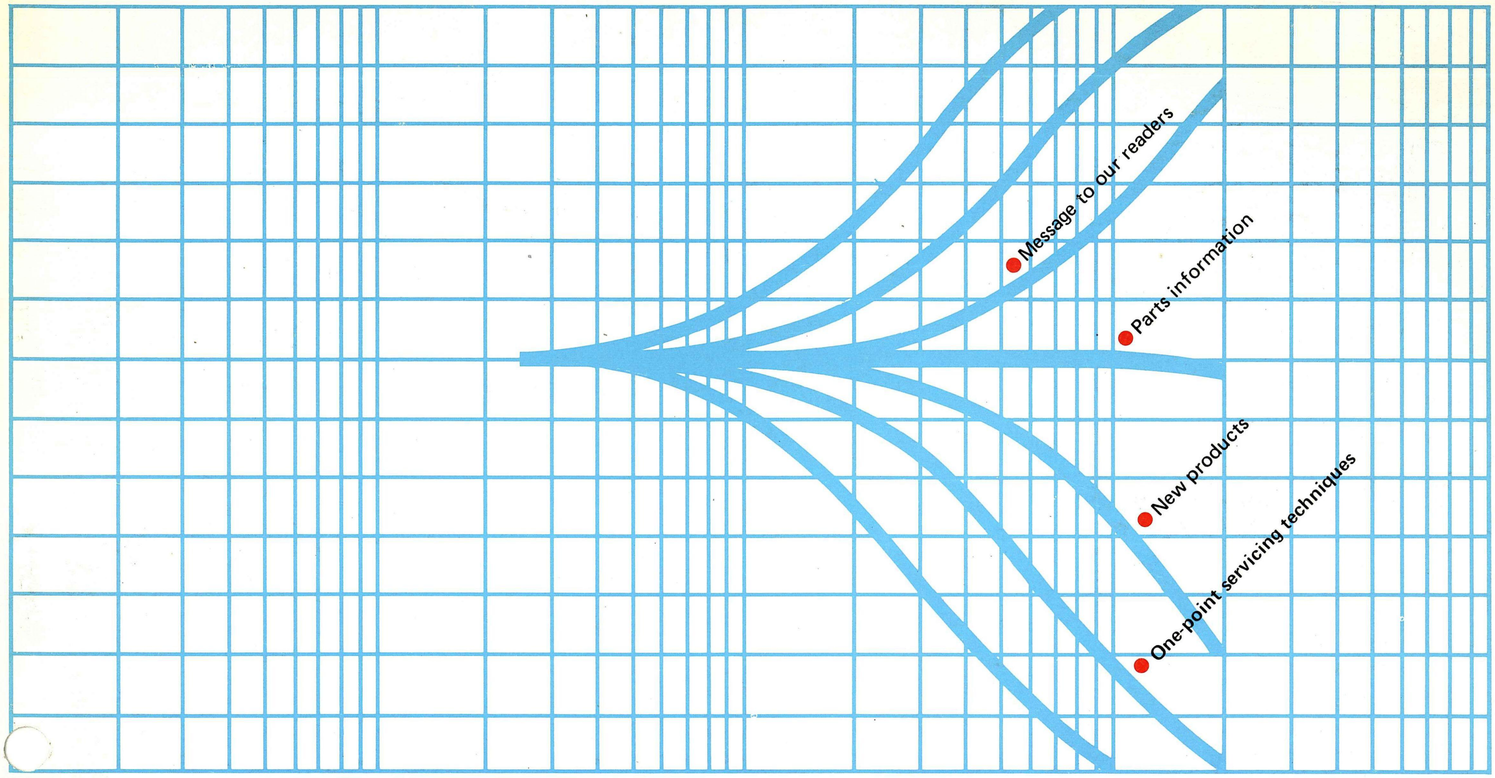
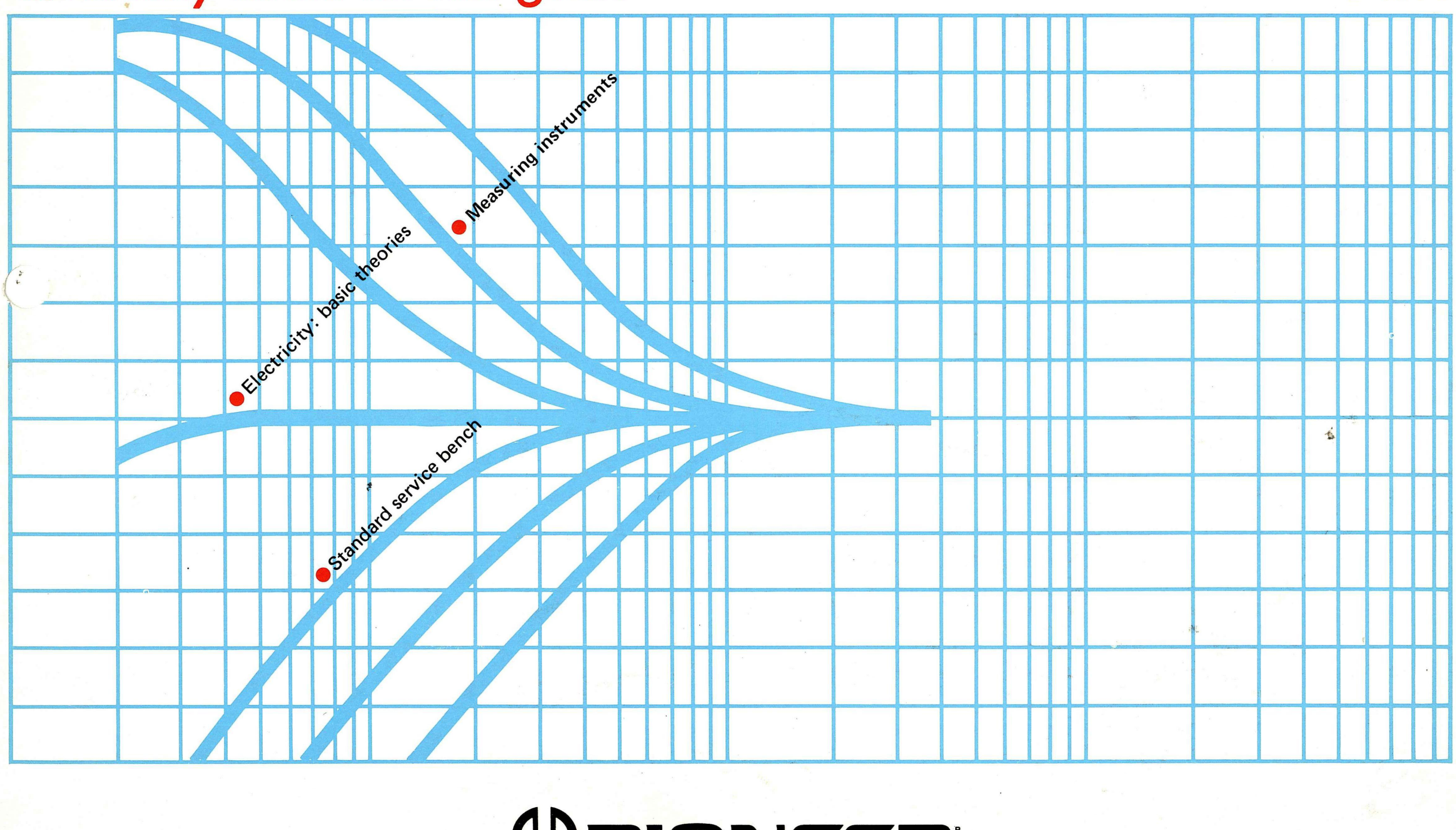


TUNING FORK

Quarterly audio service guide

No. 1



PIONEER®

CONTENTS

MESSAGE TO OUR READERS

In May 1976, Pioneer held a International Service Manager Conference in Tokyo. At the closing ceremony, we Pioneer made the following commitments to those who attended the conference:

1. Timely and speedy supply of spare parts.
2. Quicker supply of service manuals.
3. Dissemination of up-to-date technical and business information.
4. On the spot, round service by instructors from the Pioneer Tokyo Office.
5. Preparation of five-year plan and coordination between distributors.

This quarterly, which we have called TUNING FORK is a step towards the realization of our third commitment, which is the timely dissemination of up-to-date technical and business information.

It may be said that the audio business is dependent on the after sales service. The development of service system should match with the rapid progress of technology in the audio business world. Otherwise, it is the entire audio business that will ultimately suffer.

Put in another way, even if our sales division achieves its sales goal, the goal can't be maintained unless servicing gives complete satisfaction to the customers.

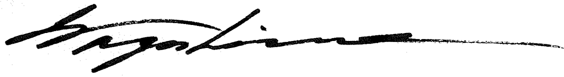
Service technicians are essential to the audio business if we are to continue meeting the expectations of our customer. One should never underestimate their importance. It is also a fact that high-quality service engineers, a faultlessly comprehensive knowledge of audio, smart sense and good customer relations, as well as the capacity to train other aspiring technicians, are the fundamental hallmarks of the truly qualified service engineer.

What all of us should be worried about, of course, is the possibility that due to the heavy volume of work, some of your service technicians may not have the opportunity to train themselves further in their job and improve their skills. We should all make it a point to study together.

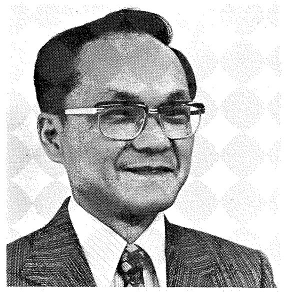
And this is where the TUNING FORK comes in. It is designed to cover any and all problems on servicing, particularly those which require advanced, highly specialized service techniques. We hope this new publication will serve to improve the quality of the work of your service stations and of those who man them.

Very truly yours,

PIONEER ELECTRONIC CORPORATION



General Manager,
Administration Deparment
International Division



PARTS INFORMATION (1)

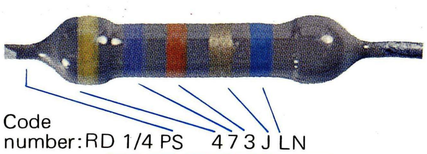
RESISTORS

Types of Resistors

Resistors are the most commonly used components in electronic equipment. However, there seems to be a misconception that all resistors have linear frequency characteristics, that is, they provide the rated resistance value at any signal frequency. This is not always true. The frequency characteristics of resistors vary according to their structure, the type of material used and the method of production. Those used in preamplifiers can be a source of noise, while those in power amplifiers or power circuits, radiate heat. It is thus very important that the right type of resistor be selected for a specific application.

1. Carbon Film Resistors (RD)

Fig. 1 Designation of carbon film resistors



Code number: RD 1/4 PS 473 J LN

(1) Carbon film resistor
(2) Power rating
(3) Lead form
(4) Nonflammable (F)
(5) Resistance value
(6) Tolerance
(7) Low-noise marking

(1) Carbon film resistors (RD), or carbon resistors as they are more commonly known, are supplied to Pioneer by two different manufacturers. Please note, therefore, that the shape and markings may differ with each manufacturer, and (2) resistors of the same power rating may not always be the same size.
(3) The lead form type mainly used at Pioneer are PS and VS (see Fig. 2).
(4) Nonflammable resistors are marked with an F and have a non-glossy reddish brown coating. These are supplied by one manufacturer only.
(5) The first two bands (yellow and violet) indicate the resistance value of the resistor. The third band (orange) indicates the multiplier 10 raised 10 to a certain power. (6) The fourth band (gold, silver or non-color) indicates the tolerance of the resistor. Gold, which is class J, has a value of ±5%. Silver, which is class K, has a value of ±10%. Non-color, which is class M, has a value of ±20%.
(7) The low noise marking, which is indicated by the fifth band, normally only applies to resistors above 47 Kohms. Manufacturer A designates it with a single blue band; manufacturer B repeats the tolerance indication.

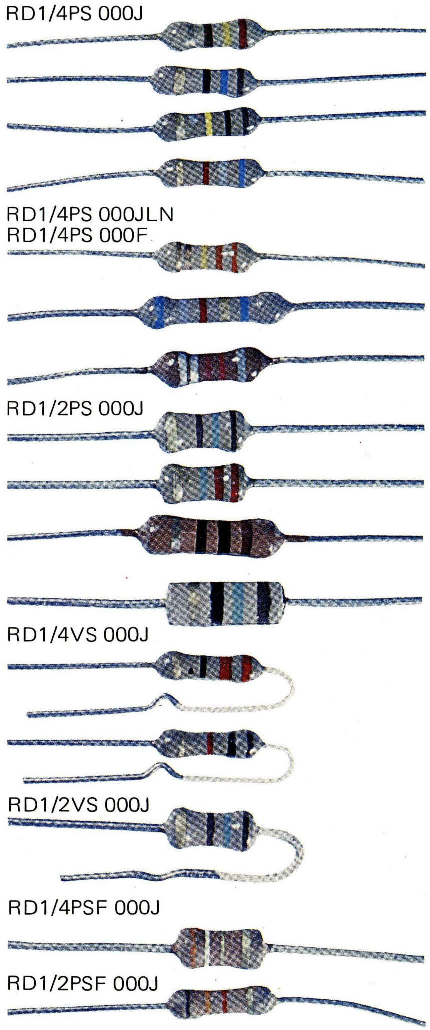
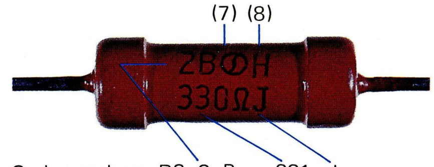


Fig. 2 Carbon film resistors in current use

2. Metal Oxide Film Resistors (RS)



Code number: RS 2 P 331 J

(1) Metal oxide film resistor
(2) Power rating
(3) Shape (tubular)
(4) Nonflammable
(5) Resistance value
(6) Tolerance

Fig. 3 Designation of metal oxide film resistors

Metal oxide film resistors are mainly used in power circuits; their power ratings are 1W, 2W, 3W and 5W.
(1) Pioneer's code for metal film resistors is RS. (2) In the photo above, "2" indicates power rating, (3) represents shapes of resistors. P is used for this type of resistor.
(4) Ordinary RS resistors have a reddish brown coating, while the nonflammable type are gray and marked F (see Fig. 4). (5) The resistance value is indicated with a 2-digit number and the multiplier 10 raised to a certain power. In Fig. 3, for instance, the resistance value should read 330 ohms, ±5%.
(6) J is generally used to describe the resistance value and in some cases, G or K are also used. The number (7) marking in Fig. 3 indicates the manufacturer; (8) represents the lot number. Resistance values of RS resistors used in Pioneer products are between 10 ohms and 220 Kohms.

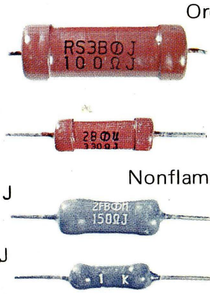


Fig. 4 Metal oxide film resistors in current use

3. Cement Case Type Wire Wound Resistors (RT)

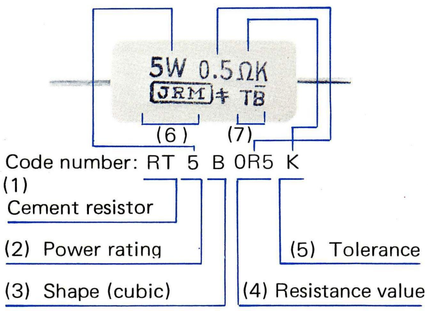


Fig. 5 Designation of power cement resistors

This type of resistor has almost completely replaced conventional RM (resin-coated type) and RW (wire-wound type) resistors in power circuit design. Because of their high insulation properties even in high temperature, RT resistors are finding a wide application in power circuits and emitter circuits in power amplifiers. (1) The Pioneer code for this type of resistors is RT and (2) their power ratings are 2W, 3W, 5W, 7W and 10W. The marking of (3) represents shapes of resistors; B for cubic and P for tubular. (4) The resistance value is given with the actual number. (5) Both class J (±5%) and class K (±10%) tolerance types are used. Resistance values available range from 0.22 ohm to 1 Kohm. Code numbers (6) and (7) are the manufacturer's markings. Note: The "Wire Wound Resistor" indication in the service manuals of current models refers to the cement case type.

RT5B0R5K

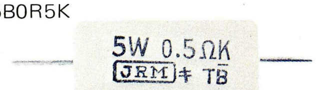


Fig. 6 Power cement resistors in current use

4. Metal Film Resistors (RN)

(A) Power type

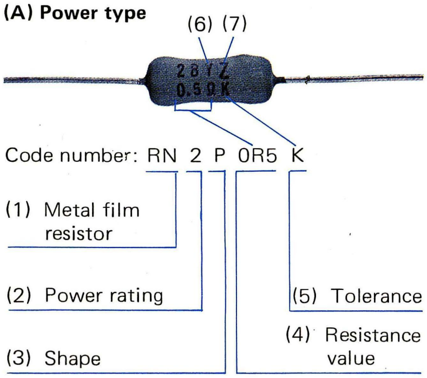


Fig. 7 Designation of power type metal film resistors

(B) Precision square type

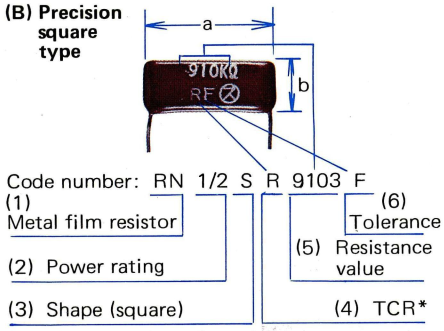


Fig. 8 Designation of precision square type metal film resistors

(C) Precision tubular type

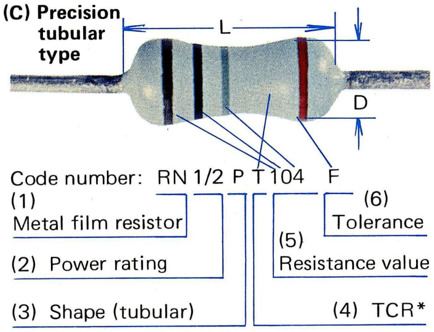


Fig. 9 Designation of precision tubular type metal film resistors

RN1/2RT104F **Fig. 10**

* Temperature Coefficient of Resistance

Metal film resistors (RN) include power type (Fig. 7) as well as precision square (Fig. 8) and precision tubular (Fig. 9) types. The designation for Power Type Metal Film Resistors (A) is the same as that of Wire Wound Resistors (RT). As for the designation of (B), which is precision square type, and (C), which is precision tubular type, please refer to the following:
(1) Pioneer's coding for this type of resistors is RN. (2) The power rating for square type metal film resistors (B) depends on their length (refer to 'a' in Fig. 8), which is 1/4W for a 9mm RN resistor and 1/2W for a 17mm type. In the case of tubular type RN resistors (C), power rating is determined by size. That is, resistors having a maximum diameter (D) of 2.4mm and a length (L) of 5.8mm are 1/4W; those measuring 3.4mm (D) x 9.5mm (L) are 1/2W. (3) Represents shape. (B) Is indicated with S, while (C) is indicated with P.
(4) The temperature coefficient of resistance (TCR) is designated R for 1/4W and R and S for 1/2W precision square type metal film resistors (B) respectively. R stands for ±100PPM/°C* and S for ±150PPM/°C. (See Fig. 8). As for (C) type metal film resistors, no marking signifies T, of which the temperature coefficient is ±200PPM/°C and marking stands for the coefficent R. [See (4) in Fig. 9].

*PPM stands for Part Per Million and is expressed as 10^{-6} (one millionth). A TCR value of ±100PPM will change the resistance value by 100 x 10^{-6}, i.e., 10^{-4} = 1/10,000 at a temperature variation of 1°C. If the temperature of the resistor is raised 40°C above normal, it will change the resistance by 40/10,000 or 4/1,000, which is equal to ±0.4%.

(5) The resistance value of precision square type (B) resistors is indicated by marking of the actual rate, but in the case of the tubular type (C), it is done by color coding (a 3-digit number and the multiplier 10 raised to a certain power). In some cases, the resistor body may have three wide color bands. For example, a wide brown, black and red band, which represent a 2-digit value and a multiplier. In which case, the coding will read 1001 (1 Kohm ±2%), which is the Pioneer code number for this type of resistor. (See Fig. 10).
(6) The tolerance code for precision resistors is red for class G (±2%) and brown for class F (±1%). Precision type resistors are used for the RIAA equalizer (feedback resistor) or de-emphasis circuit in FM tuners.

5. Carbon Composition Resistors (RC)

Code number: ACN–001 **Fig. 11**

Due to their poor noise characteristics, carbon composition resistors (solid resistors) are very rarely used in Pioneer products as especially high resistance value resistors (resistors having a special Parts Number). The types currently used are ACN-001 (200 (200 MΩ) and ACN-007 (100 MΩ).

6. Other Types of Resistors

At present, RM (resin coated wire-wound type), RB (resistance wire type) and RW (wire-wound type) are rarely used. However, some RW resistors have a limited application in certain types of amplifiers and tape decks. They are identified by the following codes:

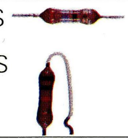
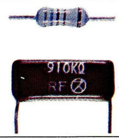
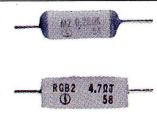
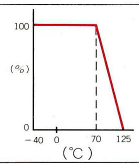
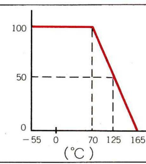
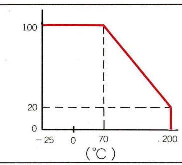
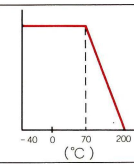
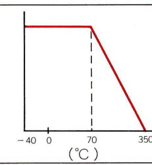
ACN-002 20W 20Ω
ACN-003 20W 3.3Ω
ACN-005 20W 20Ω
ACN-006 20W 3.3Ω
RCN-020 20W 100Ω
RCN-021 20W 300Ω
RCN-022 20W 500Ω
RCN-023 20W 2kΩ

Resistors used for Small-signal or Small-power Circuits

RD Carbon film resistors
RN Metal film resistors

Resistors used for Power Circuits

RN Metal film resistors
RT Power cement resistors
RS Metal oxide film resistors

Type	RD	RN (small type)	RN (power type)	RS	RT
Power rating (W)	¼ ½	¼ ½	1 1.2	1, 2, 3, 5	2, 3, 5, 7, 10
Resistance range (Ω)	0.47~4.7M	5.1~1M	0.22~100	10~220K	0.22~1K
Tolerance	(G), J, K	(D), F, G	J, K	(G), J, (K)	J, K
Shape	PS VS 	P S 	P 	P 	P B 
E-series	E –24	E –96	E –24	E –24	E –24
Maximum voltage rating (V)	300 350	250~350	350	350~750	350~750
Operating temperature range (°C)	–40~+125	–55~+165	–25~+200	–40~+200	–40~+350
TCR (PPM/°C)	+350/–700	±100~±200	±500	±350	±400
Power degrading curve					
Short-time overload (%)	±1	±0.5	±1	±2	±1
Moisture resistance (%)	±10	±1.0	±5	±5	±3
Load life (%)	±5	±1.0	±5	±5	±3
Temperature cycle (%)	±1	±0.5	±1	±2	±1
De-electric withstanding voltage (%)	±0.2	±0.1	±0.3	±0.3	±1
Vibration durability (%)	±1	±0.5	±1	±1	±0.5
Resistance to soldering heat (%)	±1	±0.5	±1	±1	±1
Insulation resistance (MΩ)	10^3	10^4		10^3	10^4
Current noise (dB)	–25	–35	–30	–25	–30
Nonflammable code	F			F	
Low-noise code	NL				

Color Coding

	Resistance Value	Multiplier (x 10^X)
Black	0	0
Brown	1	1
Red	2	2
Orange	3	3
Yellow	4	4
Green	5	5
Blue	6	6
Violet	7	7
Grey	8	
White	9	
Gold		–1
Silver		–2

Tolerance Codes

Color code	Brown	Red	Gold	Silver	No color
Tolerance (%)	±1	±2	±5	±10	±20
Class	F	G	J	K	M

Some small RN resistors have a class D tolerance of ±0.5%.

Resistance Value Series

E-24 Series

1.0	1.1	1.2	1.3	1.5	1.6	1.8
2.0	2.2	2.4	2.7			
3.0	3.3	3.6	3.9			
4.3	4.7					
5.1	5.6					
6.2	6.8					
7.5						
8.2						
9.1						

E-96 Series

1.00	1.02	1.05	1.07	1.10	1.13	1.15
1.18	1.21	1.24	1.27	1.30	1.33	1.37
1.40	1.43	1.47	1.50	1.54	1.58	1.62
1.65	1.69	1.74	1.78	1.82	1.87	1.91
1.96						
2.00	2.05	2.10	2.15	2.21	2.26	2.32
2.37	2.43	2.49	2.55	2.61	2.67	2.74
2.80	2.87	2.94				
3.01	3.09	3.16	3.24	3.32	3.40	3.48
3.57	3.65	3.74	3.83	3.92		
4.04	4.12	4.22	4.32	4.42	4.53	4.64
4.75	4.87	4.99				
5.11	5.23	5.36	5.49	5.62	5.76	5.90
6.04	6.19	6.34	6.49	6.65	6.81	6.98
7.15	7.32	7.50	7.68	7.87		
8.06	8.25	8.45	8.66	8.87		
9.09	9.31	9.53	9.76			

The E-24 Series apply to tolerance classes J, G and F (±5% to ±1%).
The E-96 Series apply to tolerance classes G, F and D (±2% to ±0.5%).
The E-12 Series below are applied to tolerance class K (±10%).

1.0 1.2 1.5 1.8 2.2 2.7 3.3
3.9 4.7 5.6 6.8 8.2

For class M tolerances (±20%), the following E-6 Series are used.

1.0 1.5 2.2 3.3 4.7 6.8

All these coded resistance values are multiplied by the multiplier 10^x (x=1, 2, 3, 4, 5, −1) for ordinary resistors.

Short-time Overload Ratings (All ratings comply with JIS C 5202)
The rating values are achieved by applying test voltage A, B or C, DC or RMS AC (commercial frequency sine wave) across the resistor leads for a given duration of time. After the voltage test, the resistor is left in a no-load condition for 30 minutes, then the resistance value is measured and compared with the one taken before the test. The resistance variation must not exceed the specified limit.

Test condition (voltage and test time)
A: 2.5 times the rated voltage.
5 seconds.
B: 10 times the rated voltage.
5 seconds.
C: 2 times the rated voltage.
10 minutes.

Moisture Resistance
This is determined by placing the resistor under testing conditions in a regulated chamber in which the temperature is maintained at 40°C ±2°C with a relative humidity between 90 and 95%. The voltage cycle test (rated DC voltage 90 minutes ON, 30 minutes OFF) is repeated for 16 ±1, 24 ±2, 48 ±4 or 96 ±4 hours. After the cycle test, the resistor is left at room temperature for one hour without load. The variation in the resistance values measured before and after the test must not exceed the specified limit.

Load Life
To determine the load life of the resistor under testing conditions, it is placed in a chamber with a temperature of within ±3°C. The voltage cycle (rated DC voltage, 90 minutes ON, 30 minutes OFF) is repeated for 240 ±8, 500 ±12, 1,000 ±12 or 2,000 ±12 hours.
The resistor is then left at room temperature, without load, for one hour. Any variation in the resistance values taken before and after the test must be within the specified limit.

Temperature Cycle
The temperature cycle test is carried out at low temperature for 30 minutes, room temperature for 10 to 15 minutes, high temperature for 30 minutes and room temperature again for 10 to 15 minutes. The low and high temperatures are those rated by JIS standards for resistors under testing conditions and the cycle is repeated five times. Following the test, the resistor is left at room temperature for more than one, but less than two hours. Any variation in the resistance values taken before and after the test must be within the specified limit.

Dielectric Withstanding Voltage
This is determined by increasing the test voltage applied across the resistor from OV to the rated voltage at the rate of approximately 100V per second. When the rated voltage is reached, the test voltage is maintained for 1 minute ±5 seconds, and then gradually lowered to approximately OV. The variation in resistance value before and after testing must be within the specified limit.

Vibration Durability
The resistor is subjected to a vibration cycle, in which vibration amplitude (peak-to-peak) is maintained at 1.5mm, and the vibration frequency is increased from 10Hz to 55Hz, then returned to 10Hz within 1 minute and held there for 2 hours on one of the resistor's three major axes. The test is then repeated on the two remaining axes. Total test time is six hours, and the variation in resistance value before and after testing must be within the specified limit.

Resistance to Soldering Heat
To ascertain the resistance to soldering heat, the entire resistor leads except for the 4±0.8mm area immediately next to the resistor, is dipped in the melted solder for 3±0.5 seconds, under a temperature of 270° ±5°C or 350°

±10°C depending on the rated voltage of the resistor. It is then removed and left at room temperature for the specified period. The variation in resistance value before and after dipping must be within the specified limit.

Current Noise (Complies with JIS C 5202 Appendix)

To measure this, a DC voltage, specified for the resistor under testing conditions, is applied across the resistor. The resulting noise output is then filtered through a band-pass filter having a center frequency of 1,000Hz and a –3dB bandwidth of 1,000Hz. The filtered measurement gives the noise voltage per V passing through one frequency decade band.

Resistance Value Codes

These are applicable to all resistors except the small metal film type:

Resistance value (Ω)	Resistance value code	Resistance value (Ω)	Resistance value code
0.1	0R1	1K	102
0.47	R47	4.7K	472
1	010	10K	103
4.7	4R7	47K	473
10	100	100K	104
47	470	470K	474
100	101	1M	105
470	471	4.7M	475

The following are applied to small metal metal-film resistors only:

Resistance value (Ω)	Resistance value code	Resistance value (Ω)	Resistance value code
5.1	5R10	562	5620
5.62	5R62	1K	1001
10	10R0	5.62K	5621
51	51R0	10K	1002
56.2	56R2	56.2K	5622
100	1000	100K	1003

Precautions When Selecting Replacement Resistors

Basically, there are three considerations to be taken into account when selecting replacement resistors. They are: 1) resistance value, 2) tolerance, and 3) power rating. The resistance value must be the same as that given on the Schematic Diagram. Tolerance limits must also be observed when replacing resistors for the equipment listed below, since equalization characteristics, amplifier gain, level balance, etc., may be affected if the right resistors are not selected.

* Equalizer feedback elements in head amplifiers
* Amplifier negative feedback resistors
* Attenuator or stereo tone control circuit resistors

For power ratings, the voltage across the resistor, current level and ambient temperature must all be considered. Also, important considerations to be taken into account in certain critical circuits are noise level and temperature coefficient size and shape of the resistor leads. Finally, the service cost must be considered.

Selection of RN, RS and RT Power Resistors

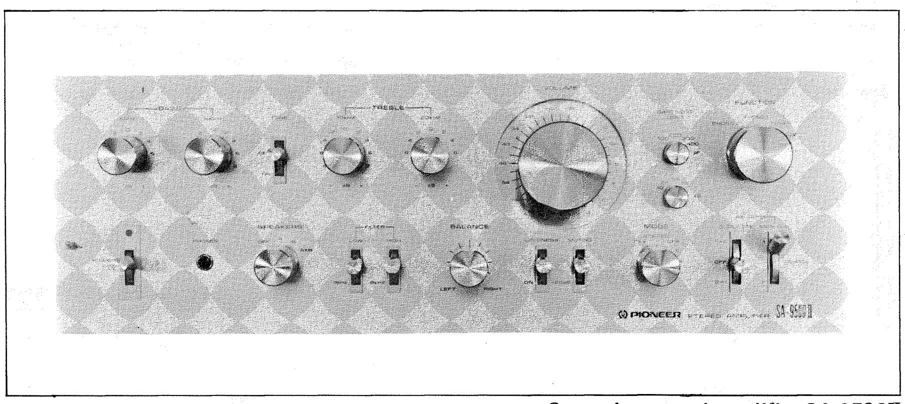
1. Recommended selection
   Resistance lower than 22 ohms: RN or RT (RN type is cheaper)
   Resistance more than 22 ohms: RS or RT (RT type is limited to 1 Kohm)
   Resistance more than 1 Kohm: RS
2. Insulation problems
   Power resistors type RN or RT are recommended in case other parts or metallic components which provide a possible break in insulation are close to the resistor.

NEW PRODUCTS

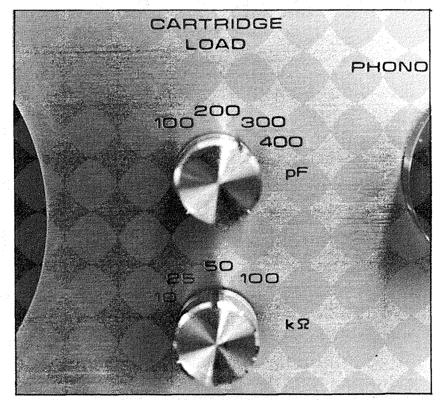
(1) SA-9500Ⅱ

This model supersedes the SA-9500, and has the same 80 watt-per-channel power output. However, other major specifications have been considerably improved and new functions have been added. One new feature of the SA-9500Ⅱ is cartridge load switching. This is achieved either by switching the load capacitance or the load resistance.

In this section we will discuss the importance of cartridge load switching and the variation in tone which accompanies it. We will also explain how the load switch is used.



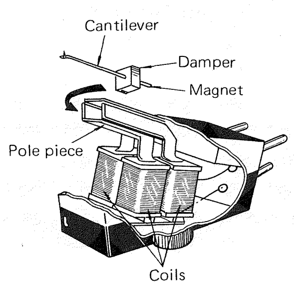
Stereo integrated amplifier SA-9500Ⅱ



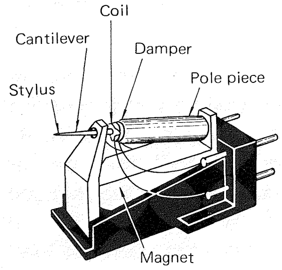
Cartridge load switch of SA-9500Ⅱ

1. Cartridge Characteristics

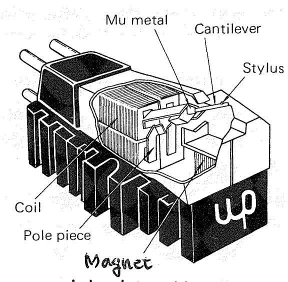
Before the importance of load switching can be appreciated, a thorough knowledge of the cartridge itself is required.
There are many types of cartridges available on the market today, but for hi-fi purposes they can be limited to moving magnet type (MM), moving coil type (MC) and induced magnet type (IM).



Moving magnet type



Moving coil type



Induced magnet type

Fig. 1 Types of cartridges

All of these cartridges have coils which transduce the information obtained from the record groove into electrical signals. But since transduction is done by coils, critical variations occur in the playback frequency characteristics as a result of load resistance or capacitance. Moving magnet and induced magnet type cartridges, in particular, have many-turned coils and therefore produce greater frequency characteristic variations due to their large inductance component.
Generally speaking, MM and IM cartridges also have a tendency to be affected by the load component. Moving coil cartridges, on the other hand, have a lower electrical impedance and are therefore not affected by load capacitance or resistance to the same degree. For this reason, we have chosen the moving magnet type cartridge to demonstrate the effect of load and the importance of load switching.

1) Mechanical Impedance Characteristics of a Cartridge

The basic structure of a typical MM and IM cartridge is shown in Fig. 4 and 5.

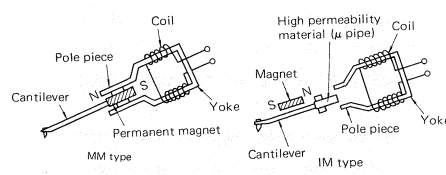


Fig. 2 The structure of a typical MM and IM cartridge

The equivalent vibration system circuit in a pick-up, including the tone arm, is represented by a combination of springs (mass neglected) and mass.
A typical equivalent circuit is shown in Fig. 3.

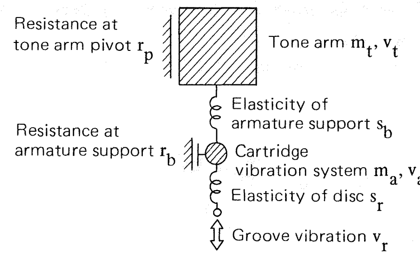


Fig. 3 A typical equivalent circuit

In this figure, spring S_r represents disc elasticity, mass M_a gives the equivalent mass of the cartridge vibration system formed by the stylus, cantilever, armature, etc., spring S_b and resistance R_b give armature support elasticity and loss, mass M_t gives the equivalent tone arm and cartridge mass, and resistance R_p gives the loss at the tonearm pivot.
For the purpose of this demonstration, we will focus our attention on the high frequency range only, since this is where the greatest degree of variation occurs.
At high frequencies, spring S_b vibrates easily, thereby producing low mechanical impedance, however, a greater force is required to vibrate the equivalent tonearm mass (M_t). The tonearm can, therefore, be neglected due to its very high mechanical impedance in this region. In which case, the vibration system can be simplified as shown in Fig. 4.

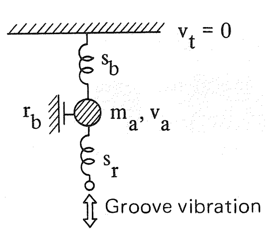


Fig. 4 Model of stereo cartridge vibration system in high frequency region

Assuming that the lower end of spring S_r in this figure is forced to vibrate at velocity V_r, and since the elasticity of the disc is considerably less flexible than that of the armature support (S_b) in the middle-frequency range, then mass M_a will track the groove vibration more accurately. In the very high frequency range, the mechanical impedance of spring S_r is considerably reduced, to the point where it absorbs the groove vibration. At this range, mass M_a cannot move, but at certain frequencies in between the middle and very high range, mass M_a and springs S_r and S_b start to resonate, forcing mass M_a to vibrate.
The following equation is used to determine resonant frequency f_h:

$$f_h = k\sqrt{\frac{S_b + S_r}{M_a}} \qquad \text{Step 1.}$$

(k is the proportional constant)

At a frequency lower than f_h, mass M_a and spring S_b start to resonate, thereby reducing the vibration velocity of M_a. At this frequency, the mechanical impedance of the system is at its minimum. The resonant frequency f_r is given as:

$$f_r = k\sqrt{\frac{S_b}{M_a}} \qquad \text{Step 2.}$$

(k is the proportional constant)

At a much lower frequency level, spring S_r and mass M_a vibrate together as one unit, and the mechanical impedance is reduced inversely proportional to the frequency. This is due to the mass (M_a) being extremely small. Typical mechanical impedance characteristics of a cartridge are shown in Fig. 5.

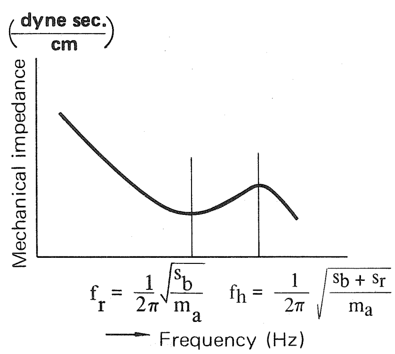


Fig. 5 Mechanical impedance characteristics of a pick-up in the high frequency range

An important thing to remember is, that the output voltage of the cartridge is proportional to the vibration velocity of armature V_a.
As a result, the frequency response of the cartridge peaks at a resonant frequency (f_h) where mass M_a vibrates the fastest, and bottoms out at a resonant frequency (f_r) where velocity is low. Typical cartridge response is shown in Fig. 6.

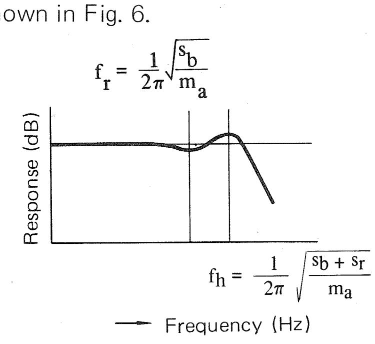


Fig. 6 Electrical impedance characteristics of a cartridge

2) Electrical Impedance Characteristics of a Cartridge

Now, let's consider the electrical impedance characteristics of an MM or IM cartridge. Due to their many-turned coils, both these types have, in general, larger inductance components. This in turn causes their electrical impedance characteristics to rise as the frequencies get higher, as shown in Fig. 7.

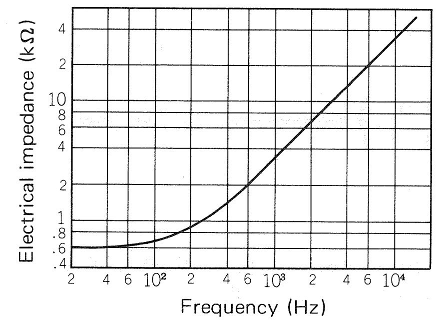


Fig. 7 Typical electrical impedance characteristics of a MM cartridge

The equivalent circuit of an MM cartridge with load connected is shown in Fig. 8.

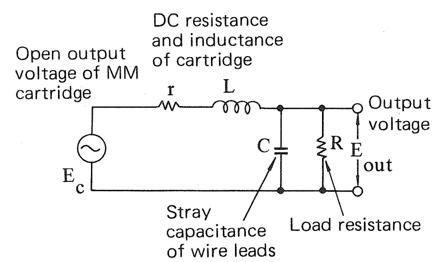


Fig. 8 Equivalent circuit of a MM cartridge with load connected

When the cartridge is connected to shielded cables and high resistance loads, its actual load impedance is equivalent to a parallel connection between lead wire stray capacitance and load resistance. The cartridge output to be supplied to the equalizer amplifier appears across the load resistor R.
As can be readily seen in Fig. 9, a series resonance circuit is formed by coil inductance L and stray capacitance of the shielded cable C. This circuit begins to resonate at a frequency which is determined by the following equation:

$$f \doteqdot \frac{1}{2\pi\sqrt{LC}} \qquad \text{Step 3.}$$

The voltage input to the equalizer amplifier is taken across capacitance C (which is the same as taking it across resistance R), thus, the cartridge output connected to the shielded cable indicates resonance, even when the cartridge has a flat open (no load) output frequency response. An example is shown in Fig. 9.

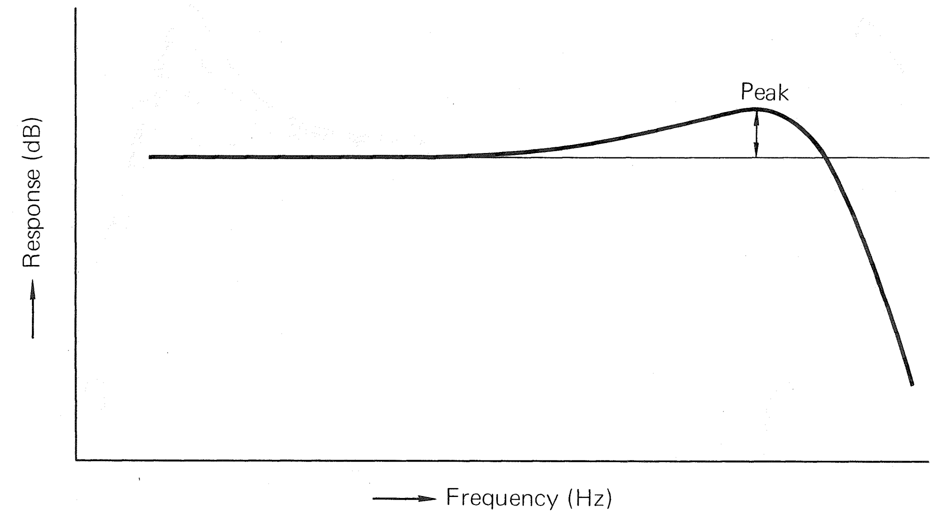


Fig. 9 Resonance frequency

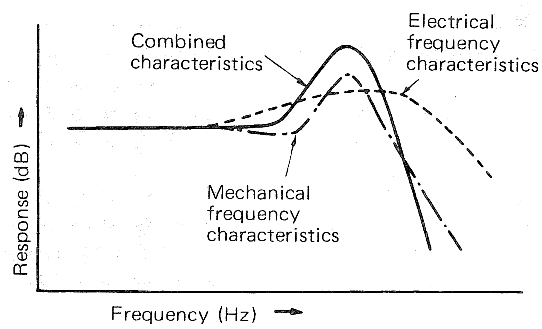


Fig. 10 Combined cartridge characteristics

Since the coil inductance differs from cartridge to cartridge, so too does the resonance frequency. (The resonance peak is determined by the inductance of the coil, the load resistance and the load capacitance.)

3) Frequency Characteristics of the Cartridge Output Voltage

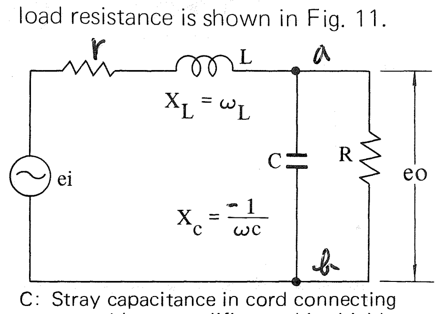
Although we discussed the mechanical and electrical characteristics of the cartridge separately, under actual operating conditions they are both combined. Fig. 10 shows the combined characteristics of the cartridge.

2. Variation in Characteristics due to Load

In actual operation, a resonance circuit is formed by the cartridge and the shielded cable which effects the output characteristics of the cartridge. Replacing the cartridge, or changing the turntable or amplifier, also affects cartridge performance.
So let us now examine what effect load resistance and load capacitance have on the performance characteristics of a cartridge.

1) Variation in Characteristics with Load Resistors

An equivalent circuit of a cartridge under actual operating conditions with load resistance is shown in Fig. 11.



C: Stray capacitance in cord connecting turntable to amplifier, and in shield wire inside the amplifier
R: Load impedance
L: Cartridge inductance
r: Cartridge DC resistance
e_0: Equalizer amplifier input voltage

Fig. 11 Equivalent cartridge circuit

Since the input voltage to the equalizer amplifier is given as eo, transmission characteristics eo/ei have to be obtained before any examination of frequency characteristic variations can be made.
Letting the reactance of the coil by represented as $X_L = \omega_L$ and capacitance as

$$Xc = -\frac{1}{\omega C},$$

then, impedance of section ab is stated as

$$\frac{jXcR}{R + jXc}$$

and the total impedance viewed from the cartridge side is stated as

$$r + jX_L + \frac{jXcR}{R + jXc}$$

Thus, from these formulas, the transmission characteristics of this circuit are determined as follows:

$$\frac{eo}{ei} = \frac{\frac{jXcR}{R + jXc}}{r + jX_L + \frac{jXcR}{R + jXc}}$$

$$= \frac{\frac{jXcR}{R + jXc}}{\frac{(r + jX_L)(R + jXc) + jXcR}{R + jXc}}$$

$$= \frac{jXcR}{rR + jXcr + jX_L R - X_L Xc + jXcR}$$

$$= \frac{XcR}{Xcr + X_L R + XcR + jX_L Xc - jrR}$$

$$= \frac{R}{r + \frac{X_L}{Xc}R + R + jX_L - \frac{jrR}{Xc}}$$

$$= \frac{R}{r + R + \frac{X_L}{Xc}R + j\left(\frac{X_L Xc - rR}{Xc}\right)}$$

Since $r \ll R$, $r \ll X_L$ and $r \ll Xc$, this equation can be approximated as:

$$\frac{eo}{ei} \doteqdot \frac{R}{R + \frac{X_L}{Xc}R + jX_L}$$

$$= \frac{R}{R\left(1 + \frac{\omega L}{\frac{-1}{\omega c}}\right) + j\omega L}$$

$$= \frac{R}{R\left(1 - \frac{\omega L}{\frac{1}{\omega C}}\right) + j\omega L}$$

Thus, the actual numeric value can be obtained by rationalizing the above equation as:

$$\frac{eo}{ei} = \frac{R}{\sqrt{R^2\left(1 - \frac{\omega L}{\frac{1}{\omega C}}\right)^2 + (\omega L)^2}}$$

Step 4.

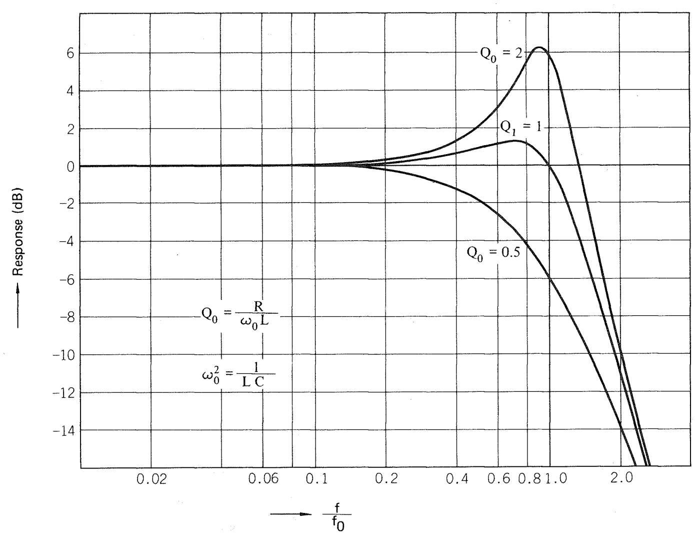


Fig. 12 Frequency characteristic variations by load capacitance

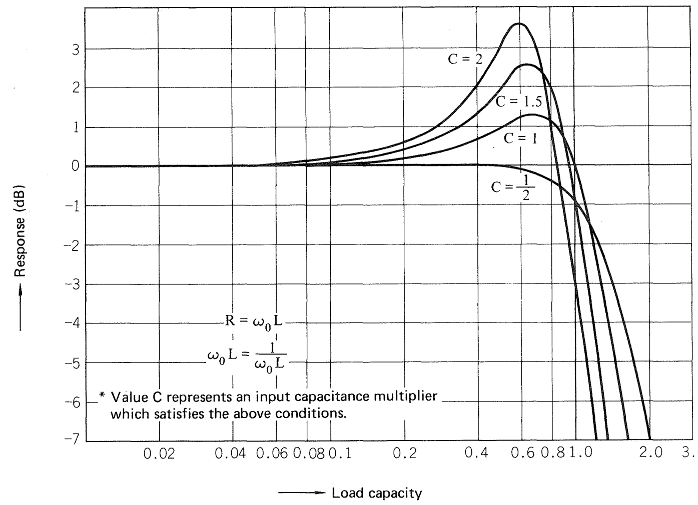


Fig. 13 Frequency characteristic variations by load resistance

Now, let's examine the transmission characteristics at resonance frequency fo.
Since

$$2\pi foL = \frac{1}{2\pi foC},$$

the equation

$$R\left(1 - \frac{\omega oL}{\frac{1}{\omega oC}}\right)$$

in step 4 becomes zero. Therefore, the equation can be simplified to:

$$\frac{eo}{ei} = \frac{R}{\omega L} = \frac{R}{2\pi foL}$$

(The equation

$$\frac{R}{2\pi foL}$$

is referred to as the Q in a resonance circuit.)
This simplified equation proves that the resonance peak varies with load resistor R.
Normally, frequency characteristics are expressed in decibels (dB). So to convert the equation in Step 4 to give a decibel value, the logarithm of the equation is multiplied by 20 as follows:

$$G = 20 \log \frac{R}{\sqrt{R^2\left(1 - \frac{\omega L}{\frac{1}{\omega C}}\right)^2 + (\omega L)^2}} \quad \text{(dB)}$$

Step.5.

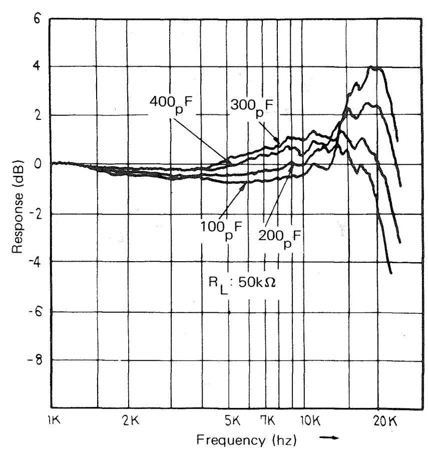
Fig. 12 plots the variation of the characteristics calculated for a desired frequency, using the equation in Step 5, for various load resistance (R) values.

2) Variation in Characteristics with Load Capacitance

Cartridge output frequency characteristics can similarly be obtained for various C values by using the same equation in Step 5.

3. Characteristic Variations of the SA-9500II

As we have already discussed, the frequency characteristics of a cartridge vary considerably under different load conditions. They also vary from model to model, so that, the optimum load condition is different for every cartridge. In fact, most manufacturers of high-quality cartridges state the optimum load condition and load capacitance for each individual product. So in order to allow the user to get the best response from any cartridge, the SA-9500II has the resistance and capacitance load switches which permit selection of the best load condition.
Fig. 14 and 15 give the variation of characteristics of the world renowned SHURE V-III cartridge for various load resistance and capacitance values.



Stray capacitance in cord connecting turntable to amplifier is 80pF.

Fig. 14 Cartridge load vs Frequency response Sample: SHURE V-III

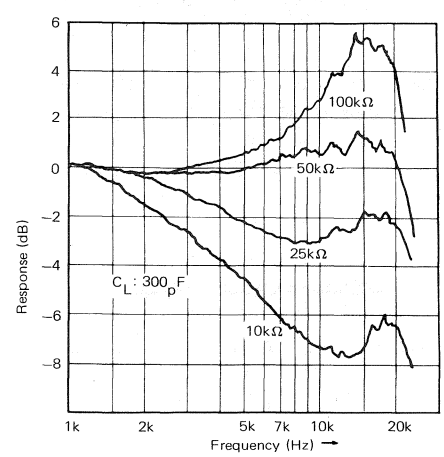
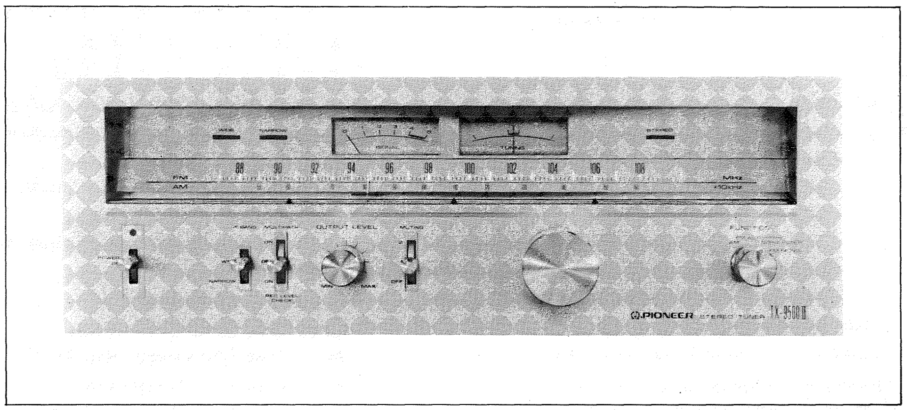


Fig. 15 Cartridge load vs Frequency response Sample: SHURE V-III

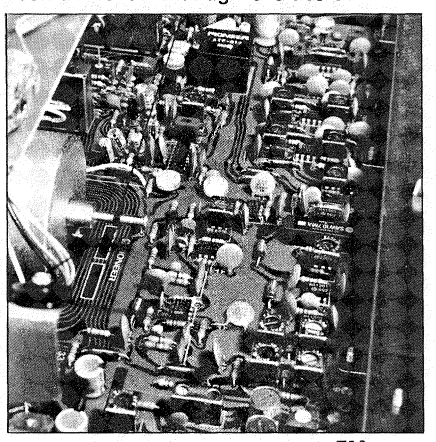
Reference

1. Capacitance values indicated on the front panel of the SA-9500II include the shielded cable capacitance in the internal PHONO input circuit.
2. Most of the current Pioneer turntables use low-capacitance output cords.
   The capacitance of each cord is less than 65pF.
3. When using a cartridge for which the load capacitance is specified, the CAPACITANCE LOAD switch should be set to the nearest corresponding value. If the manufacturer specifies 170pF, for example, the switch should be set at (170 – 65), which equals 100pF.

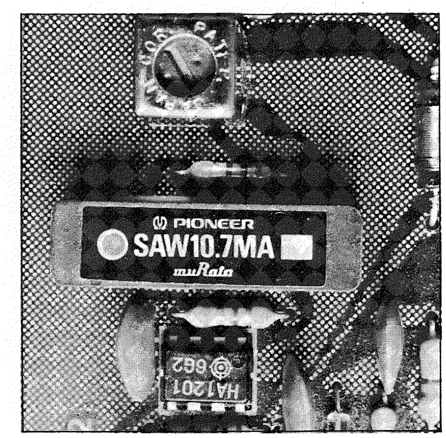


AM/FM stereo tuner TX-9500II

In appearance, the TX-9500II follows the basic external design of the TX-9500 to such an extent that many may contend that it is nothing but a minor model change. In fact, when you examine the new model closely, its difference from the TX-9500 becomes evident.
In the TX-9500II, considerable improvement in electrical characteristics and performance reliability has been achieved through the use of newly developed IC's and some other circuit elements. The unique, Pioneer-developed SAW filter is one of these. It is a new FM IF circuit element which completely supersedes conventional ceramic filters.
The matchlessly low 0.07% distortion factor (at 1kHz stereo, 75kHz deviation, 65dBf input) of the TX-9500II is the result mainly of the use of the SAW filter.



FM tuner



SAW filter

1. SAW filter

What is a SAW filter exactly? "SAW" is actually the abbreviation for surface acoustic wave. In this type of wave, energy is concentrated only on the surface of the acoustic body. This is akin to dropping a stone in a pool, and concentric waves then propagating themselves on the surface of the water (Fig. 1). The SAW filter is an application of this principle.
Surface acoustic waves may be generated in various ways. In the TX-9500II, the surface of a piezoelectric element is charged by an electric field; the subsequent piezoelectric effect produces the surface acoustic wave.

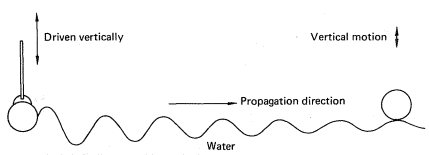


Fig. 1 Wave propagation

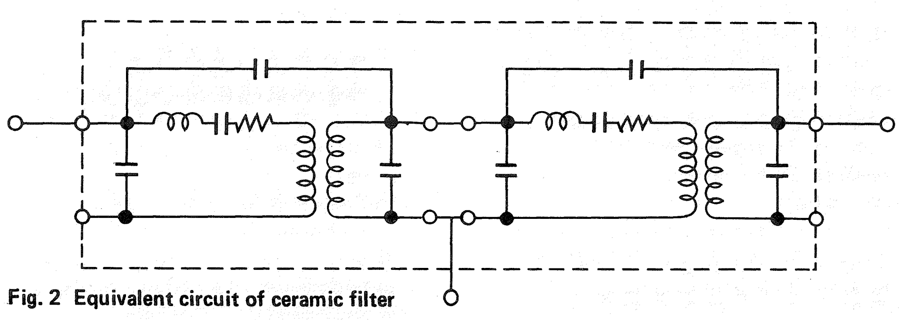


Fig. 2 Equivalent circuit of ceramic filter

2. Ceramic filter

In order to appreciate the full importance of Pioneer's SAW filter, let us first discuss the operation of conventional ceramic filters in brief.
The ceramic filter is a type of piezoelectric element using ceramics as the piezo body (main component: solid solution of $PbZrO_3$ zirconic acid lead, or $PbTiO_3$ titanic acid lead).
The resonance frequency of piezoelectric bodies of this type is determined by composition, shape and extent of sintering. It was the resonance effect which allowed ceramic filters to be used as bandpass filters.
Because of the resonance of a particular frequency, a ceramic filter can be represented by an equivalent circuit equal to the LC resonance circuit (Fig. 2).
Like those of the LC resonance circuits, the group delay characteristics of ceramic filters are restricted by their amplitude characteristics. This effectively limits the range of available flat delay region (Fig. 3).

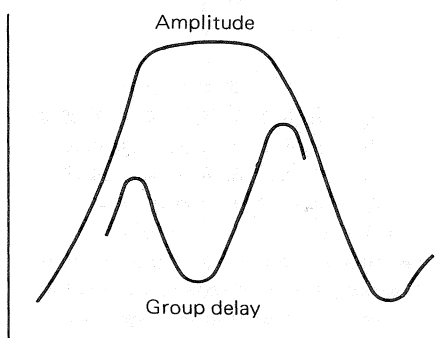


Fig. 3 Ceramic filter characteristics

And this is exactly where the ceramic filter's demerit is: an extended flat delay region affects the filter's selectivity.

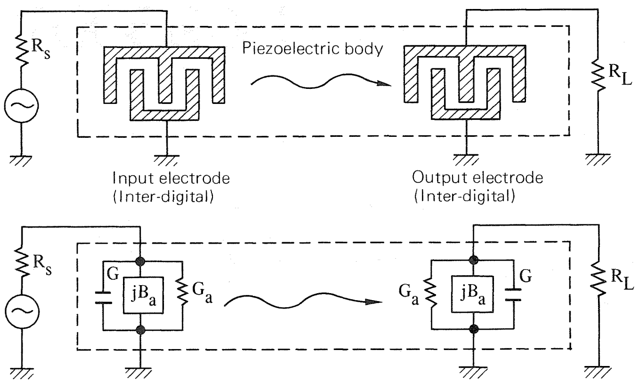


Fig. 4 SAW filter structure and equivalent circuit

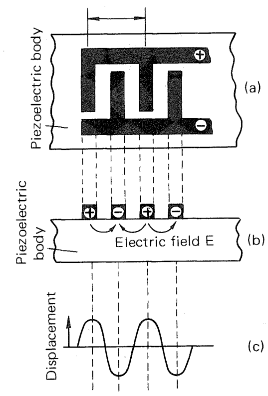


Fig. 5 Surface acoustic wave generation

3. Principle of SAW filter

The operation of a SAW filter is quite different from that of conventional ceramic filters. As was mentioned earlier, the SAW filter transfers signals by utilizing the surface acoustic wave induced on a piezoelectric surface.

Where zircon or titanic acid lead is widely used in ceramic filters, a surface acoustic wave is produced on a specially molded electrode that is precisely evaporated and photo-etched with the use of IC production techniques. It is this special electrode which has greatly contributed to the practical production of SAW filters. Figure 4 illustrates the overall structure and equivalent circuit of a SAW filter.

When the electrode is charged by voltage, an electric field is produced on the piezoelectric body, as shown in Fig. 5 (b), and displacement takes place on the surface, as shown in Fig. 5 (c). This displacement is repeated until surface acoustic wave is produced. The wave is propagated in two directions (to the right and to the left, as shown in the figure).

The other electrode on the piezoelectric body (right-hand side, Fig. 4) receives the surface acoustic wave. This results in displacement and electric charge; the charge is then transduced into the desired signal.

The displacement takes the largest amplitude to produce the greatest surface acoustic wave; this is so when the half-wavelength of the excitation signal is exactly equal to the electrode distance h, as shown in Fig. 6. The signal frequency, on the other hand, is determined by the number and shape of electrodes, and delay time depends on the distance of the electrodes.

If a full wavelength of signal is equal to the electrode distance h, the direction of the piezoelectric displacement becomes opposite to the direction of surface acoustic wave vibration; theoretically, no surface acoustic wave will be produced. These functions are what give the SAW filter its filtering ability. The amplitude characteristics of the SAW filter are shown in Fig. 7.

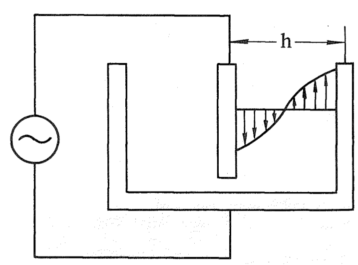


Fig. 6 Distortion given to piezoelectric element

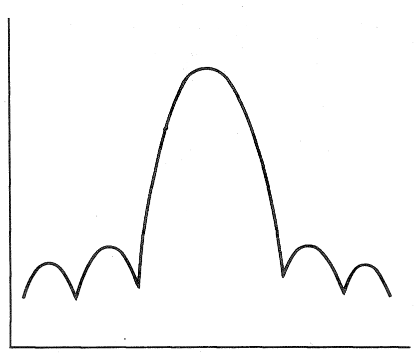


Fig. 7 Amplitude characteristics of SAW filter

4. Features of SAW filter

The SAW filter operates on a principle different from that of ceramic filters to provide the following outstanding features:

1) Excellent group delay characteristics are inherent to the SAW filter, and these are critical to the distortion characteristics of a tuner. In theory, the amplitude characteristics of conventional ceramic filters or LC block filters are closely correlated with their phase characteristics. If one is fixed, the others are automatically fixed, too. In a SAW filter, this is not the case. The phase characteristics can be changed at will without affecting amplitude characteristics—by simply changing the distance between the transducers.
2) Compared with ceramic or LC block filters in terms of resonance, the non-resonant SAW filter is scarcely affected by any variation in external impedance.
3) The LC block filter requires complicated adjustment. Like ceramic filters, however, the SAW filter requires no adjustment. Despite its high performance, the SAW filter does not entail any unnecessary increase in production cost. The comparative characteristics of all these filters are shown in the following figures.

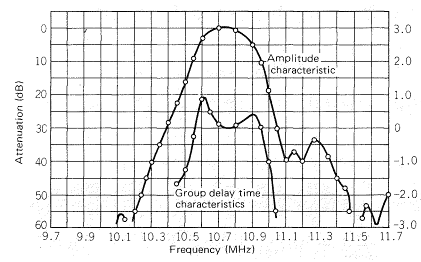


Fig. 8-1 Ceramic filter

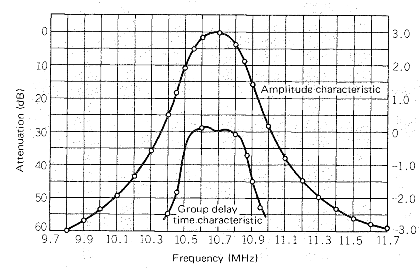


Fig. 8-2 4-pole LC block filter

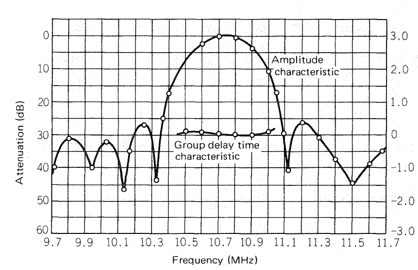


Fig. 8-3 SAW filter (SAW10.7MAI)

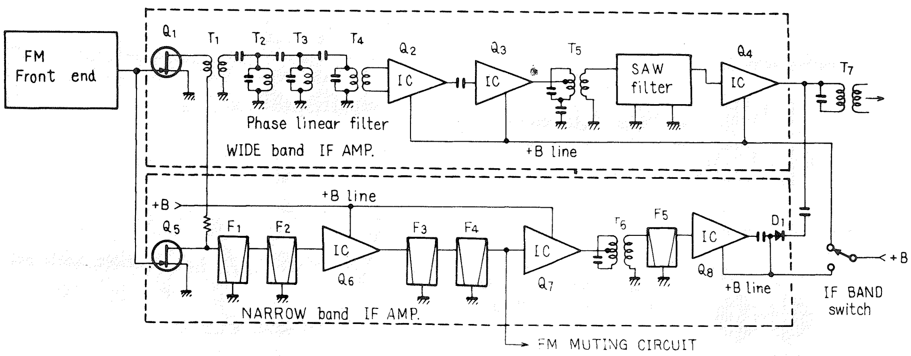


Fig. 9 Circuit of FM IF amplifier

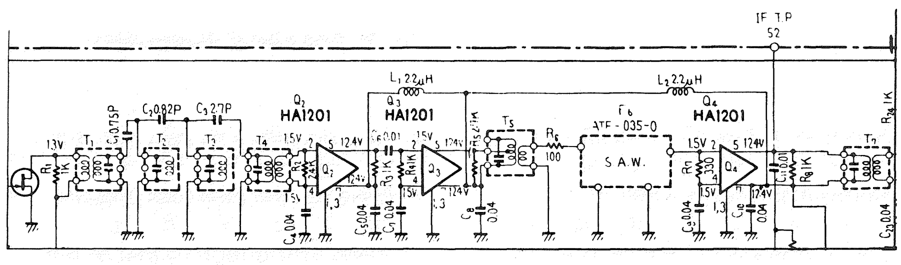


Fig 10 Part of FM IF circuit

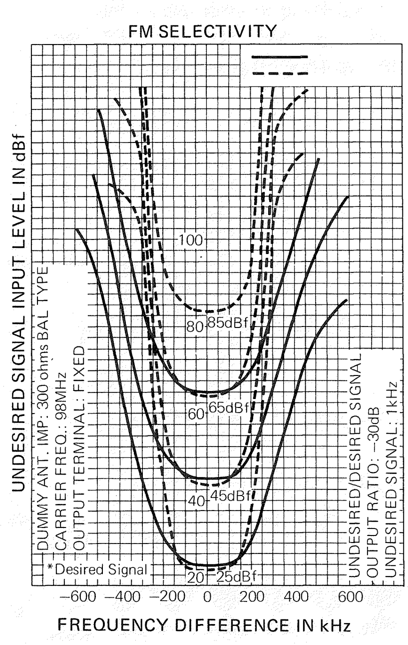
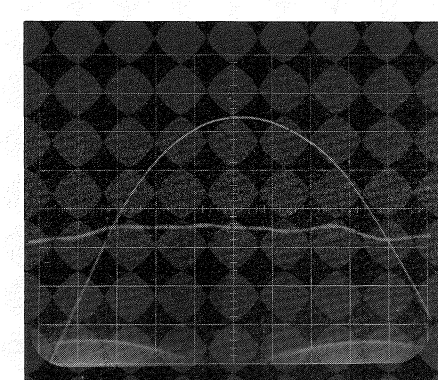


Fig. 11 Amplitude characteristics of FM IF amplifier

5. Actual application of SAW filters

Although SAW filters are distinguished by their excellent group delay characteristics, they somewhat lose out in selectivity and a considerable side lobe is inherent in the out-band. In order to meet the requirements expected of a tuner filter, SAW filters must therefore be coupled with the other filters which have sharp skirt characteristics.
In the TX-9500II, for instance, the SAW filter is coupled with a 4-pole LC block filter. Part of the IF circuit is shown in Fig. 10.
The overall amplitude characteristics of the FM IF amplifier are shown in Fig. 11. Note that the broken lines indicate narrow-band amplitude characteristics.
To assure a wide-band IF circuit in an FM tuner, a ceramic filter is coupled with an LC resonance circuit, or with a lumped constant filter. In the conventional FM IF amplifier, this combination has proved to have certain contradictions with regard to IF bandwidth, group delay and distortion characteristics. SAW filters solved this problem. They dramatically improved the distortion factor and signal-to-noise ratio of really advanced FM tuners.
As for the lumped constant filter, it involves far too many adjustments and requires the greatest care in aligning. SAW filters likewise solved this problem.
In sum, SAW filters resulted in a great improvement in the performance and production cost of the TX-9500II, giving it enough value to justify its reputation as a product of the highest quality.



Amplitude characteristics and delay characteristics

Frequency Modulation (FM) and IF Characteristics of the FM Tuner

FM tuner IF characteristics are, on the whole, determined by the amplitude and group time delay factors—both of which are closely related to the distortion characteristics of the tuner. In particular, these are very important in grading FM tuners for minimized distortion. When viewing FM tuners in terms of distortion characteristics, the following additional points must be considered.

1. Frequency Modulation (FM) and the sidebands

With FM modulation, the carrier amplitude is held constant while the carrier frequency is shifted (or modulated) in proportion to the variations in the input (or modulation) signal amplitude. Thus, as the amplitude of the modulation signal increases, carrier frequency deviation also increases; on the other hand, the rate of carrier deviation will be directly related to the frequency of the modulation signal.

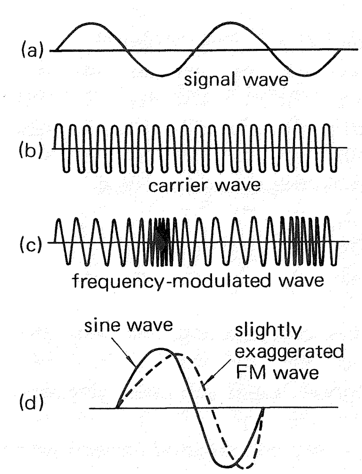
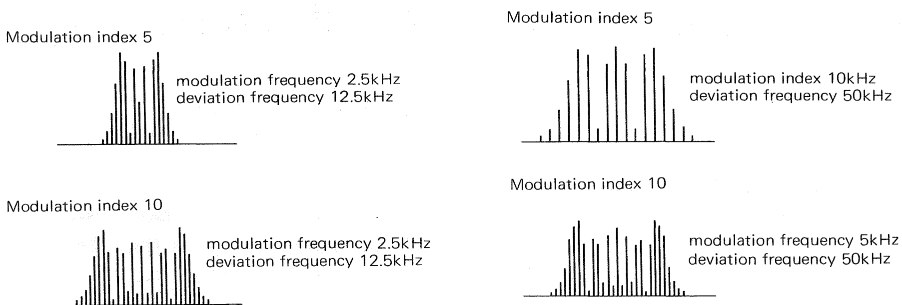


Fig. 12 FM modulation signal

In Fig. 12, carrier and sideband characteristics are represented in graphic form with signal (a) representing the audio modulation signal, signal (b) representing the unmodulated carrier, and signal (c) representing the composite FM-modulated signal.
Signal (d) in the figure compared the FM signal (one cycle) with one cycle of a typical sine wave.



(a) Bandwidth expanded with increased deviation frequency (modulation frequency held constant).

(b) Bandwidth changed slightly with modulation frequency, while deviation frequency is constant.

Fig. 13 FM sidebands

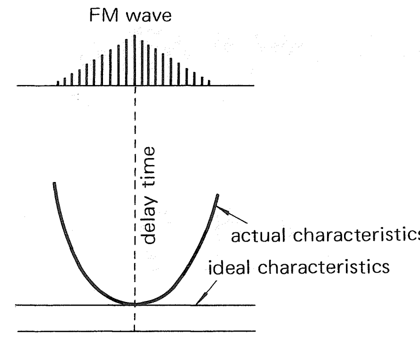


Fig. 15 Group delay characteristics

Since a distorted sine wave can be simulated by a composite group of many sine waves of various frequencies, then the frequency-modulated wave can be thought of as consisting of many sine waves, with components other than the carrier (center) frequency considered as sidebands. Fig. 13 illustrates various examples of the frequency spectrum of the FM wave. Distinctly different from an AM wave, these FM waves include many sidebands at frequencies higher and lower than the carrier.

The modulation index is a ratio of the deviation frequency to the modulation frequency, with the maximum width of the sidebands given roughly as (max. deviation frequency + max. modulation frequency) x 2. For monaural broadcasting, the sideband width is given as (75KHz + 15KHz) x 2 = 180KHz, within this bandwidth, 99% of sideband energy is contained. The maximum deviation frequency for 100% modulation in FM broadcasting is 75KHz, with the maximum modulation frequency specified as 15KHz.

In stereo broadcasting, the modulated wave is composed of the main signal, sub-signals, upper and lower sidebands and the pilot signal. These elements form a very complicated pattern which cannot be easily represented in a simplified drawing; however, it can be stated that the bandwidth containing 99% of the sideband energy is 198KHz at 15KHz modulation, or ±9KHz wider than required for monaural broadcasting.

2. Bandwidth required for tuner IF stage

Very wide IF characteristics are required for FM tuners because they must receive FM signals and reproduce the modulation signal with minimum distortion. Although the quality of the demodulated signal can be improved by using a wider IF bandwidth, it is very likely that the quality of the signal will be affected by communication noise and adjacent broadcasting signals. Thus, it's necessary to set down minimum standards for the IF bandwidth (see Fig. 14).

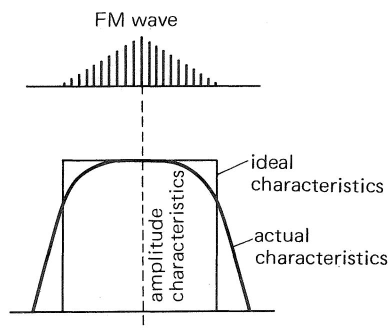


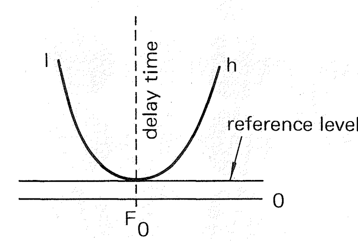
Fig. 14 Amplitude characteristics

In conventional FM tuners, ceramic filters are very popular because of their rather good amplitude characteristics (a factor which enhances selectivity), in addition to their high productivity. In stereo broadcasting, however, the IF band characteristics of 198KHz must be satisfied for proper reproduction.

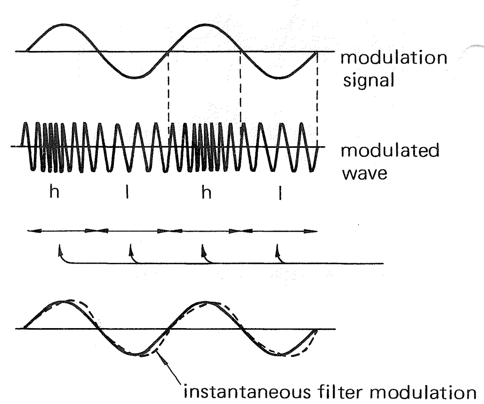
3. Group delay characteristics

The delay factor is an essential consideration when representing the IF characteristics. As mentioned earlier, an FM signal contains many sidebands, each of which must be considered (in addition to the center frequency) when discussing delay characteristics. This overall view is known as the group delay characteristics, and is illustrated in the following figure (Fig. 15), example of group delay characteristics.

If the group delay characteristics are flat irrespective of the signal frequencies, the tuner can produce output signals with an identical sideband distribution to that of the input signal. However, if the group delay is as shown in Fig. 16, it will result in different delay times for the center and sideband frequencies, thus resulting in changes in the momentary distribution of sidebands, with resulting distortion.



(a) Group delay characteristics



(b) Generation of distortion of filter

Fig. 16 Demodulated signal with distortion

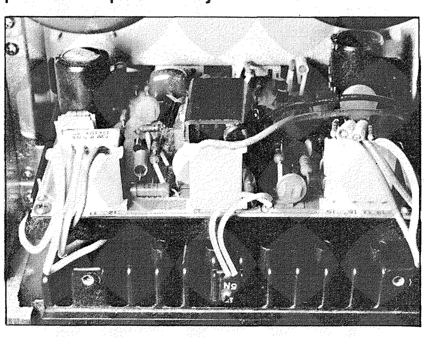
ONE-POINT SERVICING TECHNIQUES(1)

POWER AMPLIFIER ADJUSTMENT

From our experience and analysis of the service reports we have received, power amplifier malfunctions, such as power transistor breakdown, account for the major share of all services provided. This has happened time and again, regardless of the area of service or the model.

After replacing any of the parts of a power amplifier, the circuit must be checked in order to assure that the amplifier is correctly adjusted. Faulty adjustment not only causes poor tone output—it also induces additional malfunctions.

In this chapter, we shall deal with power amplifier adjustment.



Ordinarily, a power amplifier (single-channel) requires two adjustments: neutral potential adjustment and idle current adjustment. (Note that these adjustments may be omitted from some models).

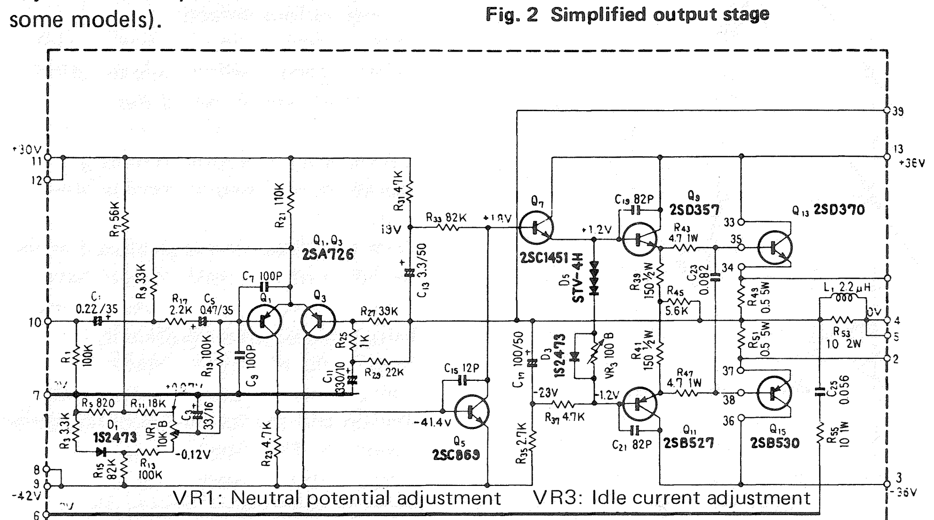


Fig. 1 Power amplifier AWH-027 (single-channel)

Taking power amplifier AWH-027 in the QX-949A as an example, faulty adjustment of neutral or idle current will manifest itself in terms of the resultant deterioration of tone and other defects.

1. Incorrect neutral potential adjustment

It is quite clear that the normal value of the neutral potential (terminals 4 and 5 in Fig. 1) is zero (0V).

Faulty adjustment of VR1 will result in the deviation of this potential from zero. When it is incorrectly adjusted, a DC current is supplied directly to the speaker. If the speaker is small, the voice coil may burn out. And even if it should be comparatively large, the cone paper would be biased by the DC current, resulting in distorted sound output or lowered maximum power input.

Also, if the voltage deviation exceeds the limit, the protection circuit will operate, and no sound output will be obtained from the speaker. Thus, to accurately assure the normal functioning of a power amplifier, your checks should begin with the neutral potential. In the amplifier, two power transistors work complementarily, as shown in their input/output relation in Fig. 3.

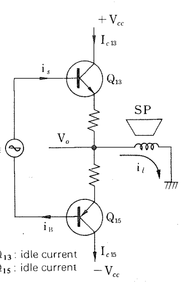


Fig. 2 Simplified output stage

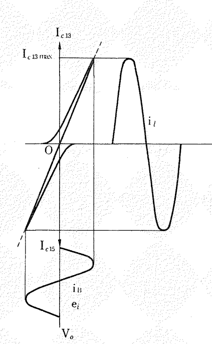


Fig. 3 Normal neutral potential

The Ic_{13} max. and Ic_{15} max. are determined by the collector supply voltages +Vcc and −Vcc, the circuit constants and load. The collector current must not exceed this limit.

In this circuit, |+Vcc|=|−Vcc|, and Ic_{13} max. = Ic_{15} max. The complementary operation of the circuit is thus guaranteed, and the output signal waveform will be correctly symmetrical in the positive and negative regions as long as the neutral potential is normal or zero V. When the rated maximum output level exceeds this limit, the signal waveform will clip simultaneously in the positive and negative regions.

If the neutral potential deviates from zero to positive or negative, the complementary operation of the circuit will be improper. The input/output relation is then changed, as shown in Fig. 4 or Fig. 5.

When the neutral potential is shifted to positive, clipping of signal waveform will occur in the positive region earlier than the clipping in the negative region. This will lower the available maximum power output. Similarly, a neutral potential shifted to negative will cause clipping in the negative region earlier than that in the positive region. This will lower the available maximum power output.

Fig. 6 shows typical output/distortion characteristics. As shown in Figs. 4 and 5, the shifted neutral potential will accelerate the start of signal clipping. Thus, the distortion factor steeply increases before the normal maximum power output is reached.

In the middle or small power output region, the unbalancing of Q_{13} and Q_{15} linearities will slightly increase the distortion factor.

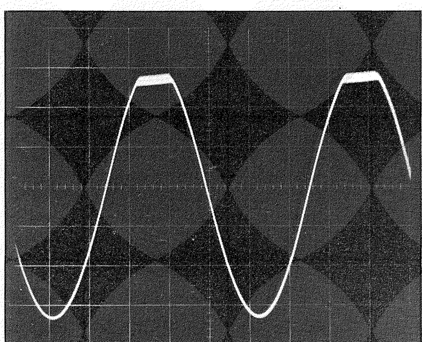


Photo 1

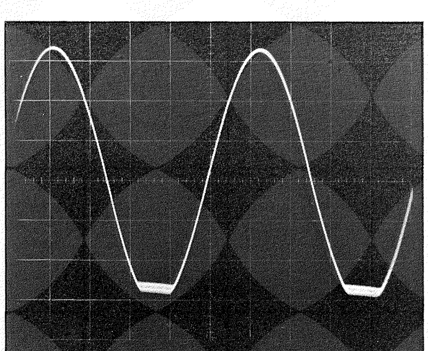


Photo 2

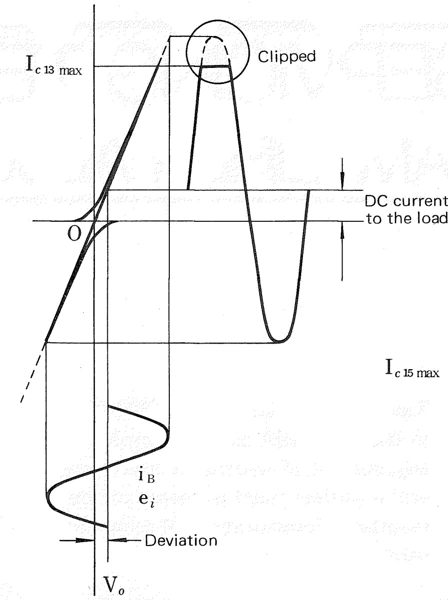


Fig. 4 Positive deviation of neutral potential

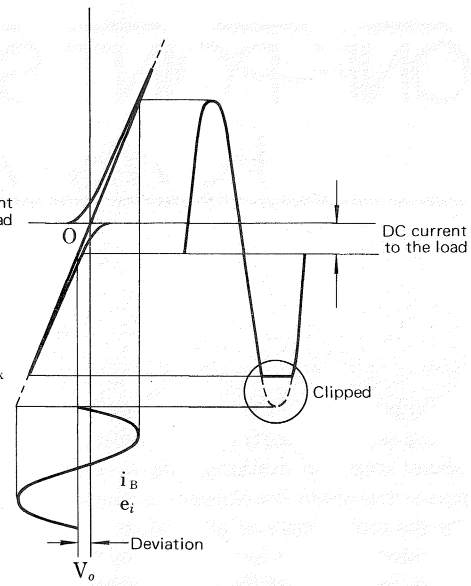


Fig. 5 Negative deviation of neutral potential

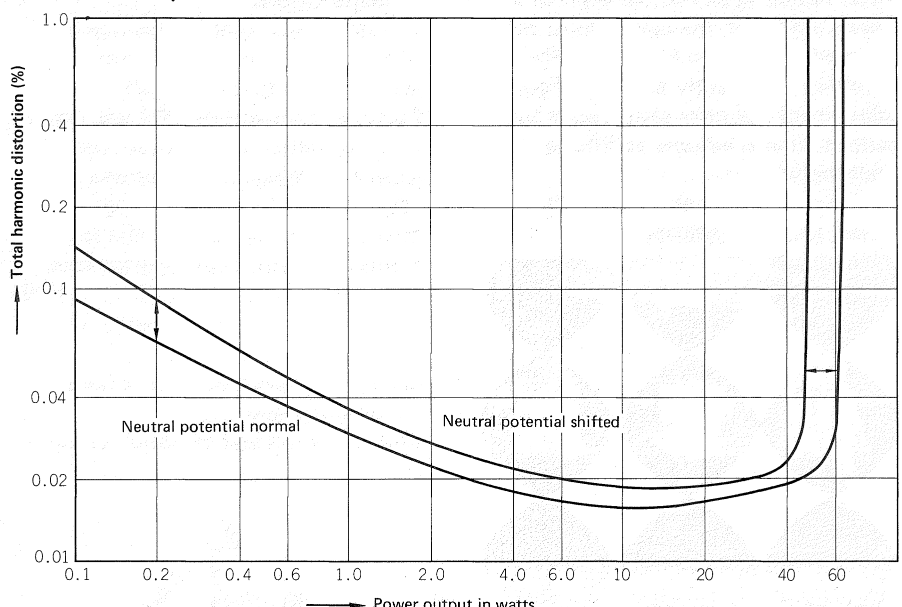


Fig. 6 Typical output/distortion characteristics

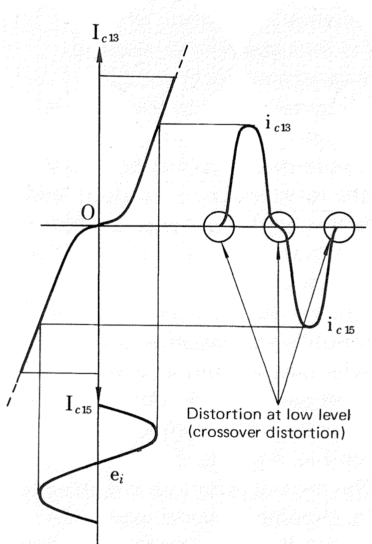


Fig. 7

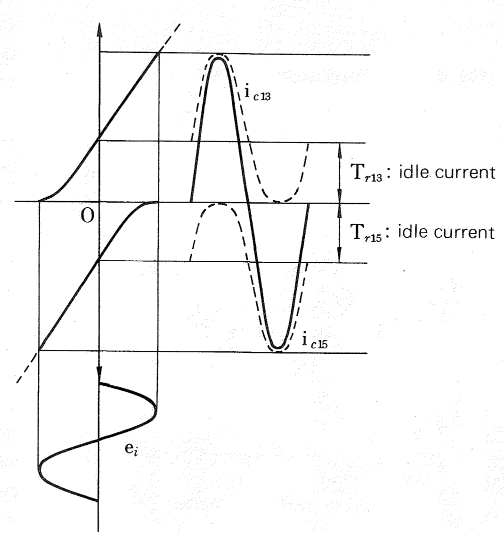


Fig. 8

2. Incorrect idle current adjustment

Incorrect idle current adjustment also induces various defects.

Let us examine the case in which idle current is too small. In this situation, the circuit cannot cancel the non-linearity of the Ic from rising. This non-linearity is amplified during operation, resulting in considerable distortion.

Since this distortion is produced at the boundary of two collector currents, it is called crossover distortion. This distortion becomes significant, particularly when the signal level is small. Fig. 7 plots the input/output relation and the formation of crossover distortion. The distortion can be corrected by increasing the idle currents. When the currents are adequately adjusted, normal operation, as shown in Fig. 3, is resumed.

Signal waveform including distortion caused by clipping is shown in Photo 3; output/distortion characteristics are shown in Fig. 10.

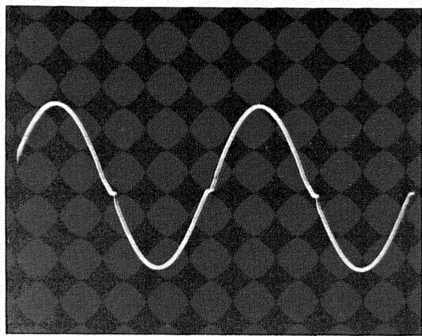


Photo 3 Crossover distortion

Now, let us examine the case in which idle current is too large. Let's turn to Fig. 8. The excessive idle current increases the collector currents close to the Ic max. It lowers the available maximum power output, compared to that at normal operation.
The continued flow of a large idling current increases heat generation in the transistors, resulting in allowable collector dissipation. This greatly lowers the durability of power transistors against large power output.

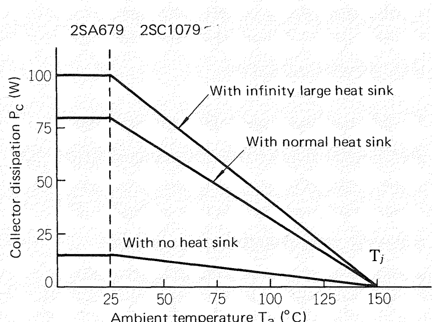


Fig. 9 Ambient temperature and maximum collector dissipation

In the case of QX-949A, the protection circuit operates depending on the overcurrent in the emitter resistors of the output transistors. Thus, the large idle current very likely to drive the protection circuit becomes too sensitive, and malfunction will result at high power outputs.
With regard to the distortion factor, the distortion may be slightly improved at medium or small power output, because the output transistors operate in a region where the linearity is good.
Fig. 10 plots the output/distortion characteristics of a power amplifier with increased idle current.
Since lack of idle current or excessive idle current leads to deteriorated or unstable amplifier performance, the idle current should be correctly set as outlined in the service manual of the respective models.

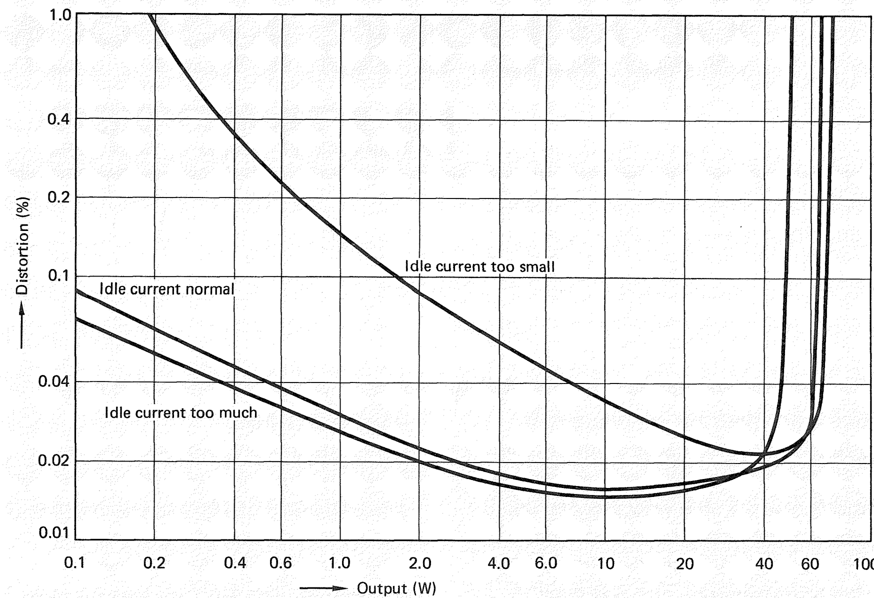


Fig. 10 Output/distortion characteristics

3. Miscellaneous: in case a quasi-complementary power amplifier is involved

A quasi-complementary power amplifier normally has a DC blocking capacitor in its output circuit; this protects the speakers from being affected by DC current.
The capacitor also protects the amplifier's operation from instability caused by faulty adjustment. However, it cannot compensate for any deterioration of electrical characteristics and other malfunctions related to this. Increased distortion, lowered maximum power output, heat generation from power transistors, and increased risk in transistor breakdown are malfunctions common to all amplifiers, including the quasi-complementary power amplifier.
The neutral potential, in this case, must be adjusted to exactly 1/2 of the supplied voltage.
The schematic diagram of a typical quarsi-complementary power amplifier is shown in Fig. 11.

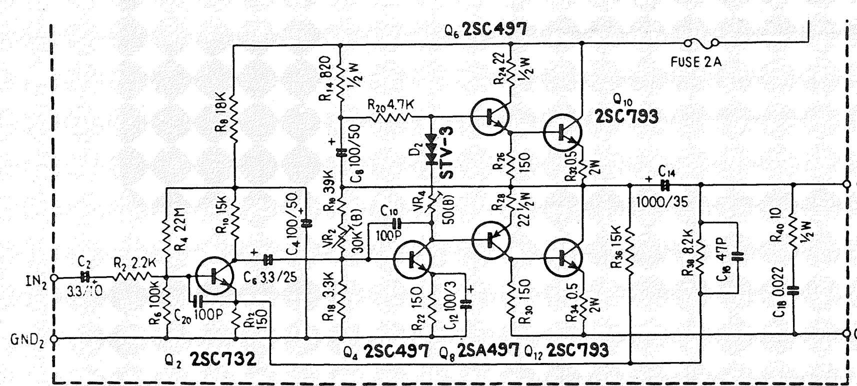


Fig. 11 Quasi-complementary power amplifier

MEASURING INSTRUMENTS (1)
MULTIMETERS—1

The multimeters are the most frequently used instrument for servicing hi-fi equipment. As its name implies, the multimetes have a diverse range of functions. It is also very easy to use. Electrical servicing normally begins with a voltage and conduction check using a multimeter, and a skilled service technician can usually complete the task with only a multimeter and a soldering iron.
The following are the functions, types and applications of multimeters in common everyday service use.

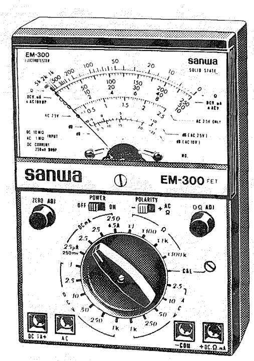
1. Multimeter Function
The multimeter is designed to carry out the basic essential functions for servicing such equipment as radio receivers, TV sets and stereo systems. These functions include:
1) DC voltage measurement
2) AC voltage measurement
3) DC current measurement
4) Resistance measurement (conduction check)

Some multimeters also have additional scales for measuring inductance (coil) and capacitance (condenser). However, these measurements are rarely required in routine servicing.

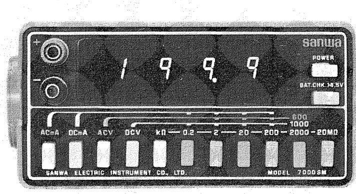
2. Multimeter Classifications
In broad terms, multimeters fall into the following three categories:
1) Conventional type
2) Electronic type
3) Digital type

The ordinary type is a combination of a meter indicator, resistors and diodes which are selectively switched to perform specific functions, such as the measurement of voltage, current, resistance and range. More recent types are improved in their accuracy and sensitivity and are sufficient for practical use. In fact, the conventional type multimeter is the most popular type due to its simple handling. Compared with other types, the conventional type has a lower internal resistance. Therefore, it is recommendable to use other types or the mV meter to accurately measure high impedance circuits and high resistance values.
An electronic multimeter functions basically the same way as the ordinary type, the only difference being that it has an internal amplifier, which is normally an FET (field-effect transistor). The FET provides a very high input impedance, which is capable of measuring minute voltage or very high resistance. This makes it a highly reliable type of multimeter for the measurement of high resistance or high impedance circuits.
The only disadvantage of the electronic multimeter is that zero-adjustment of the meter indicator is necessary prior to taking each measurement. Some manufacturers offer adaptors which enable electronic multimeters to check the current gain of transistors.

1) Conventional type



2) Electronic type



3) Digital type

The digital multimeter differs from both previous types in that it operates in the digital mode. It is composed of a range selector circuit, operation circuit and a display circuit. The measured value is directly indicated by a numeric tube or LED (Light Emitting Diode) display. However, some technicians still prefer analog indication; it's purely a matter of taste.
Personal tastes apart, digital multimeters provide a very high degree of accuracy, sensitivity and input impedance. Some types even have automatic range switching. Cost-wise, these are very expensive, up to ten times the price of an ordinary multimeter. Nevertheless, they are extremely versatile.

3. Measurement Precautions
Although multimeters are designed to take practically every kind of routine measurement, covering voltage, DC current and resistance, certain precautions are necessary to assure accurate usage. In this issue, we will discuss the precautions as they apply to the ordinary type multimeter since it is the one that is used the most.
The composition of an ordinary multimeter and the basic circuits for measuring voltage, current and resistance are illustrated in Figs. 1 and 2. (In an electronic multimeter, a DC amplifier is included to ensure high input impedance and sensitivity.)
1) DC Voltage Measurement
On selection of a DC volt range, a fixed resistor (multiplier) is connected in series to the meter indicator. The measurement range (voltage range) is switched by changing the series resistance value. Since the internal resistance of the meter indicator is much lower than that of the multiplier, the input impedance of the multimeter is determined by the multiplier used. Which means that a higher voltage range produces a higher input resistance. For voltage measurement, test prongs are connected in parallel to the circuit

which is going to be measured, making sure that the correct polarity is observed. A certain degree of error is inevitable, depending on the internal resistance of the circuit under test. Assuming that the multimeter has an internal resistance of 5kΩ/V, the resistance will be 1.5MΩ at the 300V DC range. A circuit equivalent to this, with multimeter connected, is shown in Fig. 3.
In this case, the voltage indicated by the multimeter will be calculated as follows:

$$E' = 300 \times \frac{\frac{200 \times 500}{200 + 1500}}{\frac{200 \times 1500}{200 + 1500}} + 100 = 191.5 \text{ (V)}$$

The true voltage, without the multimeter connected, is 200V ($E = 300 \times \frac{200}{200 + 100} = 200$), thus, the voltage indicated by the multiplier (191.5V) shows an error of

$$4.25\% \left(\frac{200 - 191.5}{200} \times 100 = \frac{8.5}{200} \times 100\right).$$

When measuring the voltage in a vacuum tube or other high resistance circuit, the load effect of the multimeter impedance must be considered. Preferably, a multimeter having an internal resistance per volt higher than 20kΩ should be used.

2) DC Current Measurement

For this type of measurement, the multimeter must be connected in series to the test circuit, observing the correct polarity between the test prongs and the circuit (current source). The internal resistance of the multimeter will show a certain deviation from the measured value. The true current value and meter reading are shown in Fig. 4.

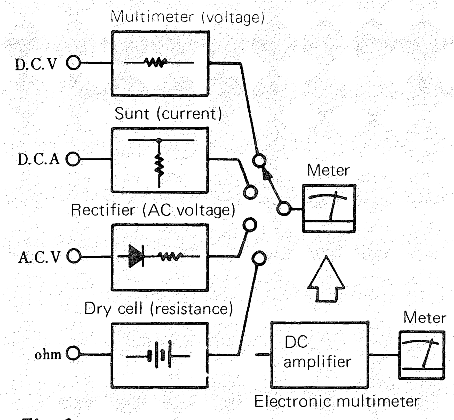


Fig. 1

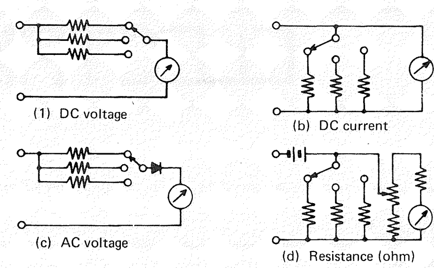
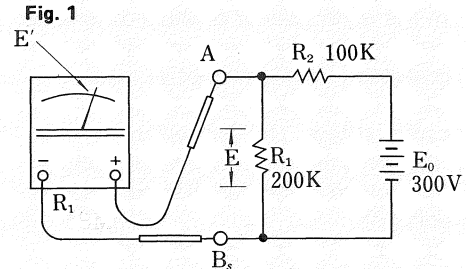
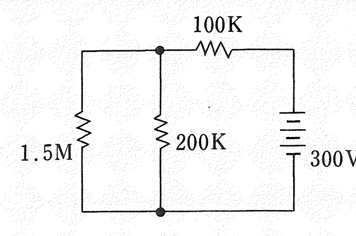


Fig. 2



(A)



(B)
Circuit with multimeter connected

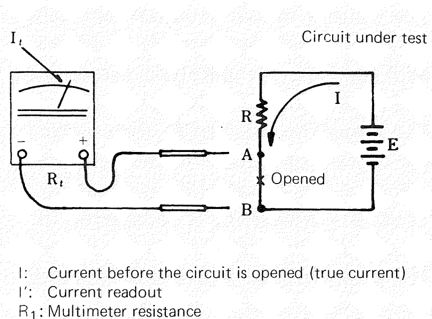
E: Voltage when multimeter is NOT connected (True voltage)
E': Voltage indicated by multimeter
R_1: Internal resistance of multimeter
Fig. 3

3) AC Voltage Measurement

Meter polarity does not apply to AC voltage measurements, and the load effect of the multimeter impedance equals that of the DC measurement. Ordinarily, the input resistance of the multimeter during AC measurement is lower than that for DC voltage measurement. Therefore, a higher voltage range will result in greater accuracy. However, if the voltage readout is too low, at the far left to the scale, readout accuracy will be lost. So for greater accuracy, it is better to select an AC volt range that will produce the largest pointer swing.
As the multimeter is graduated (AC scale) to indicate effective sine wave values (average value, rms), considerable error will result if it is used to measure pulse or other distorted waveforms besides sine waves.
Normally, in vacuum tube or transistor circuits, the AC signal voltage is superimposed with certain DC voltage components such as bias, anode, collector voltage, etc. The DC component effect can be cut by connecting a capacitor in series to the test prong. But before doing so, be sure to check the impedance of the circuit under test and the signal frequency so that the correct capacitance can be determined.
Also, select the lowest capacitance possible, since an unnecessarily large capacitance will induce noise or hum in the test circuit.
The AC volt circuit has certain limitations in its frequency characteristics. Normally, an acceptable level of accuracy is assured for a frequency range of 50Hz to 30kHz for the popular type, or 30Hz to 100kHz in the case of a specific type. Accurate measurements beyond these frequencies are out of the range of a multimeter. In which case, a professional AC mV meter or CRT oscilloscope is required.

4) Miscellaneous

In addition to the previously described measuring functions, the multimeter can also be used to check resistance values (ohm range). No particular precautions are necessary in this case, however, an ohm range that gives the most adequate readout is desirable. On an average, component testing using the ohm range for checking such things as capacitor insulation and diode conduction, is conducted more frequently than pure resistance measuring.
Details on how the ohm range can be used to test component quality will be given in the next issue.



I: Current before the circuit is opened (true current)
I': Current readout
R_1: Multimeter resistance
D: Error (%)

$I = \frac{R + R_t}{R} I_t$ $D = \frac{R}{R_t + R} \times 100$

Fig. 4 DC current measurement

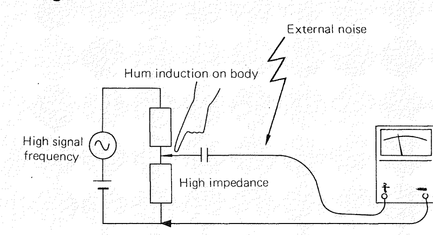


Fig. 5 When circuit impedance is too high,

ELECTRICITY: BASIC THEORIES

(1) OHM'S LAW

1. Voltage and Current

Assuming that two tanks, A and B, are filled with water, as shown in Fig. 1, and the water level in tank A is H_A (m) while that for tank B is H_B (m), then the water level difference H between the two tanks will be expressed as $H = H_A - H_B$ (m).
If the valve is opened, water will flow from tank A, the high level, to tank B, the low level, until the water level difference H becomes nil.

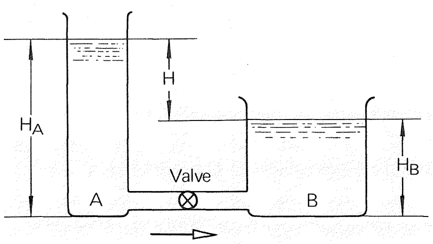


Fig. 1 Water-level difference and water current

If water is pumped to maintain a fixed level difference, or water pressure difference, between A and B, water will flow within the loop as shown in Fig. 2.
Similarly, if terminals A (+) and B (–) of a cell are connected with a conductor, electric current will flow from terminal A to terminal B.
The flow of current is caused by the difference in electric potential between the two terminals, that is, the potential difference.

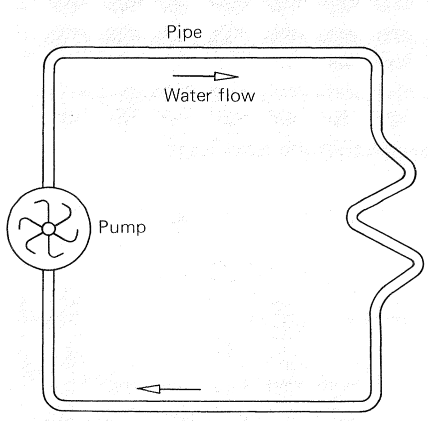


Fig. 2 Water pressure and water current

The potential difference is equivalent to the water level or pressure difference produced by the pump. In a cell or generator, the electromotive force which makes the current flow is called voltage. The unit which represents electromotive force, voltage or electrical potential difference is the volt [V].
Amount of electric current is the quantity of electricity which passes through a conductor. The unit of electric current is the ampere [A].
If Q Coulomb* [C] of electricity passes through a conductor in t seconds, the current ***I*** [A] will be expressed as:

$$I = \frac{Q}{t} \qquad (1\text{-}1)$$

The current ***I*** flows in a conductor from A to B, and in a cell from B to A, thereby completing a circuit.
This is known as an electric circuit, or simply circuit for short. In a circuit, the electric current flows continuously through the conductor, but, if the circuit is cut at any point, the current flow stops immediately. To make the current flow again, the circuit must be closed, hence the terms open and closed circuit.
If a lamp, an electric heater or a motor is included in a circuit as shown in Fig. 3, light, heat or force will be produced when current is applied. Whatever transduces energy from electric current is called the load, and whatever supplies the electric current, such as a cell or generator, is called the power source.

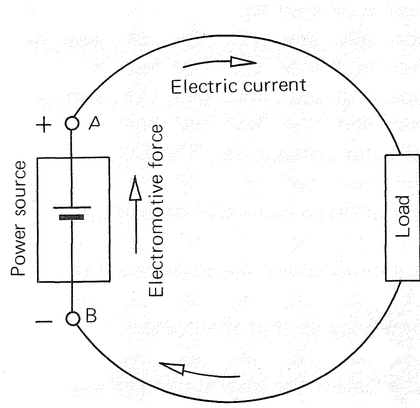


Fig. 3 Voltage and electric current

* Coulomb
Coulomb [C] is the unit of quantity of electricity, and corresponds to the unit of quantity of water, such as liter or cc.

2. Ohm's Law

In 1827, Ohm revealed that "the quantity of an electric current flowing through a conductor is proportional to the voltage supplied across it."
This is known as Ohm's Law.

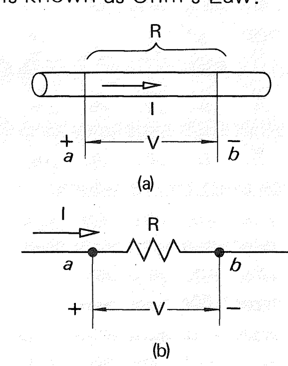


Fig. 4 Electric resistance

If a current ***I*** [A] flows through a conductor, as shown in Fig. 4 (a), while a voltage [V] is supplied across the a and b terminals of the conductor, then according to Ohm's Law it will be expressed as:

$$V = RI \qquad (1\text{-}2)$$

The value ***R*** in this equation represents a proportional constant which differs with the type, temperature, dimensions and other factors of the conductor.
The larger the value of ***R***, the smaller the current amplitude in the conductor will be if the voltage [V] is constant.
Thus, any conductor is considered to have a certain resistance to the current.
The proportional constant ***R*** is called electric resistance, or resistance for short. The unit of resistance is the ohm [Ω].
Equation 1-2 can therefore be expressed as:

$$I = \frac{V}{R} \qquad R = \frac{V}{I} \qquad (1\text{-}3)$$

Depending on the amount of the resistance, the value is also expressed in kiloohms [kΩ], megohms [MΩ] or milliohms [mΩ]. The relationship between each of these units is as follows:

$1\ [k\Omega] = 10^3\ [\Omega]$,
$1\ [M\Omega] = 10^6\ [\Omega]$,
$1\ [m\Omega] = 10^{-3}\ [\Omega]$.

*** Question 1.** If 100 volts supplied across a resistance produces a 0.2 [mA] current, what is the resistance value of the resistor?

Answer: 500 [KΩ]

*** Question 2.** If a conductor receives a 10 [A] current, and the voltage across the conductor is 40 V, what is the resistance value of the conductor?

Answer: 4 [Ω]

3. DC Current Calculations

Resistors can be connected in series, in parallel or a combination of both.

(1) Series connection

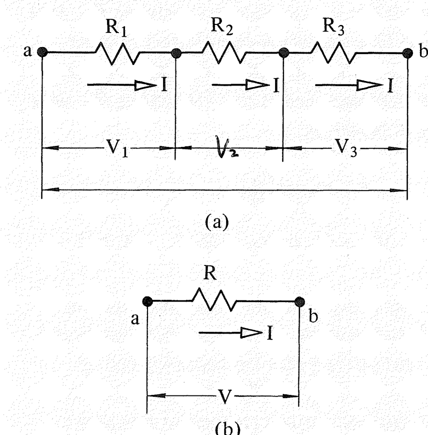


Fig. 5 Series connection

Resistors R_1, R_2 and R_3 connected in a straight line as shown in Fig. 5 (a) are connected in series. How then is their total resistance calculated?
If a voltage [V] is supplied across terminals a and b in Fig. 5 (a), all three resistors will receive the same quantity of current I [A]. Therefore, the respective voltages across the terminals of R_1, R_2 and R_3 will, according to Ohm's Law, be:

Voltage across R_1 $V_1 = R_1 I$
Voltage across R_2 $V_2 = R_2 I$
Voltage across R_3 $V_3 = R_3 I$

The total voltage V is the sum of the voltages across all three resistors, thus:

$$V = V_1 + V_2 + V_3 = R_1 I + R_2 I + R_3 I = (R_1 + R_2 + R_3) I$$

Therefore,

$$\frac{V}{I} = R_1 + R_2 + R_3 = R \quad (1\text{-}5)$$

The total resistance R is called the combined or equivalent resistance. Generally speaking, the combined resistance of series-connected resistors is equal to the sum of the individual resistance values. Thus, Fig. 5 (a) can be simplified as shown in Fig. 5 (b), and equations 1-4 and 1-5 become:

$$V_1 : V_2 : V_3 : V = R_1 : R_2 : R_3 : R \quad (1\text{-}6)$$

or

$$V = \frac{R_1}{R} V,\ V_2 = \frac{R_2}{R} V,\ V_3 = \frac{R_3}{R} V \quad (1\text{-}7)$$

These equations show that the total voltage supplied across series-connected resistors is distributed in proportion to the resistance value of each resistor.

*** Question 3.** If a 50 [Ω] resistor is connected in series to a 30 [Ω] resistor, and 40 volts is supplied across the terminals of the resistors, what is the current amplitude of the resistors?

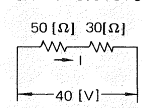


Fig. 6

Answer: The series-connected resistor will form a circuit as shown in Fig. 6.
Thus,

$$R = 50 + 30 = 80$$

$$I = \frac{V}{R} = \frac{40}{80} = 0.5\ [A]$$

*** Question 4.** What is the voltage across each of the resistors in Question 3?

Answer: 25 [V] across the 50 [Ω] resistor, and 15 [V] across the 30 [Ω] resistor.

(2) Parallel connection

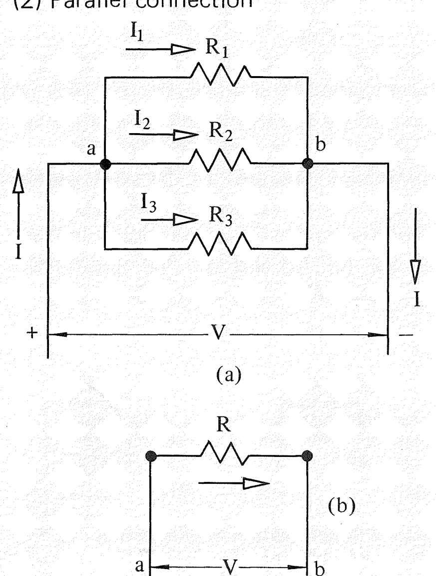


Fig. 7 Parallel connection

When both ends of resistors R_1, R_2 and R_3 are connected to a common terminal, as shown in Fig. 7 (a), they are connected in parallel. The combined resistance of parallel-connected resistors is determined as follows:
Obviously, if terminals a and b are connected to a common voltage source, the same voltage will be supplied across all resistors. Thus, the quantity of current of the individual resistors I_1, I_2 and I_3 [A] will be expressed as:

$$I_1 = \frac{V}{R_1},\ I_2 = \frac{V}{R_2},\ I_3 = \frac{V}{R_3} \quad (1\text{-}8)$$

The total current I is the sum of the three currents:

$$I = I_1 + I_2 + I_3 = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$= \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) V \quad (1\text{-}9)$$

Therefore,

$$\frac{V}{I} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = R \quad (1\text{-}10)$$

The total resistance R is the combined resistance of resistors R_1, R_2 and R_3, as shown in Fig. 7 (a).
Generally speaking, the combined resistance of a parallel circuit is equal to the reciprocal number of the sum of the reciprocal number of individual resistors. The circuit shown in Fig. 7 (a) can be simplified as illustrated in Fig. 7 (b) to facilitate calculation.
In the following cases, the calculation can be simplified as shown in Fig. 7 (a).

(1) When $R_1 = R_2 = R_3$

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = \frac{R_1}{3} \quad (1\text{-}11)$$

(2) The parellel connection of two resistors R_1 and R_2, where R_3 has an infinite value of ∞ [Ω] is expressed as:

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} = \frac{1}{\frac{R_1 + R_2}{R_1 R_2}} = \frac{R_1 R_2}{R_1 + R_2} \quad (1\text{-}12)$$

*** Question 5.** If a 4 [Ω] resistor is connected in parallel to a 6 [Ω] resistor, and 120 volts is supplied across the resistors, what is the combined resistance of the resistors and their current amplitude?

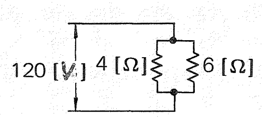


Fig. 8

Answer: Combined resistance

$$R = \frac{4 \times 6}{4+6} = \frac{24}{10} \quad 2.4\ [\Omega]$$

Current through 4 [Ω] resistor

$$= \frac{120}{4} = 30\ [A]$$

Current through 6 [Ω] resistor

$$= \frac{120}{6} = 20\ [A]$$

Total current $I = 30 + 20 = 50$ [A]

or

$$I = \frac{120}{R} = \frac{120}{2.4} = 50\ [A]$$

*** Question 6.** If the voltage across the 10 [Ω] resistor in the circuit shown in Fig. 9 is 20 [V], what is the total voltage?

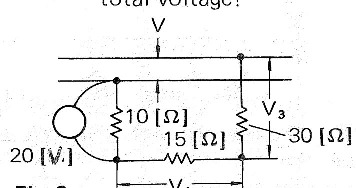


Fig. 9

Answer: 110 [V]

(3) Series-parallel connection

As shown in Fig.10 many resistors can be connected to form a series-parallel circuit. The total resistance of this type of circuit can be obtained by combining the series and parallel resistor calculations.

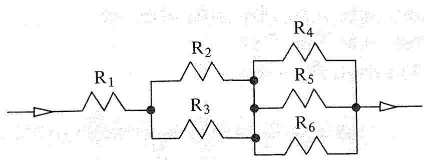


Fig. 10 - a Series-parallel connection

This circuit can be converted as follows.

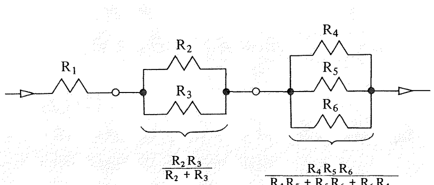


Fig. 10 - b Series-parallel connection

$$R = R_1 + \frac{R_2R_3}{R_2+R_3} + \frac{R_4R_5R_6}{R_4R_5+R_5R_6+R_6R_4}$$

$$= \frac{(R_1R_2+R_2R_3+R_3R_1)(R_4R_5+R_5R_6+R_6R_4) + (R_2+R_3)R_4R_5R_6}{(R_2+R_3)(R_4R_5+R_5R_6+R_6R_4)} \qquad (1\text{-}13)$$

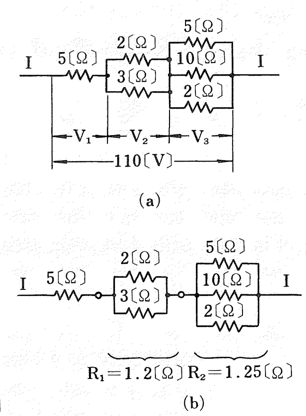


Fig. 11

In Fig. 11 (b), the combined resistance of 2 [Ω] and 3 [Ω] is obtained by:

$$R_1 = \frac{2 \times 3}{2+3} = \frac{6}{5} = 1.2\ [\Omega]$$

and the combined resistance of 5 [Ω], 10 [Ω] and 2 [Ω] is:

$$R_2 = \frac{1}{\frac{1}{5}+\frac{1}{10}+\frac{1}{2}} = \frac{1}{\frac{2+1+5}{10}}$$

$$= \frac{10}{8} = 1.25\ [\Omega] \qquad [\Omega]$$

Thus, the circuit can be handled as a series connection of 5 [Ω], 1.2 [Ω] and 1.25 [Ω] resistors. This means that the total resistance R is:

$R = 5 + 1.2 + 1.25 = 7.45$ [Ω]

And the total current I is obtained by dividing the 110V voltage by 7.45 [Ω] as follows:

$$I = \frac{110}{7.45} \fallingdotseq 14.8\ [A]$$

The voltage across each of the resistors can be obtained by multiplying the 14.8 [A] current by the combined resistances of 5 [Ω], 1.2 [Ω] and 1.25 [Ω]. The combined resistance of the series-parallel circuit in Fig. 12 (a) is obtained by simplifying the circuit as shown in Fig. 12 (b), (c), (d) and (e). The combined resistance R of this circuit is 11 [Ω].

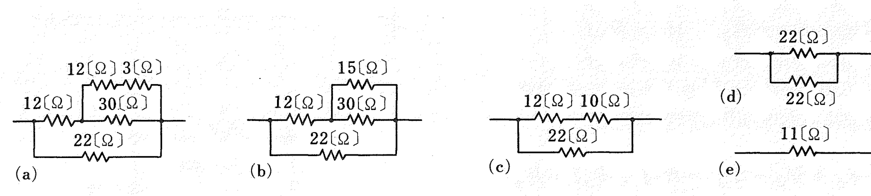


Fig. 12 Simplification of connection

4. Voltage Drop Across Resistors

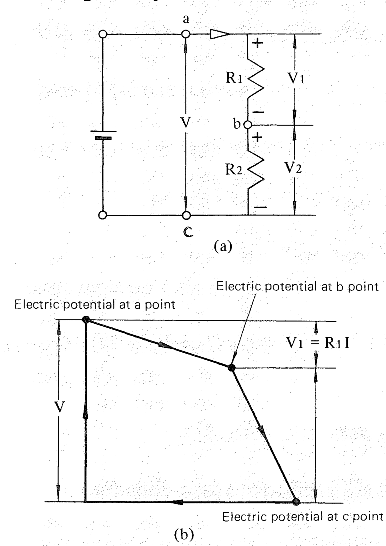


Fig. 13 Voltage drop (resistance drop)

If voltage is supplied to resistor R_1 and R_2 [Ω] in a series-connected circuit, the current through the resistors I and the voltage across the Resistors R_1 and R_2 is given as:

$$I = \frac{V}{R_1 + R_2}$$

$$V_1 = R_1 I,\ V_2 = R_2 I \qquad (1\text{-}14)$$

Using the potential at point c as the reference level, potential distribution in the circuit can be represented as shown in Fig. 13 (b). In this circuit, the power source potential between c and a is raised, but the current through R_1 lowers the potential between points a and b. In resistor R_2, the potential between points b and c is lowered and the current returns to the reference level c.

The resultant voltage produced across the resistor just described is known as voltage drop across resistor or resistance drop.

Moreover, the theory discussed in this chapter is fully applicable to alternating current (AC) as well.

(2) THE DECIBEL

For anyone working in the audio field, the one unit that he is likely to see most frequently used is the decibel, or dB for short. It appears in all stereo component literature, such as catalogs, instruction manuals, service manuals, brochures, pamphlets, in fact, everywhere you look. The decibel is a highly versatile term, and a thorough understanding of it is essential if one is to master the complexity of audio circuitry today. In this issue, then, we are highlighting the decibel.

1. The Origin of the Term

The term decibel originated from the unit Bel, which indicated the ratio of two electrical powers. Originally, the Bel unit was used in the study of acoustics to represent sensation level, or the difference in sensation levels. However, the unit was too large to accurately determine audio levels within the human listening range, so a smaller unit was required. The one found to be most suitable was one-tenth (1/10) of a Bel, and since the prefix for one-tenth is deci, the new term became known as the decibel. Theoretical adoption of the decibel will be discussed in Chapter 3.

2. Why the Decibel was Adopted by the Audio World

Unlike other units, the decibel represents the relative amplitude of a sound or signal, rather than its absolute value. There are many units which represent absolute value, but when they are used to evaluate amplitude of electrical or acoustic signals they become impractical because of the large number of digits involved. For instance, 100,000 times the value, or 0.0000012 of the value are not uncommon. The human ear can detect a wide range of sound levels from a minimum of 0.0002 microbar (NOTE 1), to a maximum of 200 microbars. This means that the audio spectrum of the human ear covers a ratio of up to 1,000,000 times. However, the human ear does not sense a 0.0002 microbar sound as one millionth of 200 microbars. In actual fact, it amplifies the very low sound sensed and compresses all the highs. Which means that, although a change from 1 microbar to 10 microbars may be the same as from 10 microbars to 19 microbars, to the ear, the change from 1 to 10 microbars a tenfold level difference, is the same as that from 10 to 100 microbars, which is also a tenfold level difference. The sensitivity of the human ear can, therefore, be represented by a relative ratio expressed in decibels. This is because the human ear possesses logarithmic sensitivity, and the relative decibel value more accurately simulates the smallest change in sound it is capable of sensing. For this reason, the decibel is the most widely used term in the audio field.

By using decibel values, a reference level for voltage, power output, sound pressure, etc., is established, and the ratio, or number of times it is larger or smaller than the reference level, is expressed numerically.

3. How a Decibel Level is Obtained

The decibel, as already mentioned, was derived from the Bel unit which found its application in the field of wired communications, such as telephone equipment. In a telephone system, very long cables are used to transmit voice signals transduced into electrical signals. In which case, the power loss factor of the cables is very important. A typical example is shown in Fig. 1.

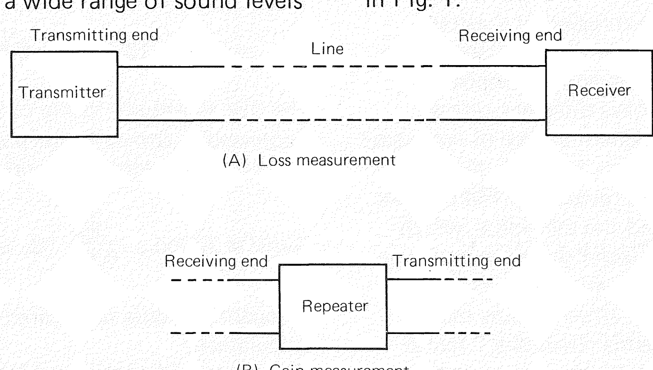


Fig. 1 Power transfer in wired communication

Line loss and amplifier gain represent the ratio of powers at two points on a line, for example, at the transmitting and receiving ends. In communication measurements, the power level at a desired point is compared with a certain reference power level, and expressed in decibels.

Letting the reference power level be Ps and the measured power level be P, then the gain will be given as:

$$G = 10\log_{10}\frac{P}{Ps}\ (\text{dB}) \qquad \text{(NOTE 2)}$$

Step 1.

If both the transmitting and receiving ends and the line have the same characteristic R ohm impedance, then the equation in Step 1 can be expressed as:

$$G = 10\log_{10}\frac{P}{Ps}$$

$$= 10\log_{10}\frac{\frac{V^2}{R}}{\frac{Vs^2}{R}} = 10\log_{10}\left(\frac{V}{Vs}\right)^2$$

$$= 20\log_{10}\frac{V}{Vs}\ \text{dB} \qquad \text{Step. 2}$$

Similarly,

$$G = 10\log_{10}\frac{P}{Ps}$$

$$= 10\log_{10}\frac{I^2 R}{Is^2 R} = 10\log_{10}\left(\frac{I}{Is}\right)^2$$

$$= 20\log_{10}\frac{I}{Is}\ \text{dB} \qquad \text{Step 3.}$$

In short, the gain or loss is given by the power ratio expressed in the first equation, while the voltage or current ratios are given in equations 2 and 3. These ratios are defined as:

Power gain $Gp = 10\log_{10}\frac{P}{Ps}$ dB

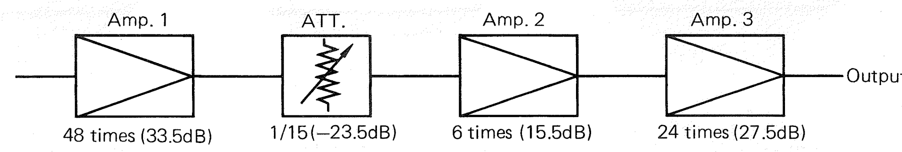
Voltage gain $Gv = 20\log_{10}\frac{V}{Vs}$ dB

Current gain $Gi = 20\log_{10}\frac{I}{Is}$ dB

4. Use of Decibels in Audio

In the previous chapter, the same characteristic impedance was assumed for both the transmitting and receiving ends for the purpose of determining the decibel value. In audio engineering, on

the other hand, transfer of power is not the primary concern, and strict impedance matching is not generally required. However, there are some exceptions as in the case of power output or cartridge load circuits. Ordinarily, signals from low-impedance sources are received by high-impedance circuits. Therefore, equations 1 to 3 cannot be used, in a strict sense, to determine audio measurements. They can, however, be used to obtain decibel values if circuit impedance is neglected, since the relative amplitude of power, voltage or current is the main concern. In practice, decibel values mainly only apply to voltage amplitudes. Power and current values are rarely expressed in decibels.
When calculating gain in tuners or amplifiers, the decibel system is used more frequently because it is obtained by simple addition or subtraction, not multiplication or division. A typical gain calculation is shown in Fig. 2.



Overall gain $A = 48 \div 15 \times 6 \times 24 = 460$ times
$G = 33.5 - 23.5 + 15.5 + 27.5 = 53$dB

Fig. 2 Gain calculation

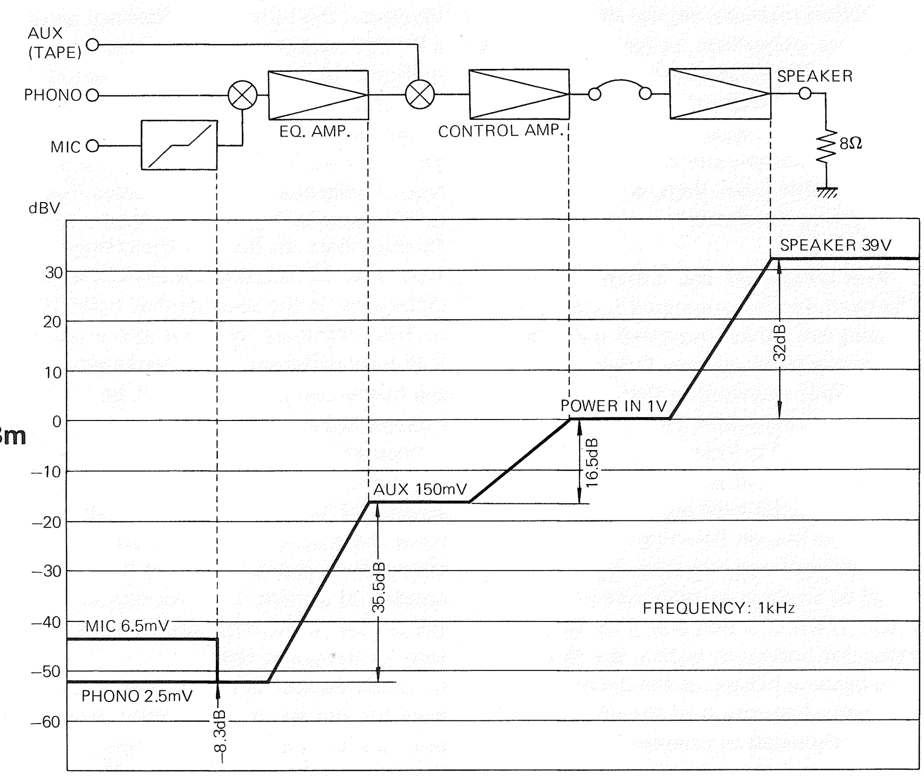


Fig. 3 Level diagram

5. Absolute Decibel Values (dBv, dBm and dBf)

Although the decibel is a relative value, it can also be used to represent an absolute level, such as dBv, dBm and dBf. The suffixes v, m and f indicate absolute values.

1) dBv

Normally, the decibel is only used to represent certain, optionally selected, reference levels. However, dBv is also used to express the absolute value 0dBv = 1V. For example, –40dBv indicates that the voltage amplitude is 10mV.
The dBv value is particularly useful for signal voltage measurements, and frequently appears in service manuals for amplifiers, receivers, tape decks and other hi-fi components. An example of a typical dBv value is shown in Fig. 3.

2) dBm

The term dBm represents the reference level 0dBm, which is set at 0.775V.
A 6dBm value, for example, indicates 1.55V. The reference level 0dBm = 0.775V is induced from a matching impedance of 600 ohms, which is widely used in radio or TV sound broadcasting equipment. A 600 ohm load consumes 1mW of power when 0.775V is applied across the load. The reference voltage is calculated as:

$$P = VI = \frac{V^2}{R}$$

$$V^2 = PR$$
$$V = \sqrt{PR}$$

Therefore

$$V_m = \sqrt{0.001 \times 600} = 0.775\ [V]$$

Pioneer models using dBm values include the T-500, T-600, T-6100, T-6600, QT-6100, QT-6600, RT-71, RT-74, T-8800, QT-2100, T-3100, T-3300, T-3300A, T-3500, CT-3131 and CT-4141. All models after the CT-3131A, CT-4141A and RT-1020H use dBv values.

3) dBf

Based on the old IHF standard, the sensitivity of a receiver always used to be given in μV. However, when sensitivity is expressed in a voltage value, receivers of the same sensitivity, but with varying antenna input impedances, have different ratings. This was a frequent source of confusion among customers. In 1975, the IHF standards were revised for FM receiver sensitivity, and the dBf value, which gives antenna input power irrespective of antenna impedance, became the accepted term. Which means that at 0dBf, an antenna receives a 1 femto watt signal, or 10^{-15} watt of power. This reference level is expressed as:

$$P = \frac{E^2}{Z} \qquad E = \sqrt{PZ}$$

Where P = antenna input power
E = antenna input voltage
Z = antenna impedance

Therefore, if the antenna impedance is 300 ohms, then the antenna input voltage at 0dBf is given as:

$$E_s = \sqrt{10^{-15} \times 300}$$
$$= 0.55 \times 10^{-6}\ [V] = 0.55\ [\mu V]$$

The dBf sensitivity rating can be expressed in conventional μV terms using the following equation:

$$S(dBf) \fallingdotseq 20 \log_{10} \frac{Ea}{0.55} \quad (Ea \text{ is given in } \mu V)$$

A logarithm table is required for this calculation.
The μV to dBf conversion table is as follows:

Table 1. Conversion table (μV – dB)

Voltage value	Power value	Voltage value	Power value	Voltage value	Power value
0.1 μV	– 14.8 dBf	1.1 μV	6.0 dBf	2.5 μV	13.2 dBf
0.2 μV	– 8.8 dBf	1.2 μV	6.8 dBf	3.0 μV	14.7 dBf
0.3 μV	– 5.3 dBf	1.3 μV	7.5 dBf	3.5 μV	16.1 dBf
0.4 μV	– 2.8 dBf	1.4 μV	8.1 dBf	4.0 μV	17.2 dBf
0.5 μV	– 0.8 dBf	1.5 μV	8.7 dBf	5.0 μV	19.2 dBf
0.6 μV	0.8 dBf	1.6 μV	9.3 dBf	6.0 μV	20.8 dBf
0.7 μV	2.1 dBf	1.7 μV	9.8 dBf	7.0 μV	22.1 dBf
0.8 μV	3.3 dBf	1.8 μV	10.3 dBf	8.0 μV	23.3 dBf
0.9 μV	4.3 dBf	1.9 μV	10.8 dBf	9.0 μV	24.3 dBf
1.0 μV	5.2 dBf	2.0 μV	11.2 dBf	10.0 μV	25.2 dBf

Table 2. Conversion table (dBf – μV)

Voltage value	Power value	Voltage value	Power value	Voltage value	Power value
– 10 dBf	0.17 μV	1 dBf	0.62 μV	11 dBf	1.95 μV
– 9 dBf	0.20 μV	2 dBf	0.69 μV	12 dBf	2.19 μV
– 8 dBf	0.22 μV	3 dBf	0.78 μV	13 dBf	2.46 μV
– 7 dBf	0.25 μV	4 dBf	0.87 μV	14 dBf	2.76 μV
– 6 dBf	0.28 μV	5 dBf	0.98 μV	15 dBf	3.09 μV
– 5 dBf	0.31 μV	6 dBf	1.10 μV	16 dBf	3.47 μV
– 4 dBf	0.35 μV	7 dBf	1.23 μV	17 dBf	3.89 μV
– 3 dBf	0.39 μV	8 dBf	1.38 μV	18 dBf	4.37 μV
– 2 dBf	0.44 μV	9 dBf	1.55 μV	19 dBf	4.90 μV
– 1 dBf	0.49 μV	10 dBf	1.70 μV	20 dBf	5.50 μV

4) Other Absolute Values

Apart from dBv, dBm and dBf, decibels are used to represent absolute values in the following cases:

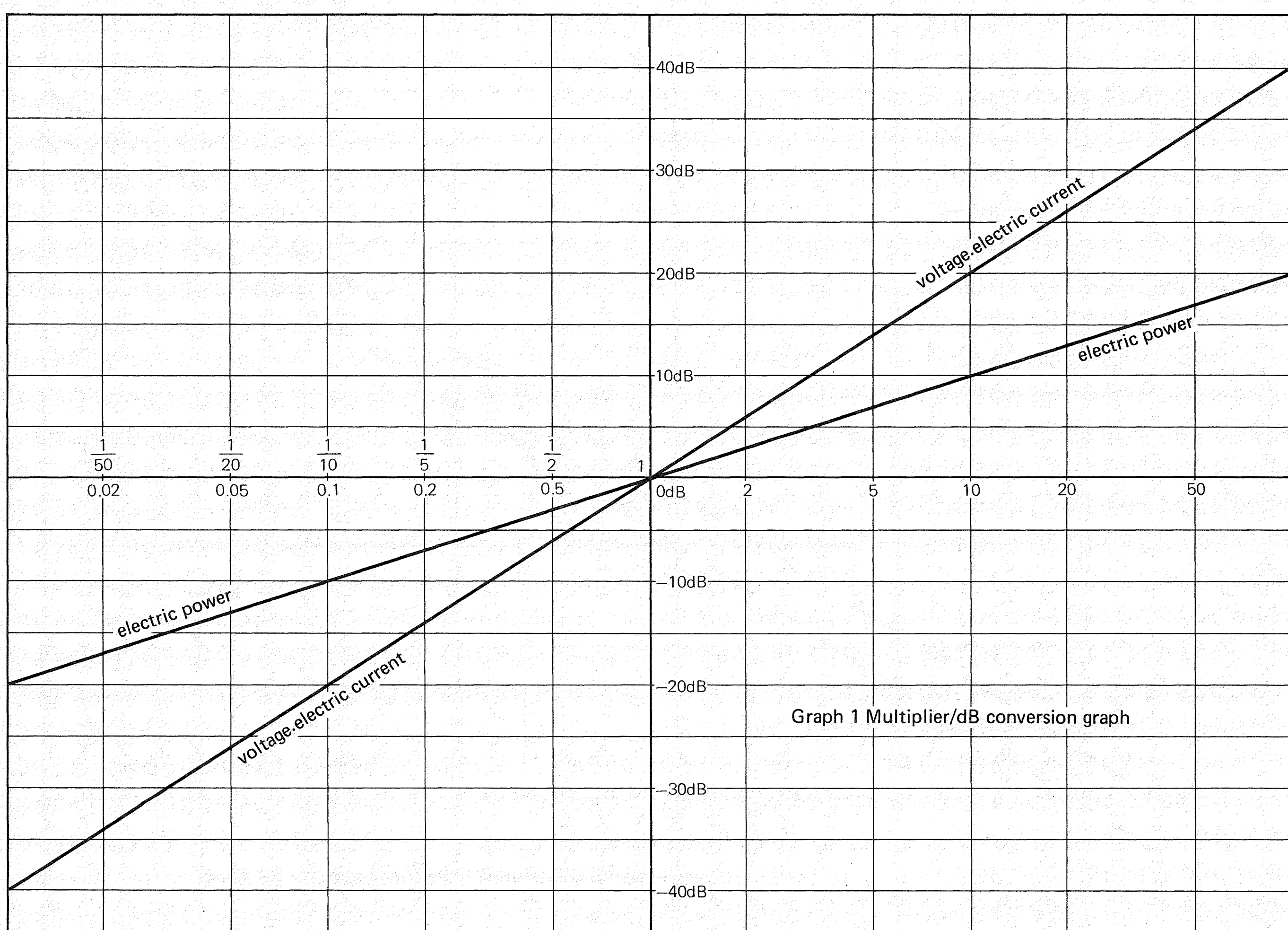
1. SSG (standard signal generator) attenuator output
2. Speaker efficiency

The attenuator dial of an SSG is graduated in dB, with 0dB equal to 1μV. Thus, a 40dB output indicates a 100μV signal level.

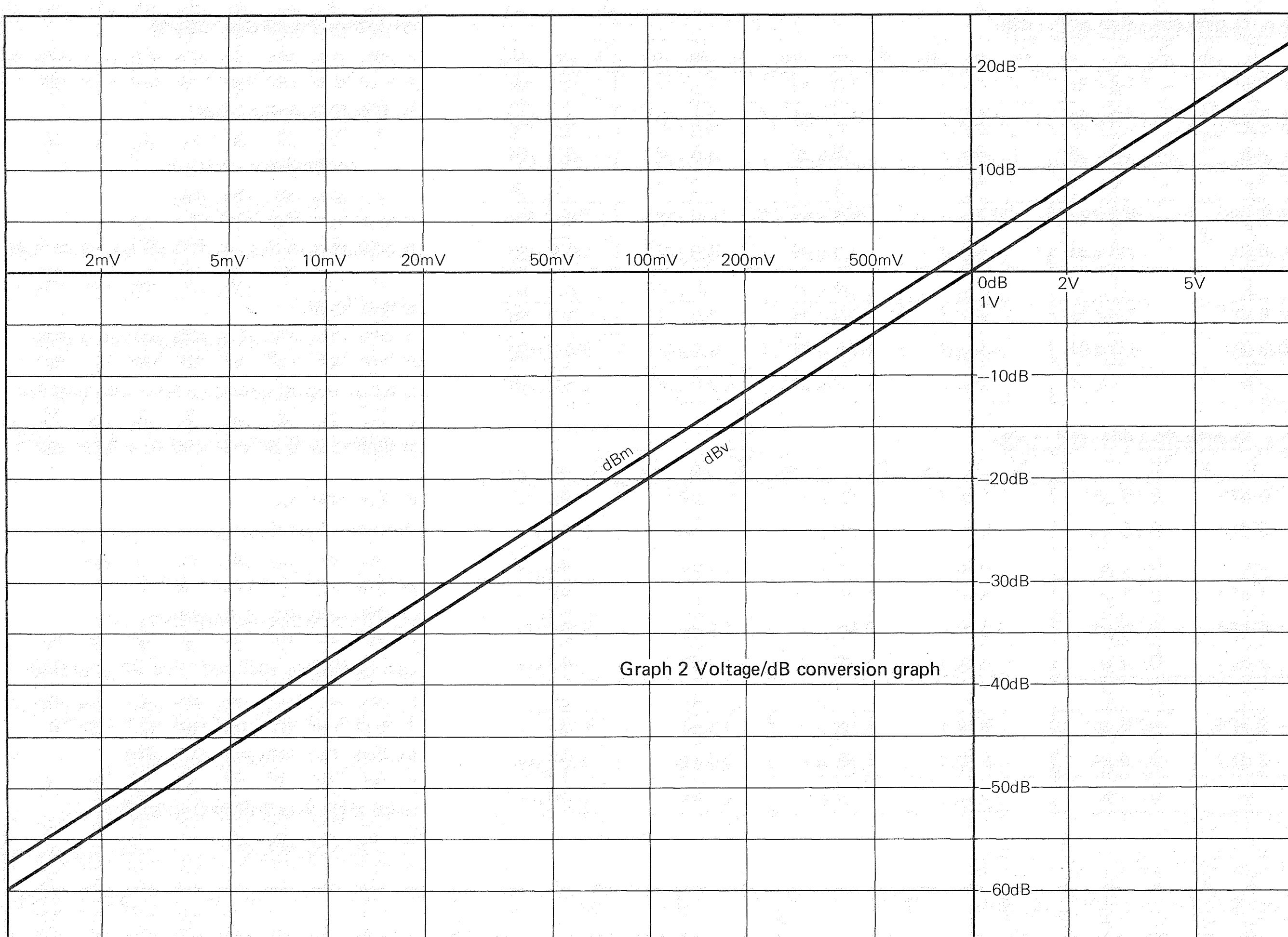
The efficiency of loudspeakers is also expressed in dB, which gives an absolute output sound-pressure level reading for a given power input. The theory of loudspeakers will be covered in a later issue.

6. Conclusion

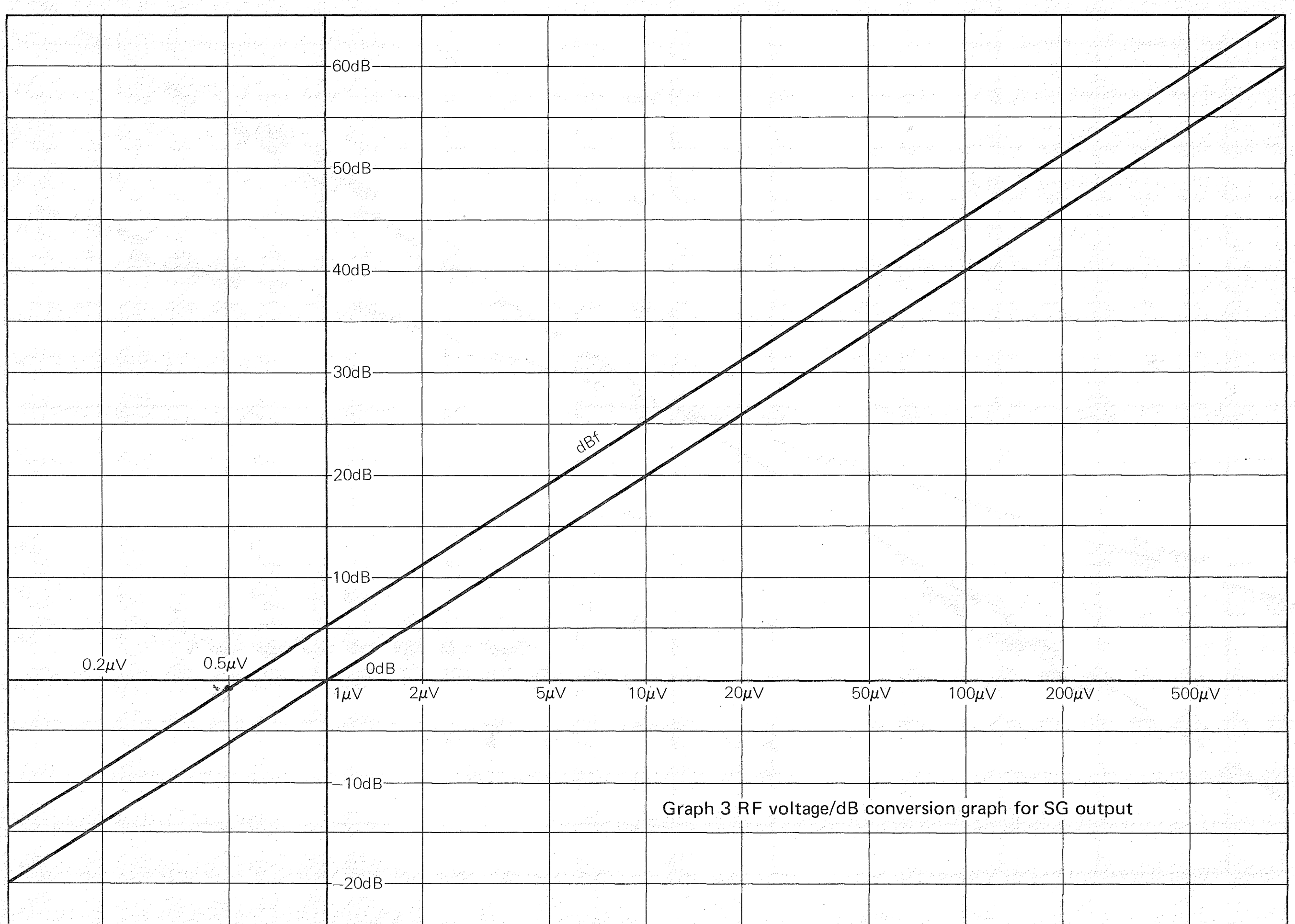
We have just dealt briefly with the decibel and its application to audio engineering, however, a full understanding of exponents and logarithms is necessary before the term can be freely utilized. For all practical purposes, an understanding of equations 1 to 3 is all that is required to make decibel or voltage amplitude conversions, providing multipliers are used with the following decibel conversion graphs.



Graph 1 Multiplier/dB conversion graph



Graph 2 Voltage/dB conversion graph



Graph 3 RF voltage/dB conversion graph for SG output

Note: 1. Microbars (μbar)
A microbar is the unit of sound pressure most widely used in acoustic theory. At 1 microbar, a 1cm² area receives a 1 dyne force.

1 dyne is the force required to move 1 gram at 1cm per second.

2. Logarithm (log)
The exponent/logarithm relationship is as follows:

If $x = a^n$, then
$n = \log_a x$

If $a = 10$, then,
$n = \log x$

Logarithm transformation is determined as follows:

If $x = c \times d$, $\log (c \times d) = \log c + \log d$

If $x = \frac{c}{d}$, $\log \frac{c}{d} = \log c - \log d$

If $x = c^m$, $\log c^m = m \log c$

If $x = c^{\frac{1}{m}}$, $\log c^{\frac{1}{m}} = -m \log c$

Reference

In many decibel calculations, a simple approximation can be made without using logarithm tables or function calculations, if three basic values are remembered. These are: log 2 = 0.3010, log 3 = 0.4771 and log 10 = 1. These values give 6dB, 9.5dB and 20dB respectively when multiplied by 20. The following are examples of dB calculations using the three basic values:

How the Multipliers are Obtained

The basic multipliers are 2, 3 and 10 times for 6dB, 9.5dB and 20dB respectively. Other multipliers can be obtained by using the following conversation table. (See Note 2.)

Example:
$3.5\text{dB} = 9.5 - 6$, thus, $\frac{3}{2} = 1.5$ times

dB	Conversion	Multiplier Calculation (times)
1	20 – (9.5 x 2)	$10 \div 3^2 = 1.11$
2	20 – (6 x 3)	$10 \div 2^3 = 1.25$
3	6 ÷ 2	$\sqrt{2} = 1.41$
4	2 + 2	1.25 x 1.25 = 1.56
5	6 – 1	2 ÷ 1.11 = 1.8
6		2
7	6 + 1	2 x 1.11 = 2.22
8	6 + 2	2 x 1.25 = 2.5
9	6 + 3	$2 \times \sqrt{2} = 2.8$
10	20 ÷ 2	$\sqrt{10} = 3.2$
11	10 + 1	$\sqrt{10} \times 1.11 = 3.5$
12	6 + 6	2 x 2 = 4
13	12 + 1	4 x 1.11 = 4.44
14	20 – 6	10 ÷ 2 = 5
15	14 + 1	5 x 1.11 = 5.55
16	14 + 2	5 x 1.25 = 5.75
17	14 + 3	$5 \times \sqrt{2} = 7.07$
18	20 – 2	10 ÷ 1.25 = 8
19	20 – 1	10 ÷ 1.11 = 9
20		10

Similar conversions and calculations can be made using multipliers above 20 or below 1.

Multiplier	Conversion	dB calculation (voltage ratio)
4	$= 2 \times 2$	20 log 2 + 20 log 2 = 6 + 6 = 12
5	$= 10 \div 2$	20 log 10 – 20 log 2 = 20 – 6 = 14
6	$= 2 \times 3$	20 log 2 + 20 log 3 = 6 + 9.5 = 15.5
7	$= \sqrt{49} \fallingdotseq \sqrt{10^2 \div 2}$	$\frac{20}{2} \log 100 - \frac{20}{2} \log 2$ = 20 – 3 = 17
8	$= 2^3$	3 x 20 log 2 = 3 x 6 = 18
9	$= 3^2$	2 x 20 log 3 = 2 x 9.5 = 19
11	$= \sqrt{121} \fallingdotseq \sqrt{2^2 \times 3 \times 10}$	$\frac{20}{2} \log 2^2 + \frac{20}{2} \log 3 + \frac{20}{2} \log 10$ = 6 + 4.8 +10 = 20.8
12	$= 2^2 \times 3$	2 x 20 log 2 + 20 log 3 = 12 + 9.5 = 21.5
13	$\fallingdotseq \frac{40}{3} = \frac{2^2 \times 10}{3}$	20 log 10 + 2 x 20 log 2 – 20 log 3 = 20 + 12 – 9.5 = 22.5
14	$\fallingdotseq \sqrt{2} \times 10$	$\frac{20}{2} \log 2 + 20 \log 10$ = 3 + 20 = 23
15	$= 10 \times 3 \div 2$	20 log 10 + 20 log 3 – 20 log 2 = 20 + 9.5 – 6 = 23.5
16	$= 2^4$	4 x 20 log 2 = 4 x 6 = 24
17	$\fallingdotseq \frac{100}{6} = 10^2 \div 2 \div 3$	$20 \log 10^2 - 20 \log 2 - 20 \log 3$ = 40 – 6 – 9.5 = 24.5
18	$= 3^2 \times 2$	$20 \log 3^2 + 20 \log 2$ = 19 + 6 = 25
19	$\fallingdotseq \sqrt{361} = 2 \times 3 \times \sqrt{10}$	$20 \log 2 + 20 \log 3 + \frac{20}{2} \log 10$ = 6 + 9.5 + 10 = 25.5
20	$= 2 \times 10$	20 log 2 + 20 log 10 = 6 + 20 = 26

STANDARD SERVICE BENCH

Repairing hi-fi equipment today to the customer's satisfaction requires special service instruments. Recently, the performance of hi-fi equipment has greatly improved and the functions have become even more diversified. As a result, it is difficult to decide what level to set a service bench up to. Especially, when the cost of bench equipment has to be considered. The purpose of this article, then, is to specify what Pioneer recommends for a standard service bench.
Here are the basic requirements:

1) Sufficient capability to check the performance and function of hi-fi components.
2) Ability to offer a speedy service.

The first requirement determines the quantity and grade of the measuring instruments needed, while the second decides basic instrument needs, what auxiliary devices are necessary, and the layout of the bench itself.

1. Measuring Instruments

The following instruments are prerequisites for servicing Pioneer hi-fi components:

1) AF generator
2) Millivolt meter (1 channel type)
3) Millivolt meter (2 channel type)
4) Oscilloscope (2 channel type)

These are the basic instruments that are required by every technician.

Milivolt meter (2 ch. type)

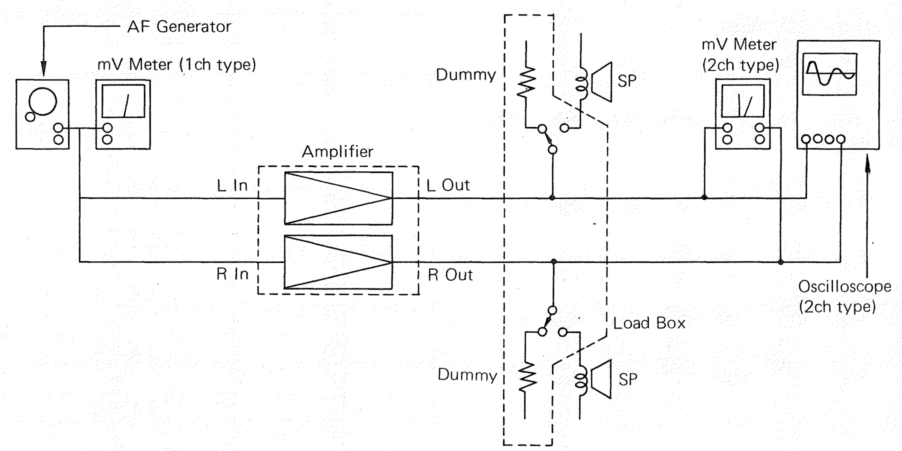


Fig. 1 Connection Diagram

The connection of these instruments, together with the load box which will be described later, is as illustrated in Fig. 1.
Connecting the instruments in this manner greatly simplifies checking of the input/output and right/left channel signals before and after repairing. It also facilitates rapid performance checking, adjustment and quantitative measuring.
In order to protect the circuit from external noise or other sources of trouble, the output impedance of the AF signal generator should be lower than 1 Kohm. This is normally around 600 ohms. Ideally, the AF signal generator should be equipped with 10dB-step attenuators, in addition to a variable output controller, as well as both square-wave and sine-wave outputs.
Also, the millivolt meters should have both dBV and dBm scales in addition to standard voltage scales.
As for the oscilloscope, a 2-channel (dual trace) type is preferable so that both right- and left-channel signals can be monitored simultaneously.
A 1-channel model will do, but, it will be less convenient.

5) AM signal generator
6) FM signal generator
7) FM stereo signal generator

An AM/FM signal generator is essential for servicing AM/FM tuners, especially for tracking alignment. And, if a stereo signal generator is built into the FM signal generator, it will facilitate operation.

8) Distortion meter

The distortion meter is used in conjunction with instruments 1) to 4) for determining whether the equipment is functioning normally after repairing. It is essential for better servicing.

9) Wow-flutter meter

This is necessary for taking quantitative measurements of turntables and tape decks. It gives a percentage (%) readout. The proper servicing of late

Oscilloscope (2 ch. type)

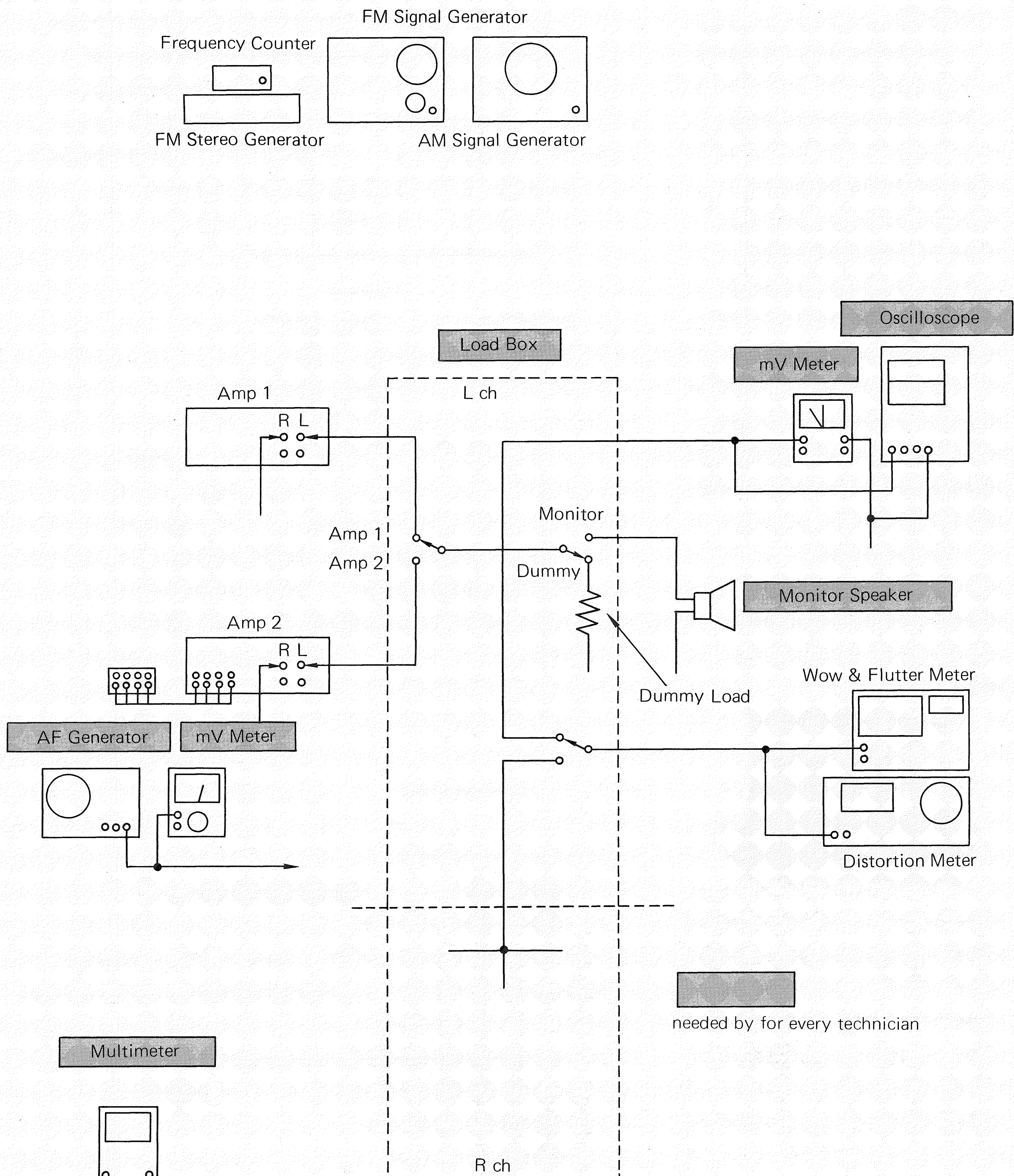
model turntables and tape decks now goes far beyond the service engineer's visual or aural checking capabilities. Moreover, a built-in digital frequency counter will greatly expand the application of the wow-flutter meter.

10) Multimeter

A handy multimeter is a great help in checking electrical parts and circuits. Unlike a decade ago, the latest multimeters have a considerably higher performance. Their ease of operation makes them indispensable for all types of servicing and every technician should have one.

These are the basic instruments for making a standard service bench. How they are combined into the bench design is shown in Fig. 2.

Fig. 2 Composition of service bench



2. Auxiliary Devices (Load box and input terminal board)

The auxiliary devices consist of a load box and an input terminal board, which improve servicing speed and efficiency. Unlike the measuring instruments, these devices have to be made, since they are not available on the market. However, they can easily be made with service parts. The advantages they offer are as follows:

1 Features

1) Immediate switching of speakers and dummy loads. The dummy load facility permits one-man operation.

2) Simultaneous testing of two amplifiers, receivers or car stereo systems.

The second facility permits one amplifier to be aged while another is being checked or repaired. It also allows the active standby (aged) amplifier to be reconnected to the test circuit at the flick of a switch.

3) Simultaneous checking of two channels.

With this facility, no switching or connections are required. The signal levels of two channels can be monitored or compared at the same time. This feature is a big benefit when adjusting FM separation, checking tape deck playback and recording levels or adjusting equalizers.

4) Aural testing of monitor or serviced speakers.

These are big timesaving features which greatly speed up servicing. The following illustrates a typical schematic diagram, outline and composition of a standard service bench.

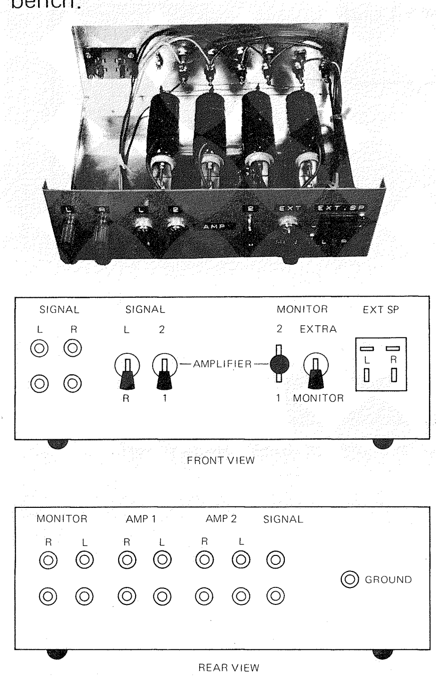
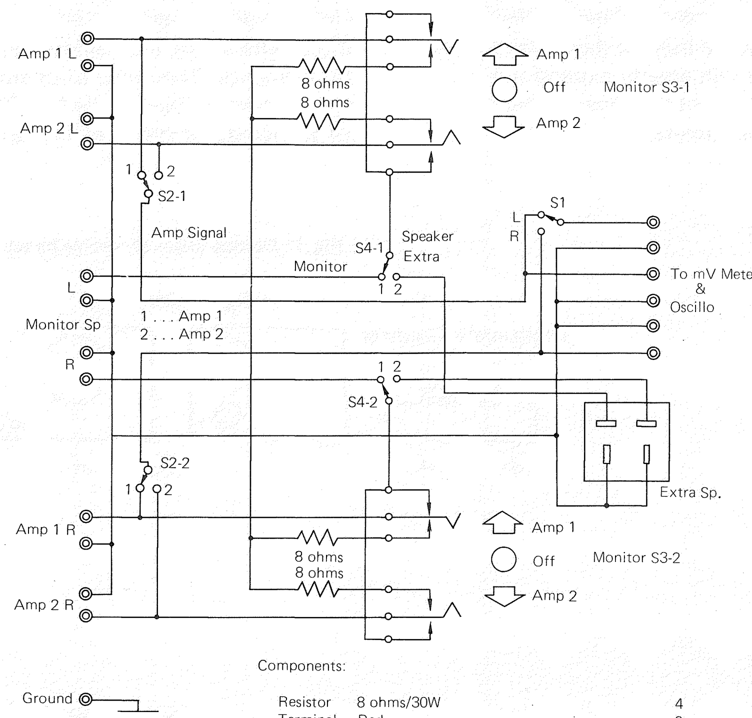


Fig. 3 Load box

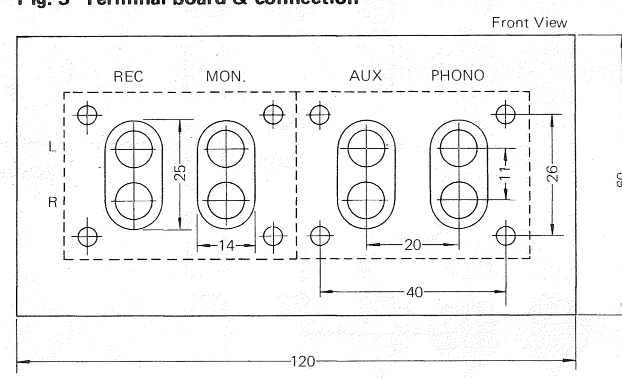
Fig. 4 Circuitry of load box



Components:

Resistor	8 ohms/30W		4
Terminal	Red		9
	Black		9
	Metal		1
Switch	Double Pole/Double Throw		3
Switch	Siemens Type		1
Speaker Socket			1
Metal Case			1

Fig. 5 Terminal board & connection



Connect as shown below.

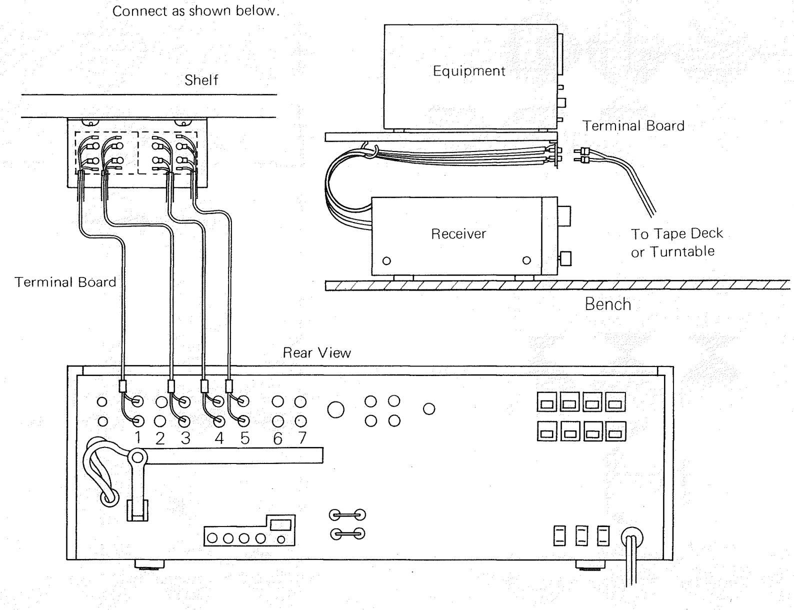
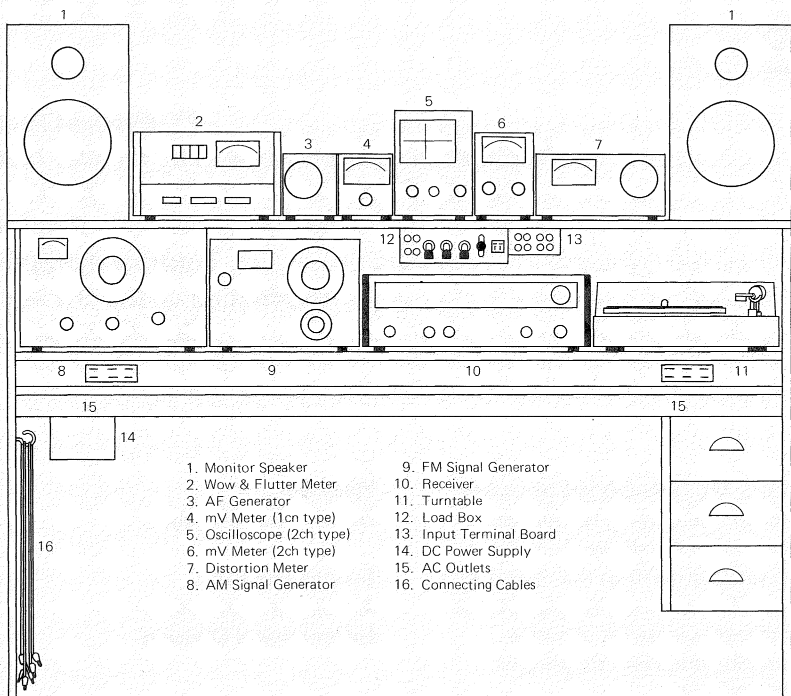


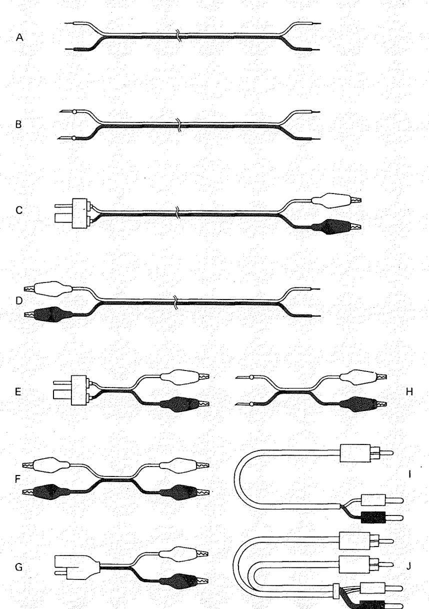
Fig. 6 Standard service bench



2 Auxiliary Cables

Certain types of cables are necessary for efficient use of the load box. The cables required are shown in Fig. 7.

Fig. 7 Cables necessary for repairing & measuring



1) Cable A
Type A cables are used to connect the SIGNAL terminals of the load box to the measuring instruments (mV meter, oscilloscope or monitor speakers). Since circuit impedance is very low, popular vinyl cables are sufficient. All cable ends should be solder finished.

2) Cable B
Type B cables are used to connect the AMP terminal of the load box to the amplifier, receiver or car stereo output. For added durability, multimeter test prongs (short tip) are recommended for the cable ends. This type should be used for cable adaptors E to G.

3) Cable C
Type C cables are used to connect the load box with the speaker for testing. This type can also be used in place of cable B for amplifier connection.

4) Cable D
This type enhances service bench versatility since it can be used for all connections.

5) Cable Adaptor E
This, together with cable B, is used to connect some of the older models, such as the SX-727, SA-1000, etc.

6) Cable Adaptor F
This, together with cable B, is used to connect the SX-800 and other earlier models. With T-type speaker plugs, this cable adaptor is designed for models made 3 or 4 years ago.

7) Cable Adaptor G
This is used with cable B for servicing car stereos.

8) Cable Adaptor H
Used with cable B or D.

9) Cable I
Used to connect a tape deck to the mV meter. In this case, the load box to mV meter circuit must be opened.

10) Cable J
Used to connect the AF generator to a tape deck or amplifier/receiver.

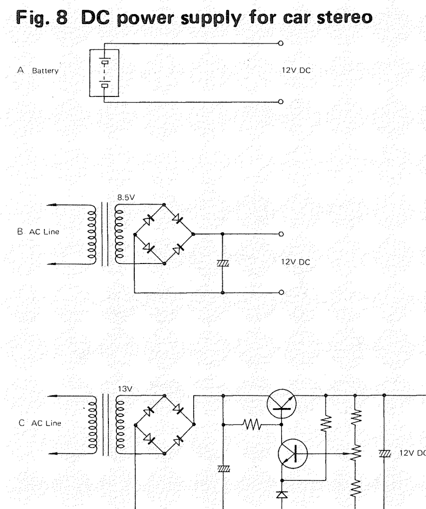
3 Tools and jigs

During actual servicing, some tools such as service jigs, test tapes and test records, are required in addition to the measuring instruments and cables.
Since there are many kinds of tools and jigs, refer to the List of Tools and Materials for Repair/Service (May 1976), for their specific application and operation.

4 DC Power Supply

A 12-volt DC power supply is essential for servicing car stereo equipment or car radios. For ordinary car stereos or receivers, a 2A DC output is sufficient, but the TP-32 requires at least 4A, and the power booster model AD-304 requires a maximum power output of 6A. A 12-volt car battery may be used as a power source, but it must be recharged and topped up with battery water from time to time. For this reason, a transistorized regulated power supply is more practical. Use of a simple rectifier with a smoothing capacitor is not recommended for servicing, because its output contains heavy rippling and the voltage regulation is poor. A suitable voltage regulated DC power supply can easily be made by hand from readily available parts.

Fig. 8 DC power supply for car stereo



IN THE NEXT ISSUE

Service-technical magazines will be published periodically starting from this year. These are aimed at improving the quality of servicing and providing close communication with the Pioneer service engineers. They are intended to provide self-training aids for shop engineers.

Hot topics will be included whenever possible for the benefit of overseas service engineers, and we are hoping to see a rapid growth in the magazine's contents. If you have any suggestions or comments, please let us know. Any contributions will be greatly appreciated, too.

Publisher
IKKI NAGASHIMA

Service Section
Administration Dept.
International Division

EDITOR'S NOTE

Contrary to our original estimate, it took much longer to get this issue into print than was expected.
I discovered that editing a technical magazine like this was much more difficult than we had imagined. Starting from scratch, it was a painstaking, time-consuming task. However, the mission was accomplished, and here at long last is the result.
The same kind of thing holds true, of course, in everyday servicing activities. A lot of effort and energy are needed to acquire all the skills and knowledge required a service technician today, along with the ability to improve the system and get away from old traditions.
The purpose of this magazine is to refresh your technical knowledge and improve your service systems. No longer will the old, conventional way do. We must change with the times. Find newer, better ways of carrying out daily servicing activities. Hopefully, this magazine will serve that purpose.
In the process of injecting new ideas into the system, we will no doubt encounter many problems and difficult tasks. But we are all professionals.
It is our job to overcome them.

Tatsuo Taguchi
Hitomi Koike

Correction of TUNING FORK

page columm line	error	correction
10 Fig. 12 Fig. 13	by load capacitance by load resistance	by load resistance by load capacitance
10 3 10 Fig.14 Fig.15	SHURE V-III SHURE V-III SHURE V-III	SHURE V-15III SHURE V-15III SHURE V-15III
10 Reference	3. When using a cartridge for which the load capacita-nce is specified, the CAPAC-ITANCE LOAD switch should be set to the nearest corre-sponding value.	3. When using a cartridge for which the load capacita-nce is specified, the CAPAC-ITANCE LOAD switch should be set to the nearest corre-sponding value, after subtr-ucting cord capacitance from the specified.
10 1 2	clipping	crossover
19 1	$E' = 300 \times \dfrac{\frac{200 \times 500}{200 + 1500}}{\frac{200 \times 1500}{200 + 1500} + 100} =$	$E' = 300 \times \dfrac{\frac{200 \times 1500}{200 + 1500}}{\frac{200 \times 1500}{200 + 1500} + 100} =$
19 Fig.1	Multimeter Sunt Rectifier	Multiplier Shunt Rectifier and Multiplier
19 2 19	(average value,rms)	(mean value indicating, effective value scaling.)

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