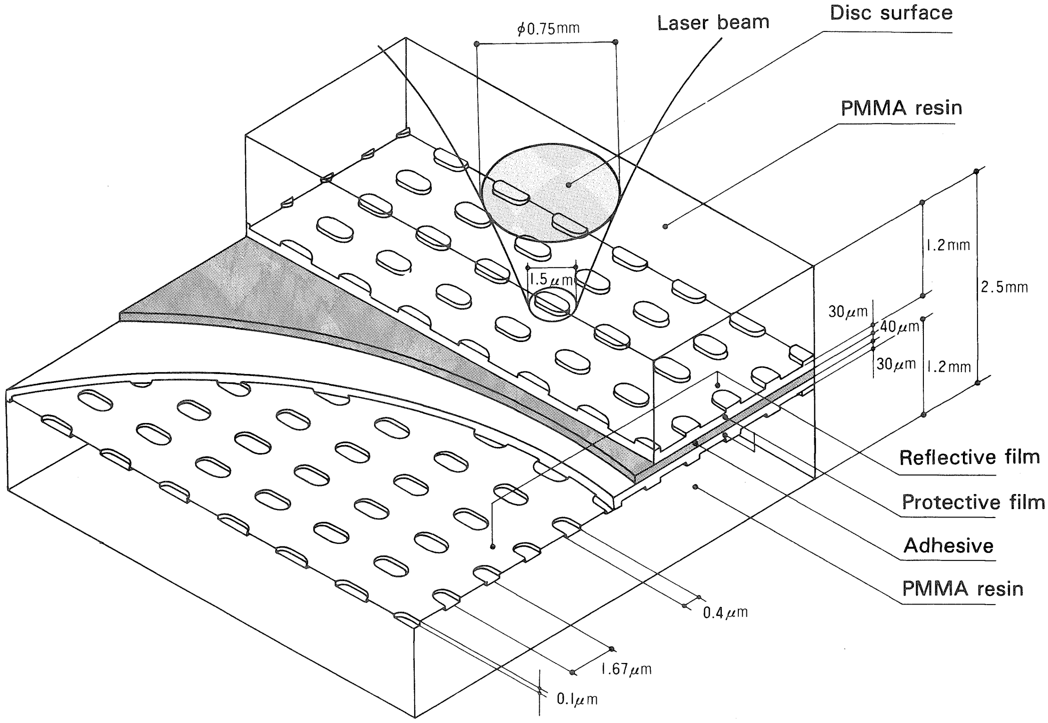


Fig. 4 Cross-section of Laser Disc

4. PHILIPS (MCA) codes

To control the various functions of the system, PHILIPS codes (MCA codes for industrial use), which have the information of LEAD IN, LEAD OUT, CHAPTER NUMBER, FRAME NUMBER (CAV), ELAPSED TIME (CLV), etc. are inserted at the end of the invisible vertical blanking signal. Each of the 54,000 pictures of CAV disc has a FRAME NUMBER. By addressing the number, a particular frame is accessible instantly. If the program in the disc has been divided into several chapters, the beginning of each chapter is also accessible quickly.

5. Manufacturing discs

The manufacturing process of LDs is divided into three; signal processing, mastering and replicating. The mastering and replicating rooms are extremely clean equal to those of the manufacturing room of LSIs.

5.1 Signal processing

The video and audio signals taken from a movie film or 1-inch VTR source are independently frequency modulated. The center frequency of the modulated video signal is 8.5MHz and its frequency deviation is ±1.7MHz and the modulated audio signals are 2.3MHz (CH-1) and 2.8MHz (CH-2) with the frequency deviation of ±100KHz (NTSC). Bilingual as well as stereo recording is possible because 2-channel sound signals are independently frequency modulated.

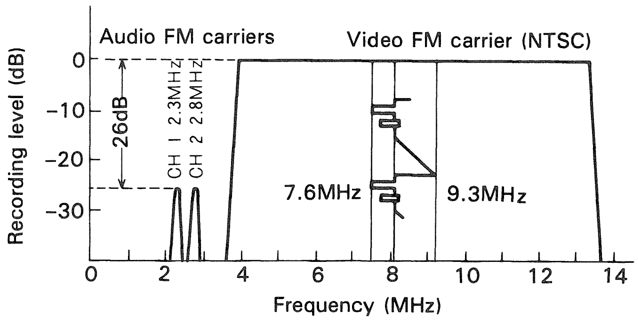


Fig. 5 Frequency spectrum of LD composite signal (NTSC)

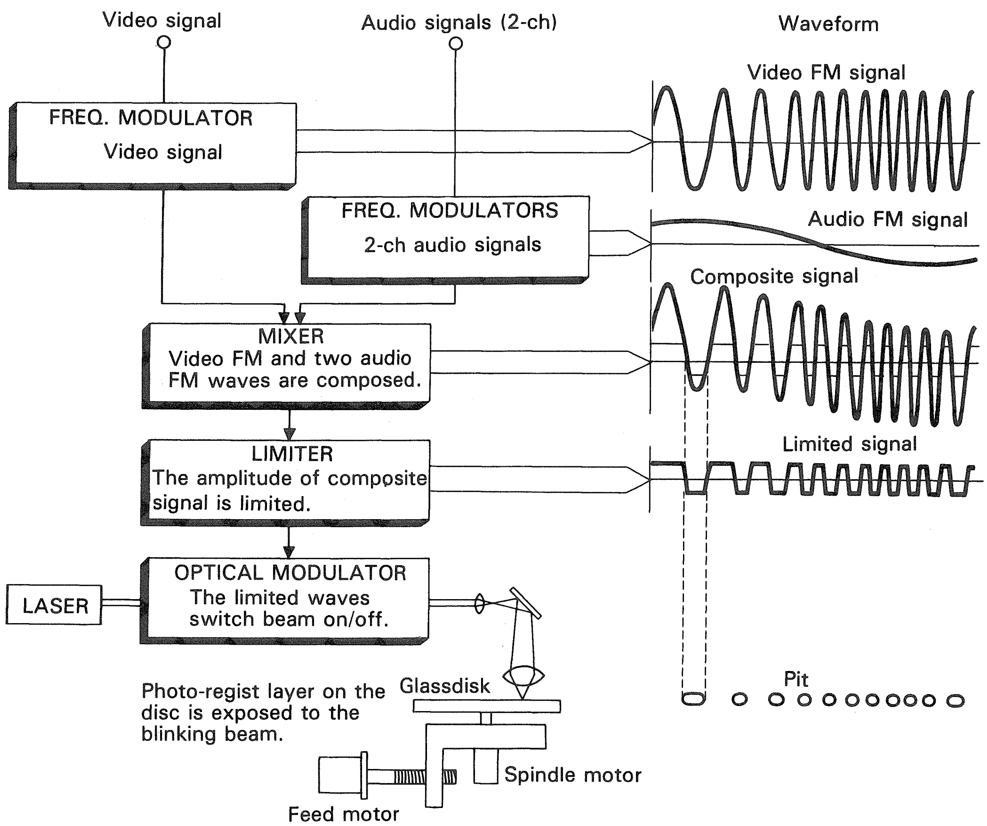


Fig. 6 Composing video and audio signals

The frequency spectrum of NTSC system is shown in Fig. 5. The modulated signals are multiplexed and amplitude-limited by a limiter and are shaped into squarewaves. Although the signal is pulsive, it is still analog because the frequency and pulsewidth vary gradually. The variation of the repetition frequency of the pulses and that of the *duty factor represent video information and audio information respectively.

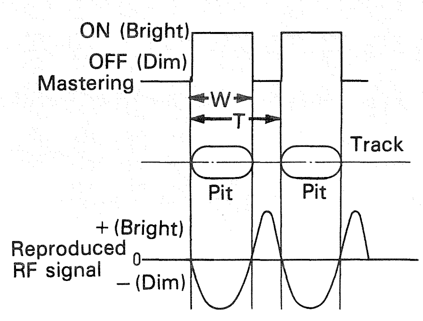


Fig. 7 Duty factor

*Duty factor:
In a pulsed system, the ratio of pulse width (W) to the wavelength of one cycle (T): W/T.

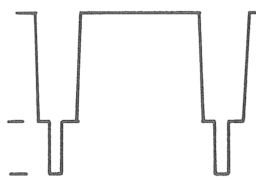
		NTSC	PAL
Audio carrier frequencies	CH1(L) CH2(R)	2.301136MHz 2.812499MHz	683.593KHz 1,066.40KHz
Video carrier			
White peak level		9.3MHz	7.9MHz
Pedestal level		8.1MHz	7.1MHz
Sync. tip level		7.6MHz	6.76MHz
Video pre-emphasis	T1: T2:	300nsec 100nsec	400nsec 100nsec
Pilot burst		None	240xfh (3.75MHz) Multiplexed on Sync. tip fh: Horizontal frequency

Table 3 NTSC and PAL discs

The adding rate of video carrier and sound carriers has been set at 10:1 to obtain high modulation linearity and high signal-to-noise ratio and to avoid intermodulation. When the picture carrier and sound carriers are multiplexed, the former becomes the carrier and the latter is distributed to the both side bands.

With the video signal bandwidth set at 4.2MHz (NTSC) or 5.5MHz (PAL), the picture is free from moire and carrier leak interferences because the lower sideband of the video FM carrier does not overup the audio signal bands.

5.2 Mastering

The surface of the ϕ35cm and 1cm thick original glass disc is precisely polished, washed supersonicly and evenly coated with photoresist (sensitizer). The disc is loaded on a real-time disc cutter.

The squarewaves of composite signal made by limiter is applied to an optical modulator to switch the high powered mastering laser beam on and off. The modulated beam is projected onto the photoresist layer, 55mm off the center of the revolving glass disc, moved outward to make the pits spirally in the layer with the track distance of 1.67μm. The photoresist surface is developed. Then, a stamper is made by nickel electroforming. Cleanliness is especially required because the quality of LD is almost determined here. The master disc is inspected while playing.

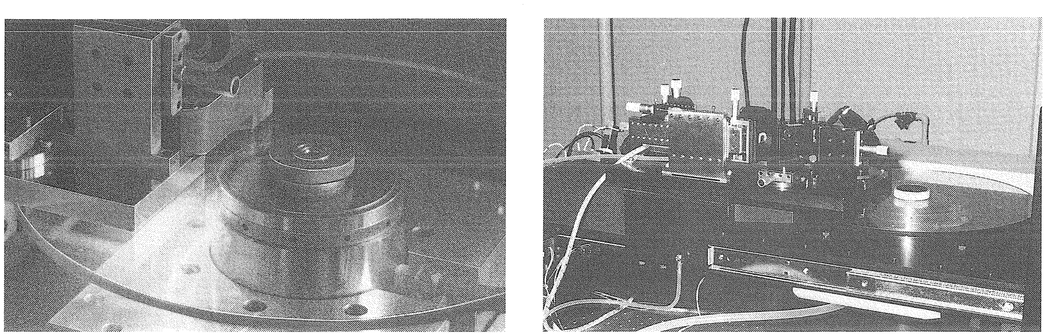


Photo 1 Glass master disc and disc cutter

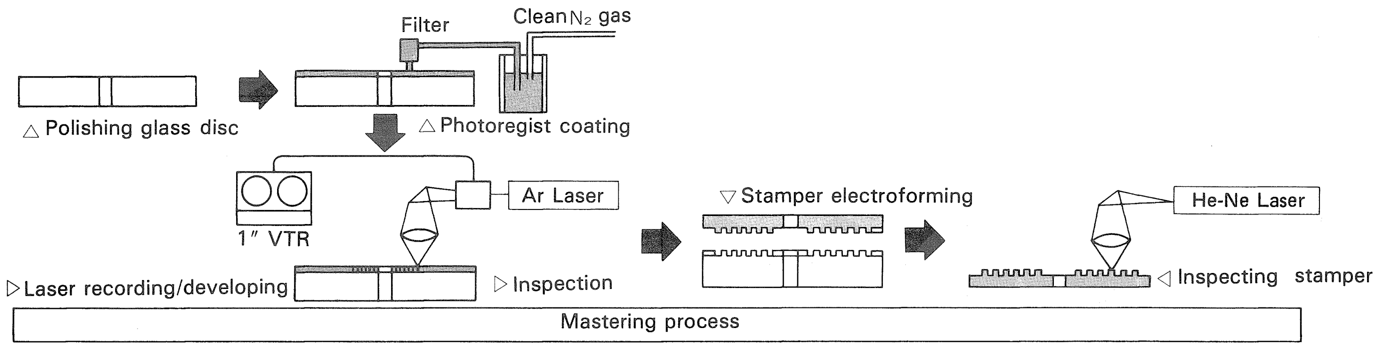


Fig. 8 Mastering process of LD.

5.3 Replication

The mastering process of the original LD is similar to that of the conventional analog discs except that LD system uses a laser beam instead of a diamond cutter. But, the replicating process is quite different.

The stamper is conveyed to a replicating line and installed on an injection molding machine. The machine makes discs by injecting some melted transparent acrylic resin into a metal mold and cooling it off till it sets. The Sides 1 and 2 are separately molded.

On the aluminum vapor-depositing line, a reflective aluminum film is formed on the pitted surface of the transparent disc. Then, protective resin is coated on the film. The dynamic weight balance of Side 1 and Side 2 is measured, and they are trimmed precisely. Then the both sides are laminated together recorded surface inside, the light part with the heavy part so that the inevitable imbalance of each side is cancelled. Perfect dynamic balance of a disc can hardly be taken if the sides 1 and 2 are made at a time by a compression molder. The completed discs are checked again if they have dust and scratches.

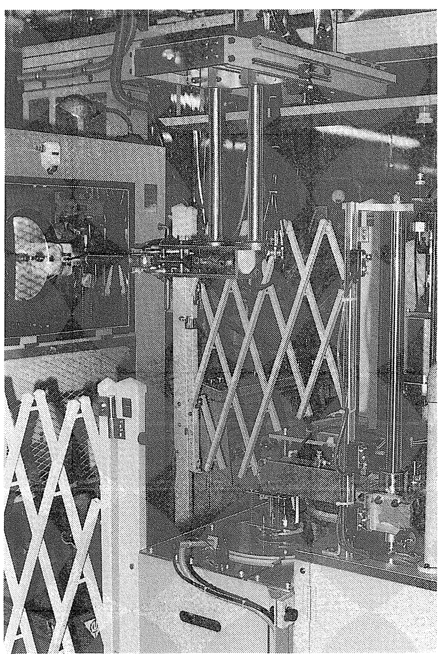


Photo 2 Injection molder

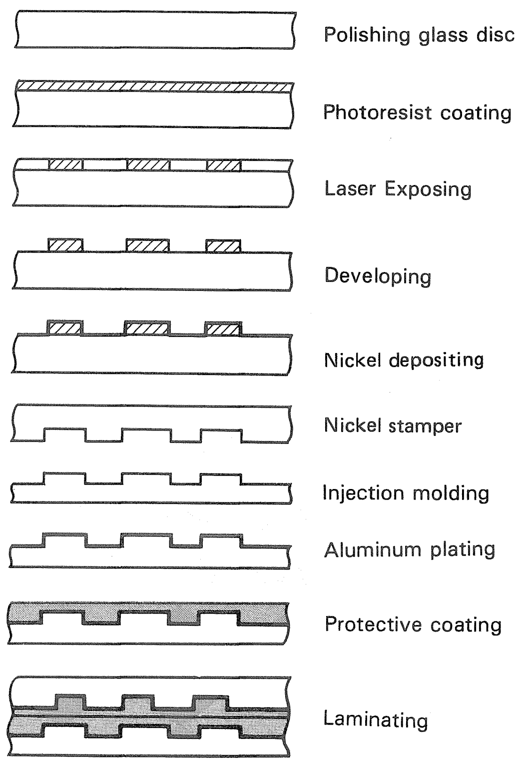


Fig. 9 Manufacturing steps of LD

5.4 CAV (Standard-play or Active-play) disc

With this type, the player turns the disc at the constant speed of 1800rpm. A CAV disc has 54,000 individual and distinct still pictures on each side because its one turn or one circle track has the information of one frame of still picture which is consisting of two fields. Each track of one turn has a frame number from 1 to 54,000 and each chapter has a chapter number. On the disc, the horizontal blanking and synchronizing signals are aligned into narrow radial stripes. The vertical blanking and synchronizing signals and control signals are contained in the two wide stripes lying opposite each other. As one track has one picture information, random access and trick play such as STILL, STEP and x3-SPEED are capable. A CAV disc has pits of about 14 billions on one side. This is suitable for recording still pictures, encyclopedias and video game programs.

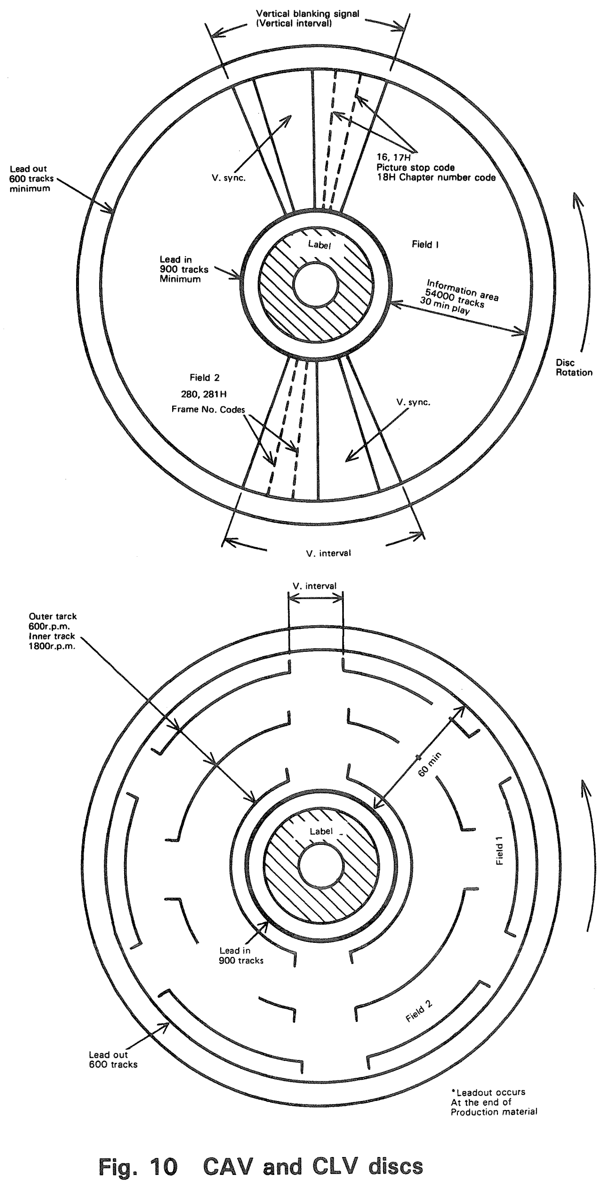


Fig. 10 CAV and CLV discs

5.5 CLV (Extended-play or Long-play) disc

The constant linear velocity of 11m/sec or the constant relative speed of the pits can be achieved by gradually slowing the rotating speed of the disc from 1800rpm down to 600rpm as the track radius increases. In such a speed, one frame is recorded on the innermost track and three frames on the outermost track. A CLV disc has two times as much information as a CAV disc does. But, trick play is incapable with this type. This is suitable for recording movie programs.

The player detects the type of the disc loaded and selects the mode automatically.

There are a number of important differences between the CAV and CLV discs. Table 4 outlines the main differences.

LaserDiscs: Playing Time per Side

	CAV		CLV	
	NTSC	PAL	NTSC	PAL
Maximum Playing Time	30 min	36 min	60 min	60 min
Spindle Motor rpm	1800	1500	1800-600	1500-570

CAV & CLV Discs: Main Differences

	CAV	CLV
Basic Functions		
Play	#	#
Pause	#	#
Scan (Fwd/Rev)	#	#
Audio Channel (1/L, 2/R)	#	#
Additional Performance Features		
Fast x3 (Fwd/Rev)	#	—
Slow (Fwd/Rev)	#	—
Still	#	—
Step (Fwd/Rev)	#	—
Random Access		
Frame No. Search	#	—
**Chpt No. Search	#	#
Frame Display	#	—
**Chpt No. Display	#	#
(Elapsed) Time Display	—	#
Elps. Time Search	—	#
***Picture Stop	#	—
**Chapter Stop	#	#

**Only for discs with recorded chapter codes.

***Some CAV discs are encoded with Automatic Picture Stop: wile reproduction in Play or Slow mode, picture freezes automatically where coded to permit special interactive uses (video games, etc.). To cancel this function, press another key (Play, Slow, Fast x3, Scan or Step).

\# = can be provided.
— = cannot be provided.

Table 4 CAV and CLV discs

6. Player

The player is composed of an optical pick-up, signal demodulators, motor drive, servo control and function control systems, power supply, etc.

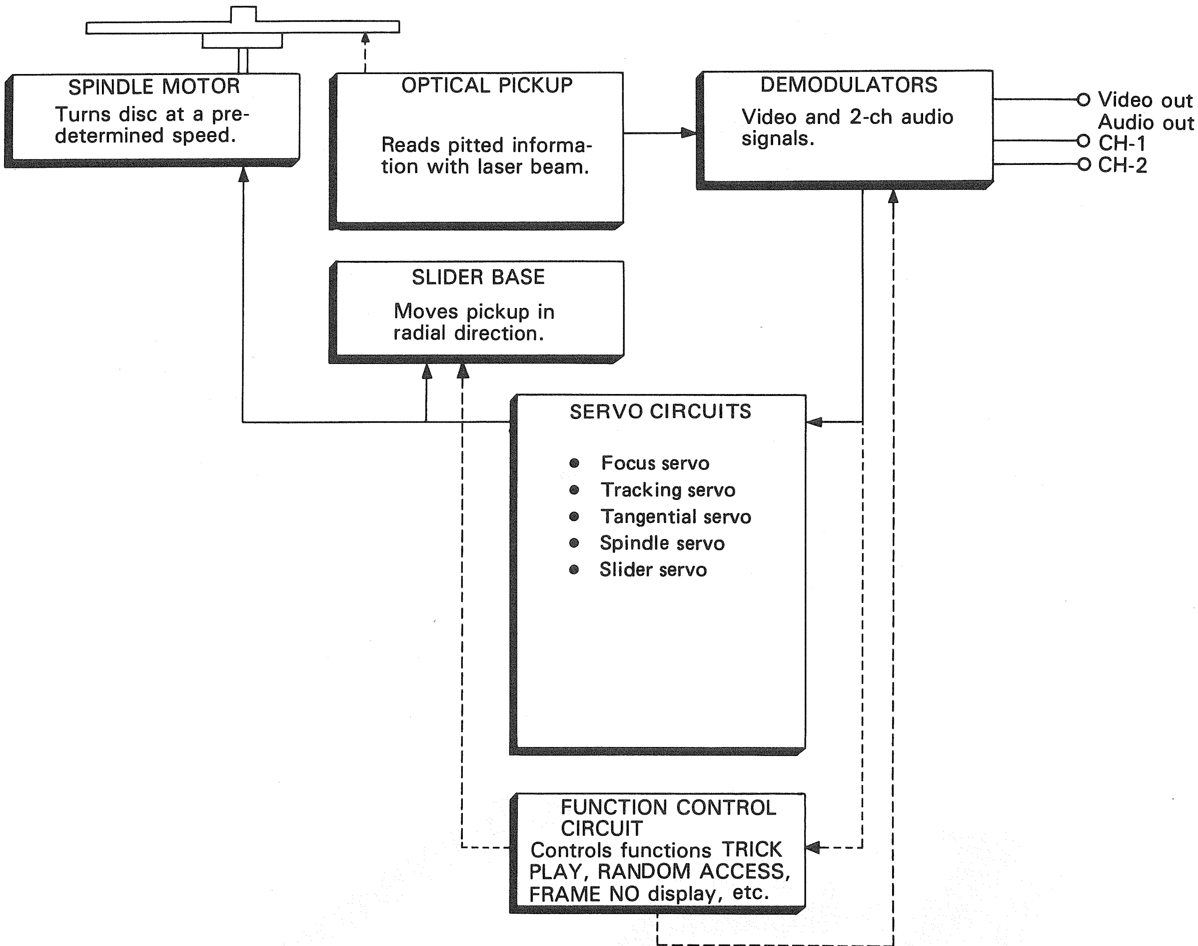


Fig. 11 Block diagram of LD player

6.1 Optical pickup system

Laser pickup reads the information of video, audio and various control signals.

Fig. 12 shows the optical pickup system. Laser-beam travels as illustrated by arrows. The whole system has been mounted on Slider-base assembly as shown in Photo 3.

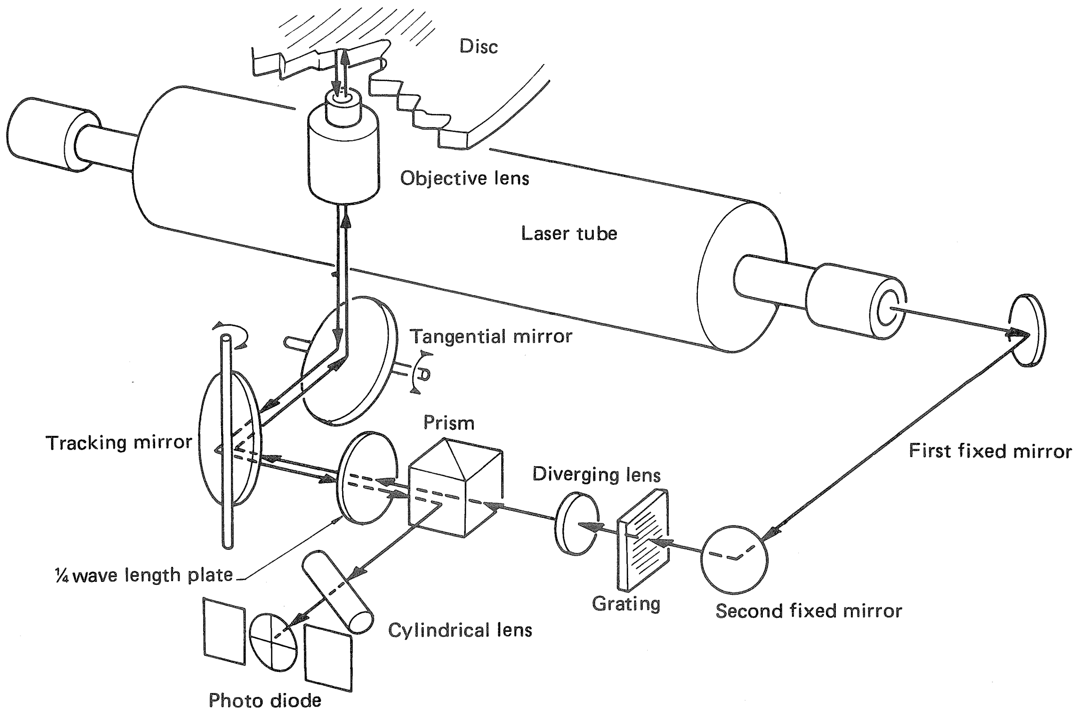


Fig. 12 Optical pickup system

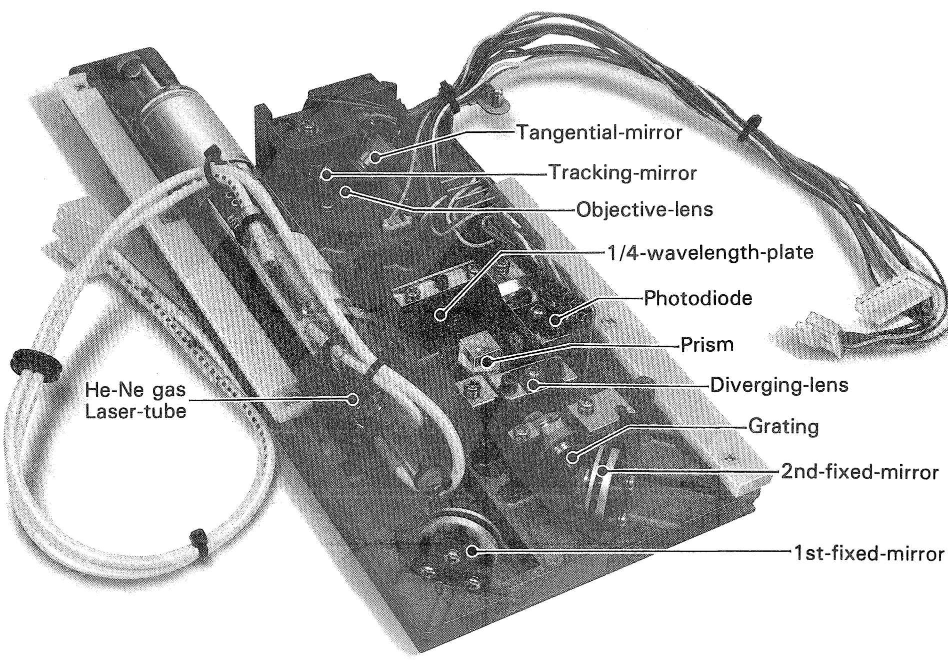


Photo 3 Optical system on Slider-base

Let's see where and how the beam travels.

a) Laser-tube

A horizontally polarized red Helium-Neon laser beam of about ϕ1mm and 1mW with the wavelength of 632.8nm comes out of this tube.

b) 1st & 2nd-fixed-mirrors

The beam direction is turned by 180° by these mirrors.

c) Grating

Here, the beam is divided into linearly aligned three beams. The center beam is used for reading video and audio signals and control signals, and the side beams are for tracing the right track.

Grating is a glass plate having narrow parallel grooves (about 100-grooves/mm) on its surface. It divides a beam into many linearly aligned beams. The divided beams are called 0'th-, ±1st-, ±2nd-, ±3rd- and ... ±nth-order beams keeping the 0'th-order beam in the center. The 0'th-order beam (center beam) and each of the ±1st-order beams (side beams) are given 50% and 20% of the whole light energy respectively. The farther sidebeams from the center, the dimmer. The other side beams are suppressed as much as possible to save the light energy.

To simplify the principle, the center beam only will be discussed here except in the paragraph of tracking servo system. The other two beams travel in the same way as the center one as shown in Fig. 14.

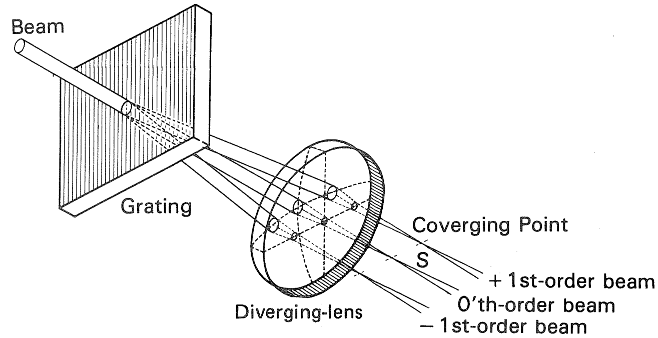


Fig. 13 Dividing beam

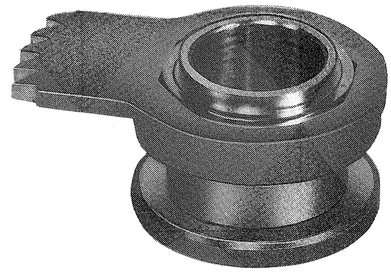


Photo 4 Grating

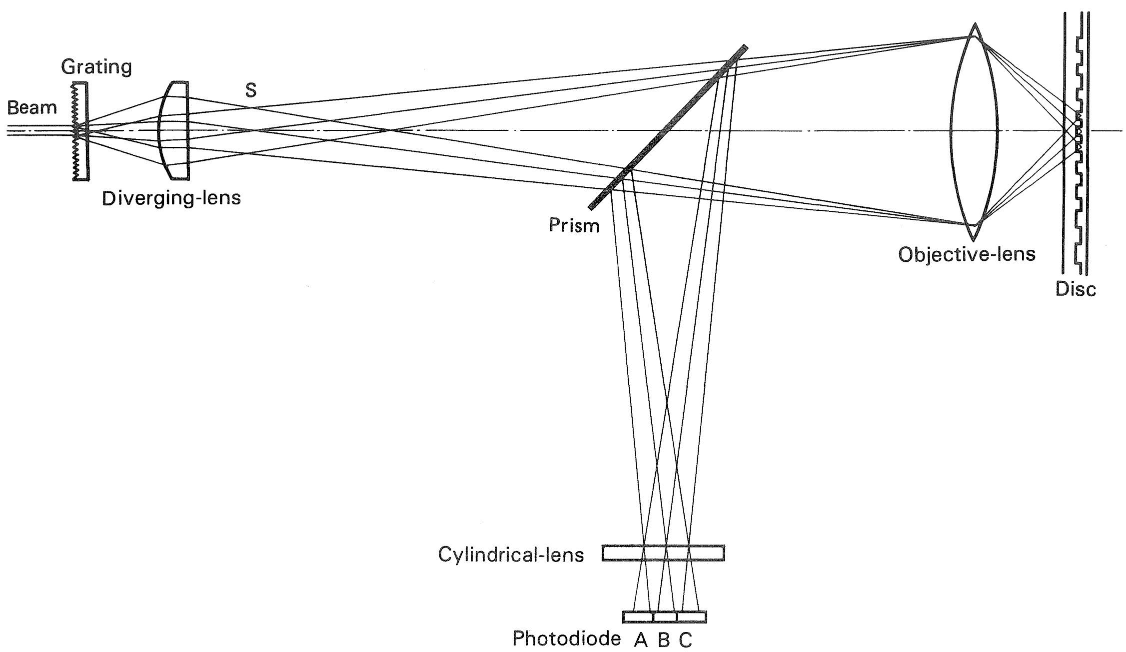


Fig. 14 Route of the 3 beams

d) Diverging-lens

The beam is once converged and then diverged before passing Prism to be projected onto the whole area of Objective-lens for best converging in the disc. Refer to Fig. 14. Objective-lens works best when a light comes in with a particular incidence angle.

e) Prism

The beam which has a horizontal polarization plane, coming from Laser-tube, straightly passes through Prism. The Prism has been so aligned to allow a horizontally polarized light pass through it and to refract vertical polarized one by 90°.

f) 1/4-wavelength-plate

The beam's *polarization plane is turned circularly here. A light has x and y components vertical each other. The plate is a piece of quarts which delays the phase of one light component from the other by λ/4. Then the combined vector of the two components is turned. Refer to Fig. 16.

*Polarization: Generally, a linearly polarized light has x and y components which are in-phase and vertical each other. If the phase of x is delayed from y by 90°, the polarization plane (the combined vector of x and y) will turn as shown in Fig. 16. If the x's phase is further delayed by 90°, the light is linearly polarized again and the spatial angle of the plane to the original becomes 90°. Imagine the Lissajous figures.

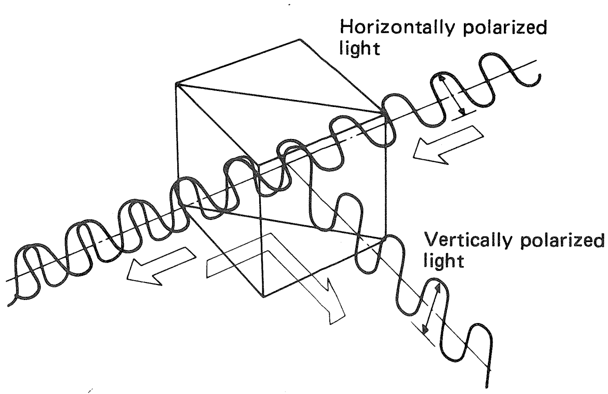


Fig. 15 Prism works as a traffic controller

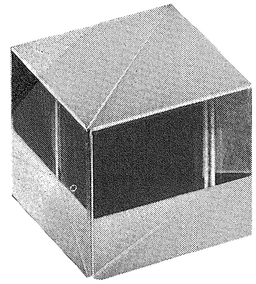


Photo 5 Prism

When x and y components are inphase.

When a linearly polarized light passes through a 1/4-wavelength-plate x-component is delayed from y-component by 90° (λ/4).

When the circularly polarized light passes through the plate, the x-component is delayed by 180° (λ/2). Then, the polarization plane becomes vertical.

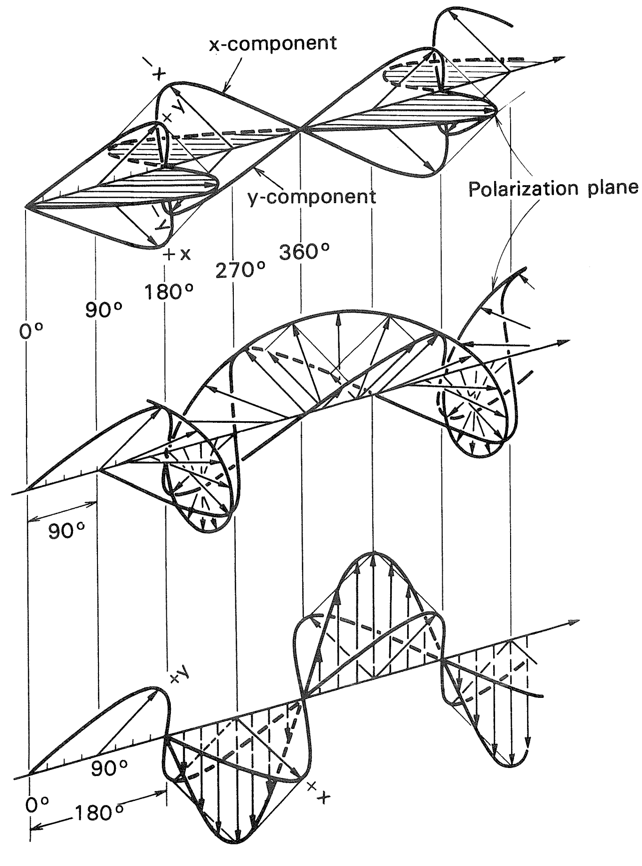


Fig. 16 Delayed x-component of light turns polarization plane.

g) Tracking-mirror

The beam's direction is changed by this mirror as illustrated in Fig. 12 so that the beam can shoot the right track. The mirror is driven by tracking servo control system which will be discussed later.

h) Tangential-mirror

The beam's direction is changed by this mirror in the tangential direction to the disc as illustrated so that the quick time-axis deviation of picked up signal can be compensated. This is driven by tangential servo control system.

i) Objective-lens

The beam is converged by this lens, and makes a spot of $\phi 1.5\ \mu m$ on the signal plane in the disc for reading recorded information. It is driven by focus servo system.
High precision and *resolving power and low *aberration are required to Objective-lens.

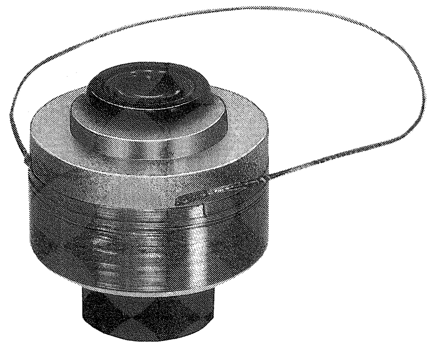


Photo 6 Objective-lens

*Resolving power of a lens: This is the ability to resolve a picture and is determined by numerical aperture (NA) and wavelength. When the recording frequency is extremely high, the shortest pit of about 0.5 μm on the inmost track requires a very clear lens with the NA of 0.45 (F = 1.1). The NA is obtainable with the following equation:

$NA = \sin\theta\ max.$

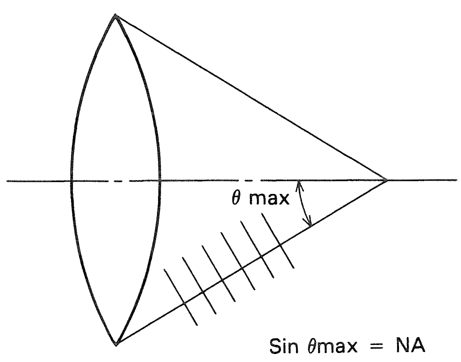


Fig. 17 Numerical aperture (NA)

*Aberration: A defect of a lens that causes inexact focusing and produces a halo around the beam spot. Chromatic aberration is not required to be considered here because a laser beam has a single frequency. However, the critical compensation of coma, which produces comet-shaped image, astigmatism and spherical aberration is required.

j) Disc

The beam is reflected on the pitted aluminum surface, there the beam is modulated into bright and dim light by pits and returns the same route to converge again at the once converged point S of Fig. 14. In reality, the returning beam does not reach to S but is refracted by Prism.
The non-pitted aluminum surface works as a plane mirror and reflects the beam completely while the pits diffract and scatter it and interfere it to return. As the laser beam is coherent, its reflected power is easily affected by the *pits (bosses) of 1/4 wavelength (0.1 μ m) deep (high). Some of the beam projected on the pits are scattered at the edge or diffracted. The rest is reflected from the center and sides of the pits. The beam reflected from the center is delayed (actually advanced) by 180° ($\lambda/2$) and interferes the beam reflected from the sides. As the result, the total beam becomes dim. The contrast of the reflected beam becomes maximum when *the spot diameter becomes about three times as long as the width of pits.

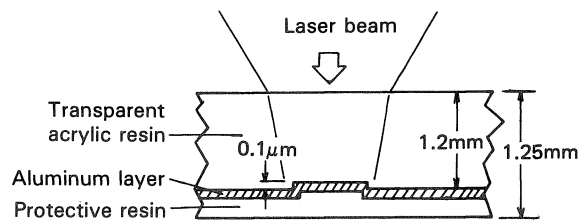


Fig. 18 Cross section of LD

*Pits: When playing, Pickup reads the bosses or the back side of the pits.
Pits of 1/4-wave length ($\lambda/4$) deep: Actually the pits' depth is not $\lambda/4$ of He-Ne laser beam but is determined by the following equation:

$$d = \frac{\lambda}{4n_1}$$

d: pit's depth
n_1: Refractive index of the disc (1.5)
λ: Wavelength of He-Ne laser beam (632.8nm)

*The optimum spot radius is determined by:

$$W_0 = \frac{0.41\ \lambda}{NA}$$

W_0: The radius of beam spot
NA: Numerical Aperture of the Objective-lens (0.4–0.45)

k) Objective-lens

The reflected beam is converged.

l) Tangential/Tracking-mirrors

The beam is just reflected and passed to 1/4-wavelength-plate.

m) 1/4-wavelength-plate

The beam is linearly polarized again and its polarization plane is made vertical to that of the original. Refer to Fig. 16.

n) Prism

The direction of the vertically polarized beam is turned by 90°.

o) Cylindrical-lens

The beam is coverged in a particular plane and is not affected in a plane vertical to the former plane by this lens. By this lens, the beam is deformed if the distance between the disc and objective-lens is incorrect. The alignment is different by models. An example is shown in Fig. 36 at the end of this chapter.

p) Photodiode

The beam finally arrives this diode and makes a spot on it. Here, the bright and dim signal is converted into electric signal as shown in Fig. 19. As mentioned, there are three beams which make three spots. Photodiode consists of six diodes, A, B1, B2, B3, B4 and C as shown in Fig. 25. The diodes are fixed at the point where the returned beam becomes round when the disc distance is optimum.

All optical components should be aligned or adjusted perfectly. If the beam polarization adjustment of Laser-tube and the azymuth adjustment of Prism are imperfect, for example, the polarization plane of the returning beam will not be perfectly vertical to the Prism. Then, some of the returning beam will not be deflected but will pass straightly through Prism, return to Laser-tube, vary its output power and paralize all pickup and servo systems.

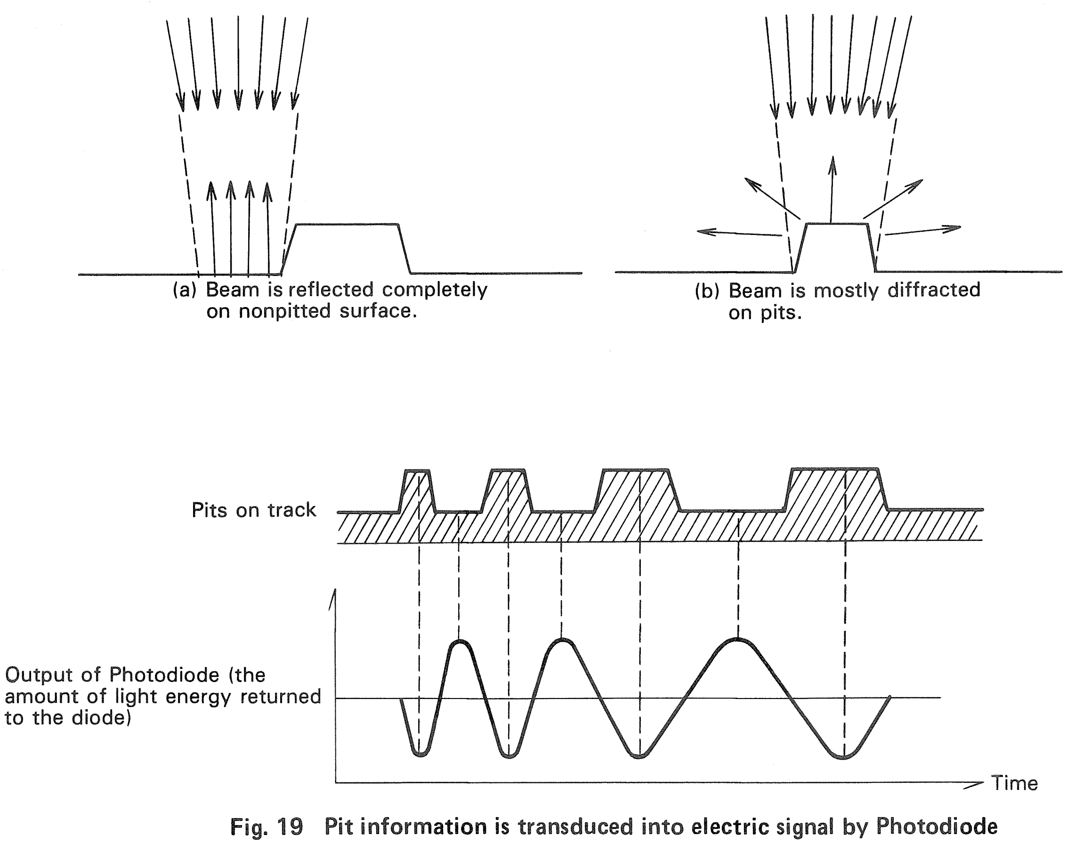


Fig. 19 Pit information is transduced into electric signal by Photodiode

6.2 Demodulation

The signal from the diodes are amplified in Pre-amplifier (RF-amp). The focus control signal (B1 + B3) — (B2 + B4) and tracking control signal (A — C) are separated here. B-sum signal (B1 + B2 + B3 + B4) is applied to Band-pass-filter (BPF) via Compensator, and is distributed to video and audio frequency demodulators.

The video signal came from the BPF (3.5M-15MHz) is frequency-demodulated. The main current of the video signal goes into the main demodulator. The rest goes into the *1H-delay circuit and then to the Auxiliary-demodulator connected parallelly to the main one. Whenever a *dropout is detected, the dropped out portion is filled with the 1H-delayed signal or the signal of the previous horizontal line. The dropout time of LD is within one horizontal scanning period (1H) shorter than that of VCR. Although the auxiliary signal is monochrome, we feel it natural because our eyes are not so sensitive to color as to the bright and dark signal. Synchronizing signals and control codes are separated from the dropout-compensated video signal and supplied to the servo circuits and microprocessor respectively.

*1H: One horizontal scanning line on the screen.
(63.5 μs NTSC)

*Dropout: When scratched, a disc loses pitted information, and when covered by thick fingerprints, the information can not be read out. Then, the reproduced video and audio signals are suddenly lost simultaneously for a short period.

The 2-channel audio signals separated by BPF are separately frequency-demodulated and become audio signals. When, the signals have been CX-encoded, they are decoded in CX-noise-reduction circuit. If dropout is detected, the previous level is supplied by previous-value-holding circuit.

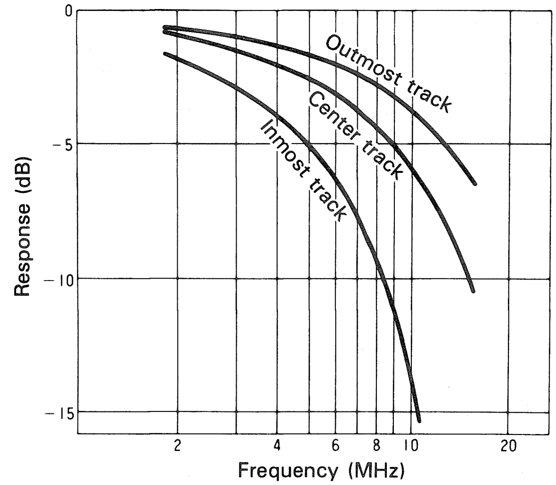


Fig. 20 Frequency characteristics of reproduced signal

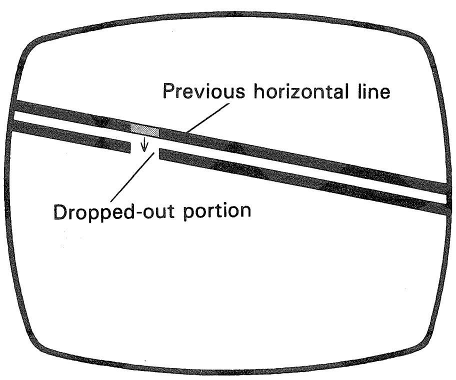


Fig.21 Dropout compensation

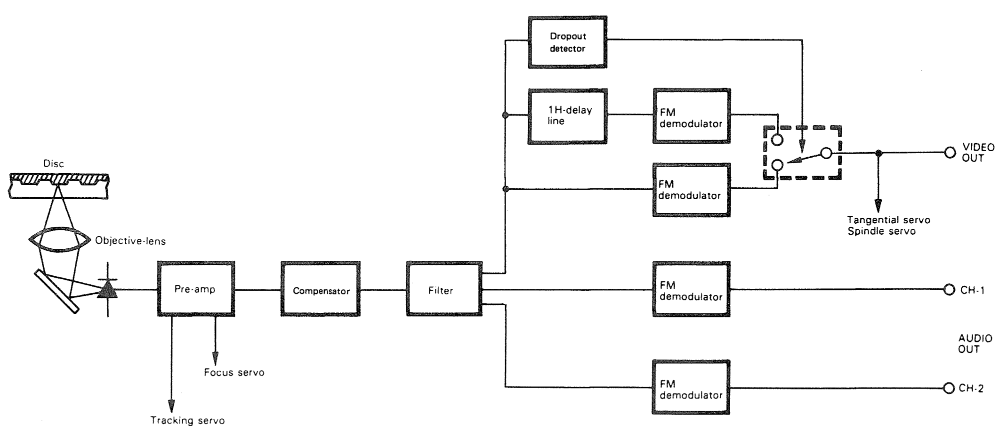


Fig. 22 Block diagram of demodulating circuit

6.3 Servo control system

High precision servo control is required to trace the pits of 0.4μm wide. The electro-optical servo system takes charge of fine adjustments which are impossible mechanically. The main servo control systems employed in the LD system are: Focus, Tracking, Spindle, Tangential and Slider servo control systems.

a) Focus servo system

Slight up and down fluttering of the disc is inevitable when playing because every disc has uneven and warped surface. Objective-lens should move up and down to keep the optimum distance from the disc and to *focus the beam on the recorded signal plane. *Cylindrical-lens and Photodiode-B play important rolls to keep the distance. The Cylindrical-lens deforms the beam to help the diode see if Objective-lens is in the correct position.

*Focus: Strictly speaking, the beam is not focused but converged because focusing can be made with a parallelly travelling beam while this beam has ever been converged and diverged and is not parallel. And pin-point focusing is unnecessary to get a center spot of $\phi 1.5\mu$m on the aluminum surface.

*Cylindrical lens: As shown in Figs. 23 and 36, it works as a plane glass plate against a light in an axial plane and as a convex lens in a lateral plane, thus, when a converging beam passes it, the lateral converging point is made closer to the lens than the longitudinal converging point.

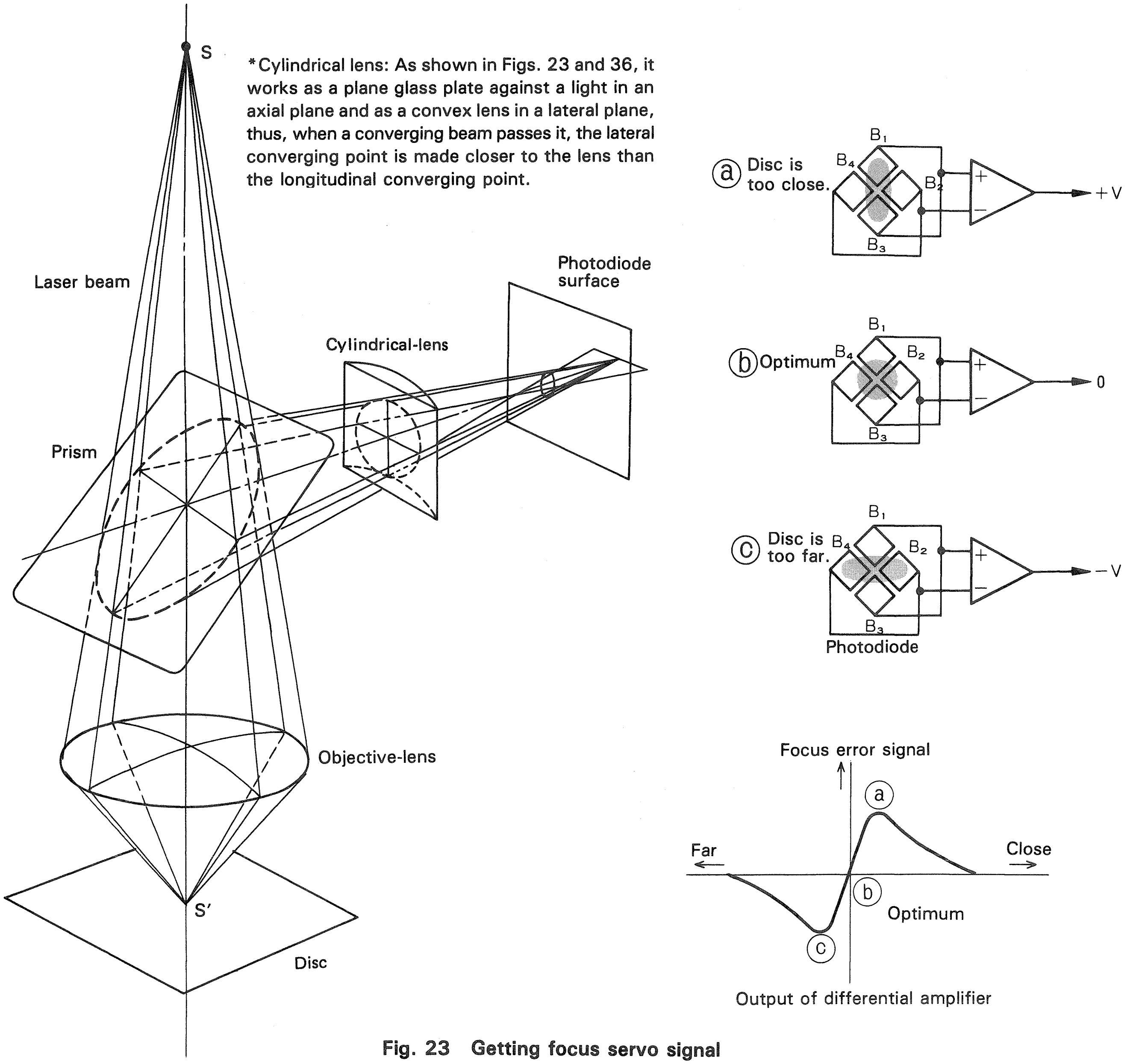


Fig. 23 Getting focus servo signal

The beam refracted by Prism passes Cylindrical-lens and reaches 4-segment-Photodiode-B. When the disc distance is optimum to make a ϕ0.75mm center spot on the disc surface, the returned beam becomes round and equally lights the four segments of the diode-B. When the disc moves close to Objective-lens, the returned beam becomes thick and the spot on the diode becomes tall, and when it moves far, the beam becomes thin and the spot becomes flat as shown in Fig. 23. The differential amplifier, connected to the 4 segments, satisfies the following equation and puts out the differential voltage or error voltage proportional to the spot deformation.

$(B1+B3) - (B2+B4) = V$
$V = 0$ Optimum distance (in-focus)
$V > 0$ Disc is too close.
$V < 0$ Disc is too far.

The error voltage is applied to the focus-motor (the coil on the Objective-lens that works like the voice coil in a speaker) and moves the lens up and down to keep it in focus. If there is no disc on the turntable, the disc-sense circuit senses it and generates a stand-by signal.

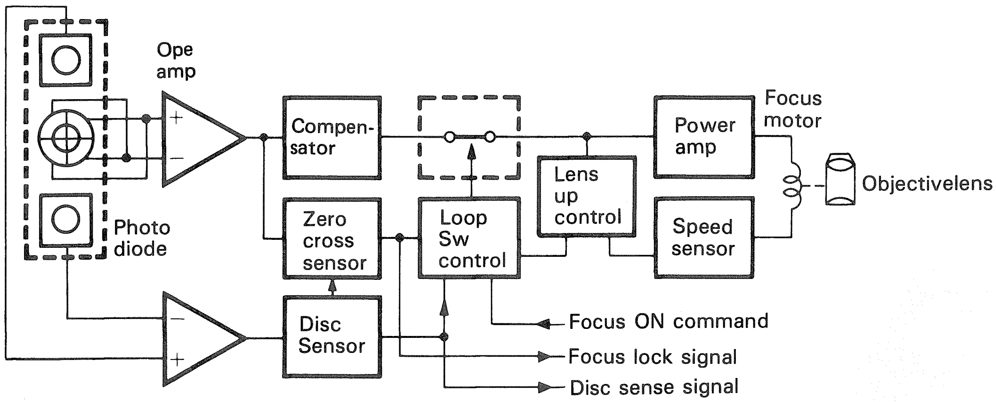


Fig. 24 Block diagram of focus servo circuit

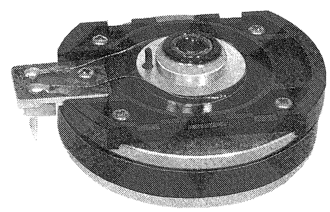


Photo 7 Objective-lens built in lens-drive motor

b) Tracking servo system

Every disc and Disc-clamp are eccentric to some extent, and the signal track, therefore, meanders and vibrates laterally when playing. Carrying the whole pickup system, Slider can not follow the track which quickly meanders or vibrates in the radial direction. Tracking servo system takes charge of driving the beam to let it shoot the correct track. The two side beams are aligned to offset slightly to both sides from the track center as shown in Fig. 25. Photodiode-A&C detect the deviation of the side spots A and C from the track center. The (A-C) difference voltage goes into the coil on Tracking-mirror and turns it laterally. When the center beam traces the track, the error voltage is OV. In Fig. 25, if it derails rightward, (A-C) becomes positive because A becomes brighter than C.

$A-C = 0$	Optimum
$A-C > 0$	The beam is deviated to the right.
$A-C < 0$	The beam is deviated to the left.

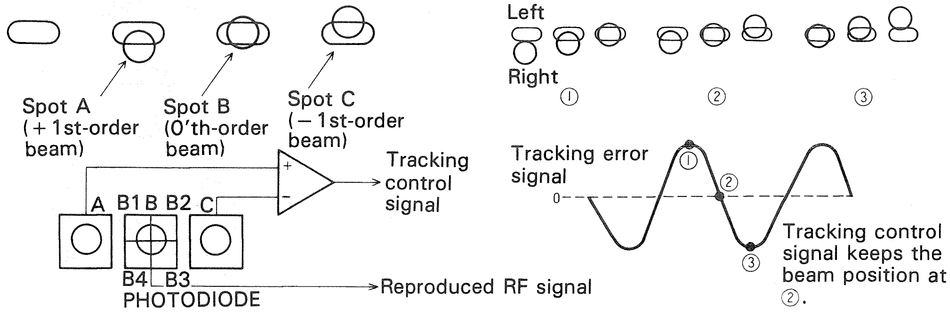


Fig. 25 Side spots and (A-C) signal

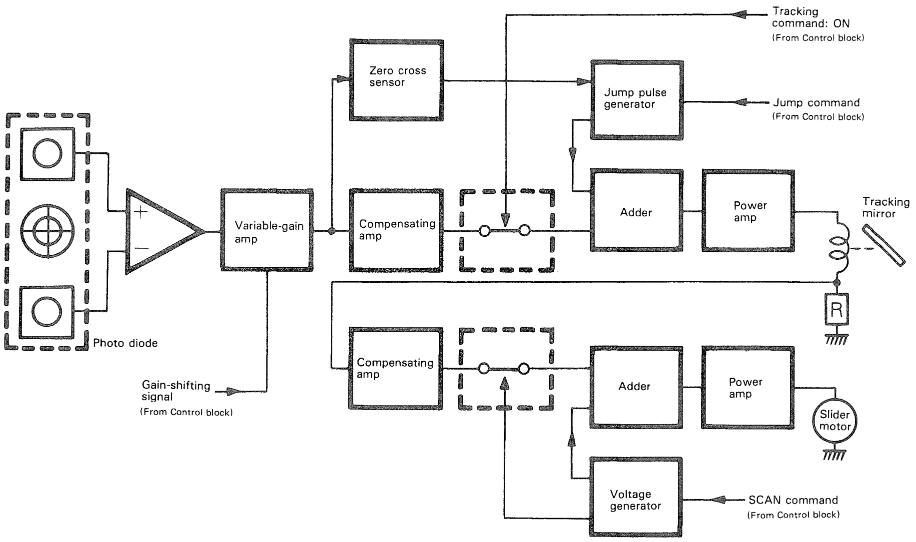
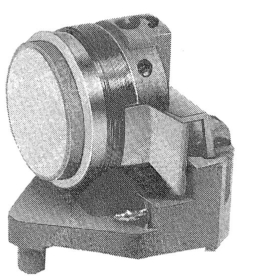


Fig. 26 Block diagram of tracking servo circuit



Electromagnetic mirror transducer: It is composed of a mirror, a magnet and a coil like a galvanometer. The mirror held by rubber pieces at two points is turned by the error current. The mirror has been multilayer-coated so it can obtain the maximum reflexibility against the light of 632.8nm. This has been employed in the tangential and trancking servo systems.

Photo 8 Electromagnetic mirror-transducer

c) Spindle servo system

Spindle servo system keeps the rotating speed of Spindle-motor constant at 1800rpm for a CAV disc and at a predetermined linear speed (11m/sec or 1800rpm-600rpm) for a CLV disc. Spindle-ON command lets Spindle-motor start rotating. When focus servo and tracking servo are locked, video and audio signals are read out. The horizontal synchronizing signal separated from the picked up signal is compared by Frequency/phase comparator with the reference signal obtained from a quartz oscillator. The error voltage proportional to the deviation from the rated speed appears at the comparator's output. When the rotation of Spindle-motor reaches a predetermined speed, Spindle-servo-switch is closed and the error signal is applied to the motor to control its speed. The low frequency error component of the tangential servo system is added to the signal to make the speed more accurate.

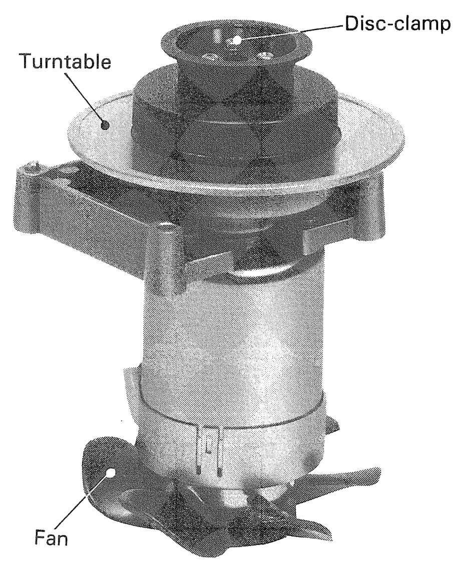


Photo 9 Spindle-motor

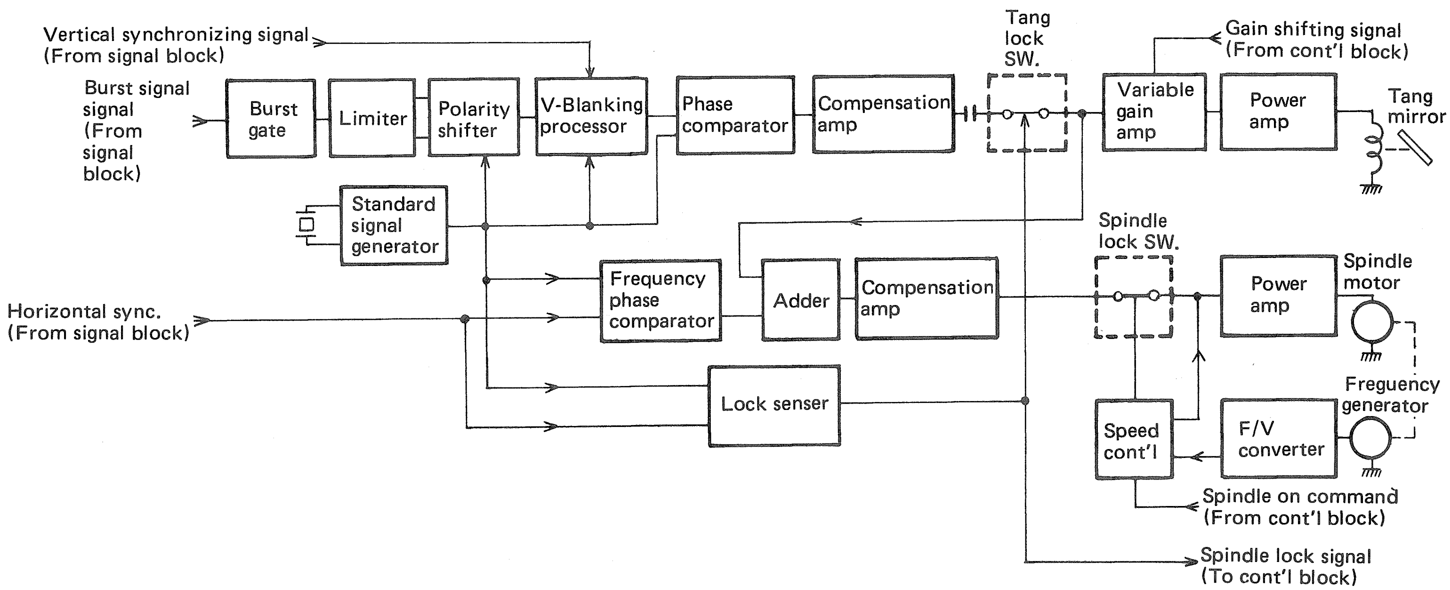


Fig. 27 Block diagram of time-axis servo system (spindle/tangential servo)

d) Tangential servo system

However accurate Spindle-motor is, an eccentric or warped disc causes jittering or momentary speed fluctuation of pits. When the error signal of Spindle-servo control becomes OV, Lock-detector generates a spindle-lock signal and closes Tangential-loop-switch. Phase-comparator compares the phase of the color burst signal, which has been separated from the video signal, with the reference color subcarrier. The difference voltage obtained from the comparator is applied to the coil on Tangential-mirror transducer to turn the mirror. It controls the relative speed of the pits and cancels the fluctuation by turning its mirror back and forth in the tangential direction. When the momentary speed of the pits becomes slow, the Tangential-mirror turns to let the reflected beam shoot a little backward. When the speed becomes fast, the mirror turns to let the beam shoot a little forward. Without this control, the picture will be unstable and deformed. The low frequency error component taken out of the error signal is applied to Spindle-motor to directly control its speed.

e) Slider servo system

Slider-base assembly, which bears the whole optical system, is driven on the guide rail in the radial direction by Slider-motor. The low frequency component of the tracking error signal is added to the slider control signal. Pickup should be moved slowly when playing regularly and quickly when trick playing keeping the distance between Objective-lens and the disc constant. A geared motor provides you with a wide range of speed and the quick shifting ability of the speed.

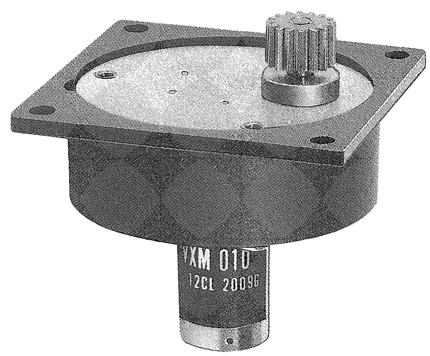


Photo 10 Slider-motor

6.4 CX (Compatible Expansion) noise reduction system matched with LD system

The Dolby system is only for minimizing the high frequency hiss noise inherent to the cassette tapes. The system is not effective for LD because LD's noise has been distributed to the medium and low frequency ranges. The CX system which has been developed by CBS, Inc., compresses high level audio signals when recording and expands them when reproducing irrespective of their frequency and improves the signal to noise ratio (S/N) by 14dB at maximum and expands the dynamic range up to 70dB or more. Some LaserDiscs, therefore, employ the new system.

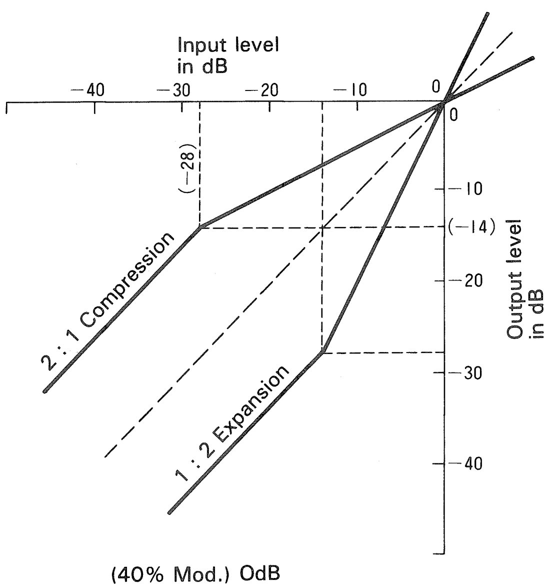


Fig. 28 CX NR compression/expansion characteristics

After frequency demodulated, the audio signal of each channel passes a 75μs deemphasizer. In CX expander, the signal level is adjusted and the signal is applied to a gain-variable amplifier and a level sensor. The amplifier senses CX-ON/OFF signal. When CX is OFF, its gain becomes constant. When CX is ON, the signal is rectified by the level sensor and is compared with a reference level. The gain of the amplifier against the signal over the reference level is made constant. If the signal level is lower than the reference level, the signal is level-detected by the main filter of 1ms attack time and 10ms release time and then is peak-detected by LPF and HPF accurately. The detected signal controls the gain of the amplifier to get the original signal. With this system, natural sound is obtainable being free from the frequency equalizer which is required by the Dolby System.

6.5 Function control

The control system has two main blocks, microprocessor and data processor, and provides the following functions:

- Receives commands from the keyboard or remote control unit.
- Deciphers the PHILIPS codes separated from the picked-up signals.
- Stores the above data and generates character signals for displaying.
- Provides the servo systems with control signals in proper timing in accordance with the player's mode.
- Processes frame and address information when searching, etc.

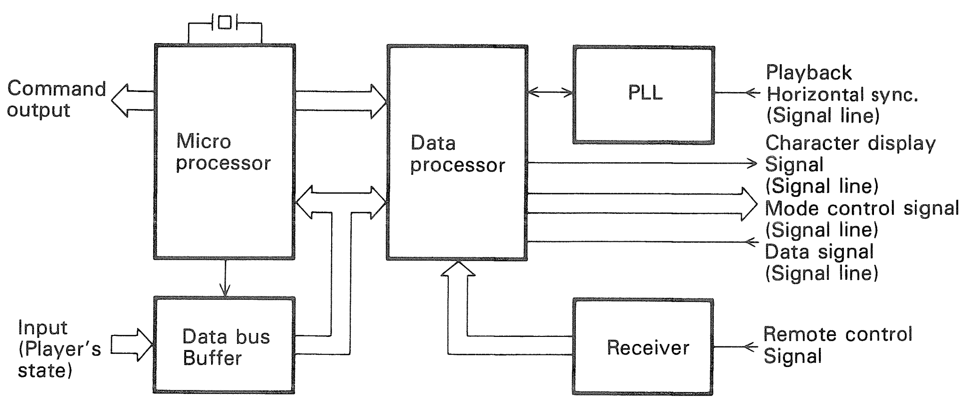


Fig. 29 Block diagram of function control

a) Random access

The random access instructions from the keyboard is received by Receiver. FRAME or CHAPTER number is taken out of the composite signal, deciphered and displayed on a CRT. The address information is sent from Data-processor to Microprocessor and are processed there and command signals are produced.

When searching Frame # 1000 from # 2000, for example, depressing SEARCH—FRAME—1000—SEARCH makes the Data-processor read the input, display on the screen and send the information to Microprocessor. Data-processor also reads the played-back data and sends the frame number of the picture now playing to the Microprocessor. Microprocessor compares the present frame number with the one being searched and makes the slider move right and left till it recognizes that the beam is tracing the track # 1000. The slider movement is rough and quick first and then gradually becomes precise and slow as shown in Fig. 30.

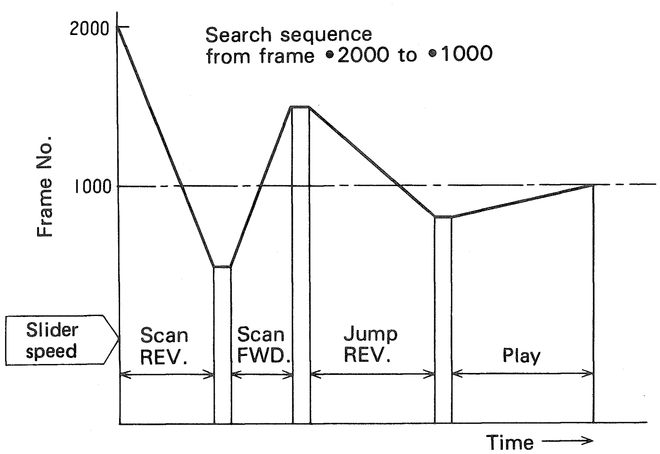


Fig. 30 Search sequence from FRAME # 2000 to # 1000

b) Trick play

When a trick key is pressed, a command signal makes the Tracking-mirror turn to let the beam jump back or forth. The picture is not interfered by the jump operation because the beam jumps in vertical blanking period or in a horizontal scanning period of 16thH, 17thH, 18thH, 279thH, 280thH or 281thH (NTSC). Refer to Figs. 10 and 31. Fig. 32 shows how the beam traces the track. STILL command makes the beam jump back every one revolution. x3SPEED let it jump forward in every half revolution. x3 REVERSE lets it jump back two times in every half revolution. SLOW speed can be varied gradually down to one frame per second with the slow speed control lever. The longer a frame is repeated, the slower it becomes

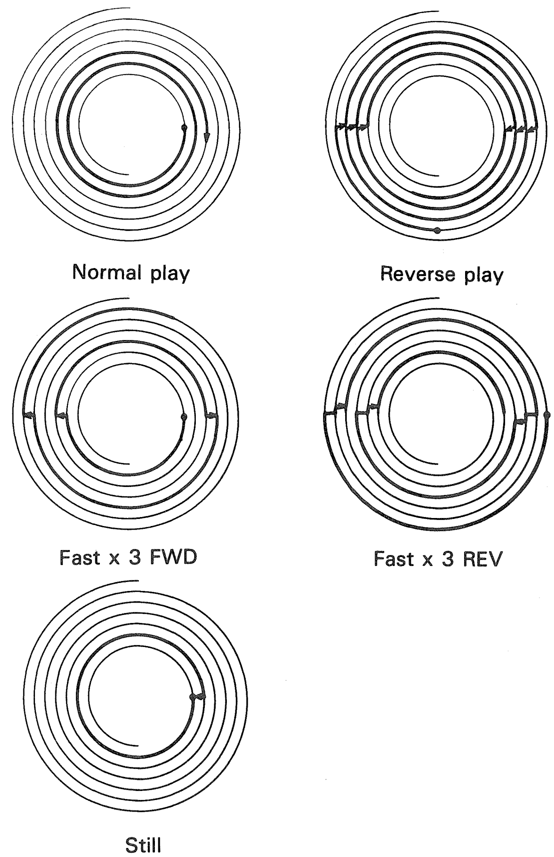
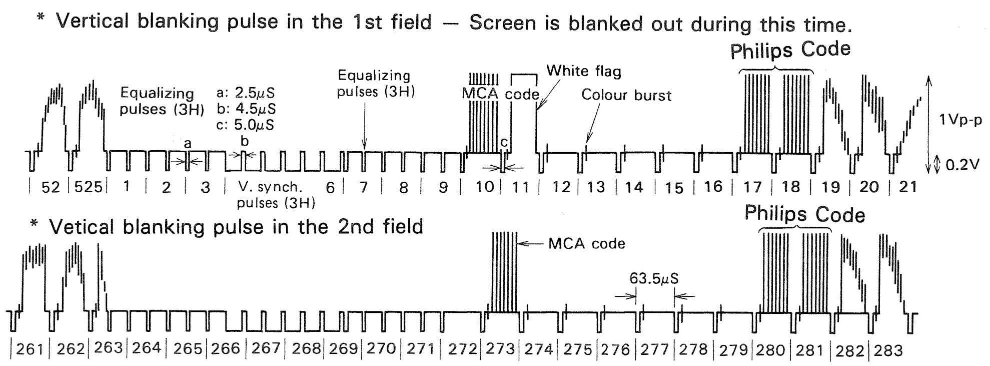


Fig. 32 Jump operation in each playback modes

Fig. 31 PHILIPS codes on vertical blanking signal



7. LASER (Light Amplification by Stimulated Emission of Radiation)

A device for generating a coherent light which has wave components of an equal length and uniform phase. The ordinary lights are incoherent having various wave components and phases because in the emission of the light, the atoms vibrate randomly and independently of each other and give it various frequencies and phases. A single colored ordinary light still has waves of various phases although its wavelength is almost uniform.

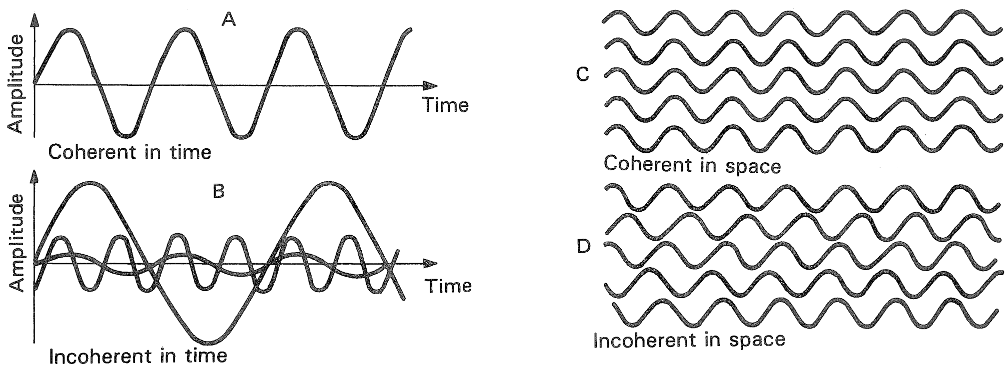


Fig. 33 Light waves

He-Ne laser generator consists of three blocks, a laser tube, mirrors, and power supply.

As an active material, a blended gas of helium and neon has been filled in a specially designed glass tube. Two mirrors are installed at the both ends of the tube to be faced each other. The atoms in the gas is excited by the voltage applied to the tube and emits a radiation. Actually, neon gas only emits radiation and helium gas works as an agent and helps the neon emit the light effectively. The excited atoms stimulate the emission of radiation of other atoms. The light generated in the tube is reflected repeatedly by the mirrors, resonated and gets an energy of higher level till it leaks out of the tube through one of the two mirrors which is partially reflective. The continuous resonance maintains the continuous emission of radiation. About one percent of the energy applied to the tube comes out of it in the form of a laser beam.

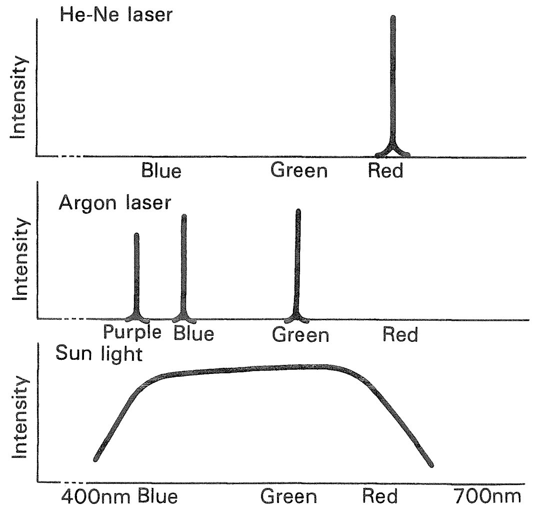


Fig. 34 Frequency spectrum of lights

Power supply circuit generates high voltage pulses. When start oscillating, the tube requires the pulses of several thousand volts.

A high powered (a few watts) purple argon laser beam is used for cutting a master disc because the photoresist coating on the original glass disc is very sensitive to it.

On the other hand, a red He-Ne laser beam is used for playback because it can be generated stably with low energy for many hours. Laser beam is the best for reading quickly moving small pits and patterns because it is very thin and stable and travels long way straightly without diffusing. Semiconductor laser generators will be employed in the near future.

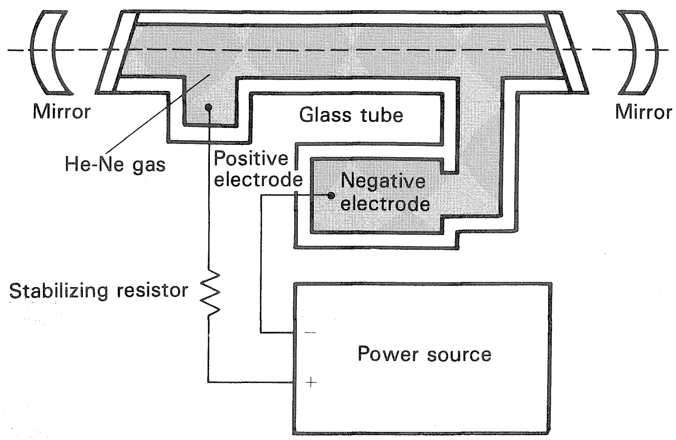


Fig. 35 Laser-tube

8. Application of LD system

Being highly durable, reliable and computer-compatible, LD system has been applied in various fields as a component of audio-video system, video game console, Karaoke or sing-along player, still-picture-with-sound player and light and sound programming system for amusing, training, filing and exhibiting purposes. It is unpredictable how widely it will be used.

Reference

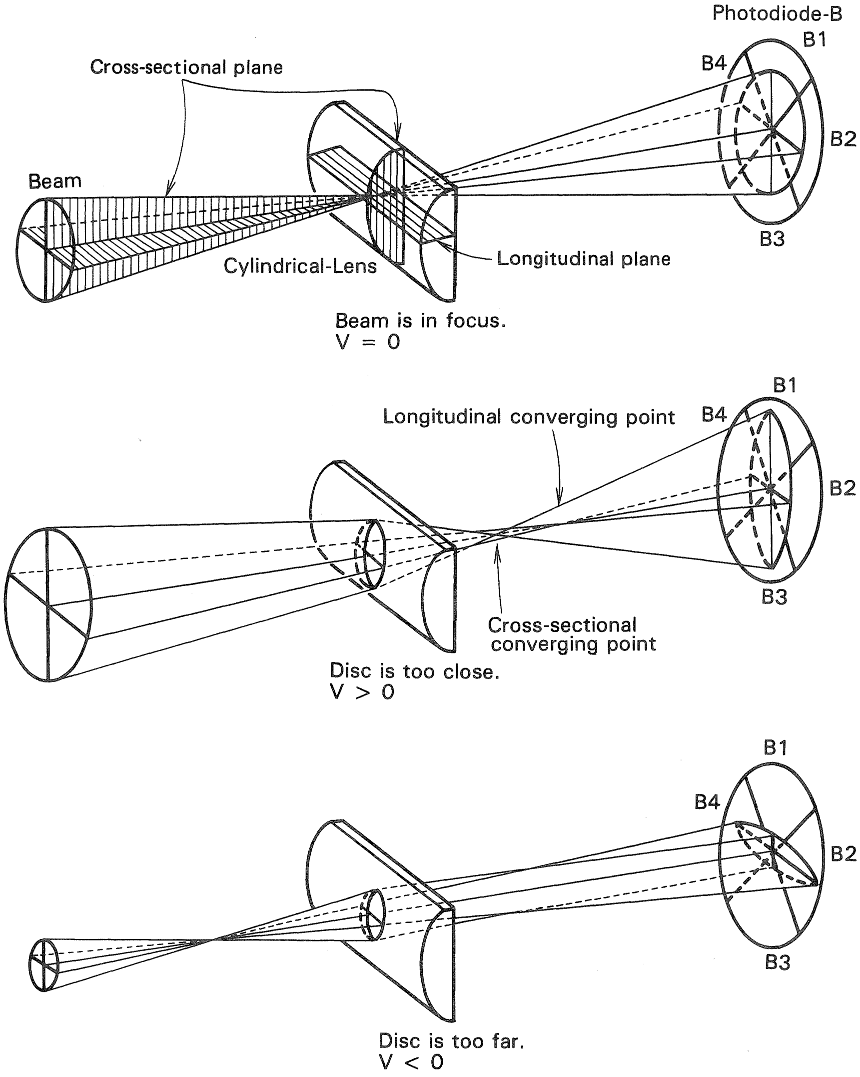


Fig. 36 Cylidrical-lens deforms beam spot

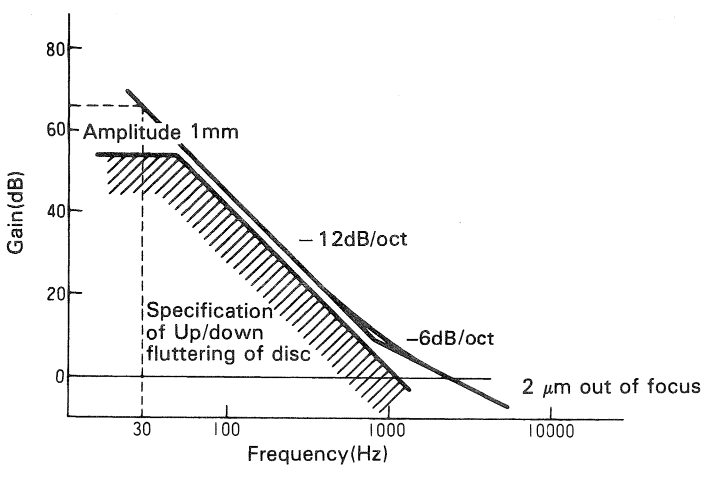


Fig. 37 Open loop characteristic of focus servo system

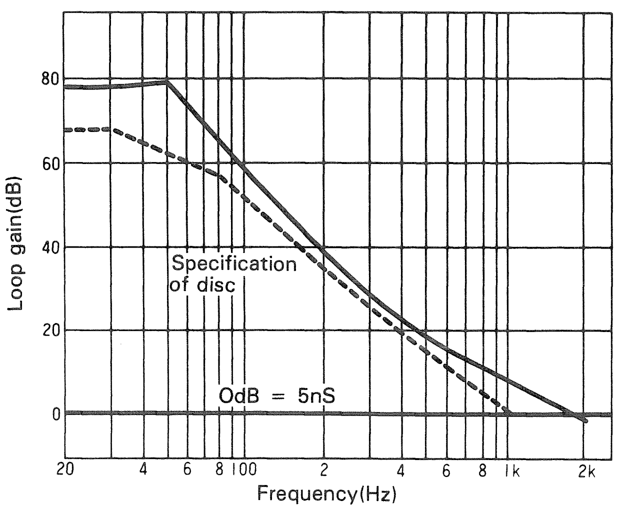


Fig. 38 Open loop characteristics of tangential servo system

QUESTIONNAIRE

MODEL ____________

One Model per questionnaire

Dear Servicer,

Thank you for your cooperation in the post-sale service of Pioneer products.

This questionnaire is used as a tool to improve the serviceability of our products and service manuals. Please evaluate this model and service manual by answering the following questions. Your ideas may be realized in our future products. Your answers will be appreciated. Thank you.

PIONEER ELECTRONIC CORP.

T. Nakagawa, Manager, Service Section, International Division

1. SERVICING EVALUATION Circle applicable number:	Good		Fair		Poor
a. Disassembly/Re-assembly:	1	2	3	*4	*5
b. Circuit Checks:	1	2	3	*4	*5
c. Replacement of Parts:	1	2	3	*4	*5
d. Adjustment (s):	1	2	3	*4	*5

* If (4) or (5) was circled, please be specific.

e. Your advice, opinion or ideas related to servicing this product.

2. SERVICE MANUAL EVALUATION

a. Circuit & Mechanism Description

b. Circuit Diagram

3. OTHER

Please describe other areas of servicing which you may find difficult.

Completed by :

Date :

Company Name :

Address :

City/State/Zip :

Please send this form filled to the distributor in your country.

PLEASE ANSWER THE QUESTIONNAIRE

Dear Servicers,

As you are aware, many of the recent products are multi-functioning, small-sized and lower-priced for better marketing. And this has brought difficulties in repairing due to the complicated circuitry and high density of unit.

In consideration of this fact, we are now trying hard in Tokyo to improve the service manual and serviceability of products by deeply involving in creating service manual and in designing major models at prototype stage, resulting in success at a certain extent.

For further improvement, we planned to investigate how you evaluate the service manual and serviceability of our products. The questionnaire form on the previous pages is the one recently inserted in the service manuals.

Please answer it and tell us the pains which you might be suffering from. Your ideas may be reflected in the future models.

Any request or advice on this TUNING FORK will highly be appreciated.

Thank you for your great cooperation.

TUNING FORK No. 6

First printing: 1983

Compiled and edited by
Editors in Chief:
Ikki Nagashima
Administration Department
International Division
Tadahiro Nakagawa
Service Section
Administration Department
International Division

and

Editors:
H. Abe, F. Tsukamoto,
A. Kogirima, Y. Narumai,
K. Nohara, S. Hirose
and Y. Kojima

PIONEER®

PIONEER ELECTRONIC CORPORATION
4-1, Meguro 1-chome, Meguro-ku, Tokyo 153, Japan

PIONEER ELECTRONICS (U.S.A.) INC.
5000, Airport Plaza Drive, Long Beach, California 90815, U.S.A.

PIONEER ELECTRONIC (EUROPE) N.V.
Keetberglaan 1, 2740 Beveren, Belgium

PIONEER ELECTRONICS AUSTRALIA PTY LTD.
178-184 Boundary Road, Braeside, Victoria 3195, Australia

Printed in Japan