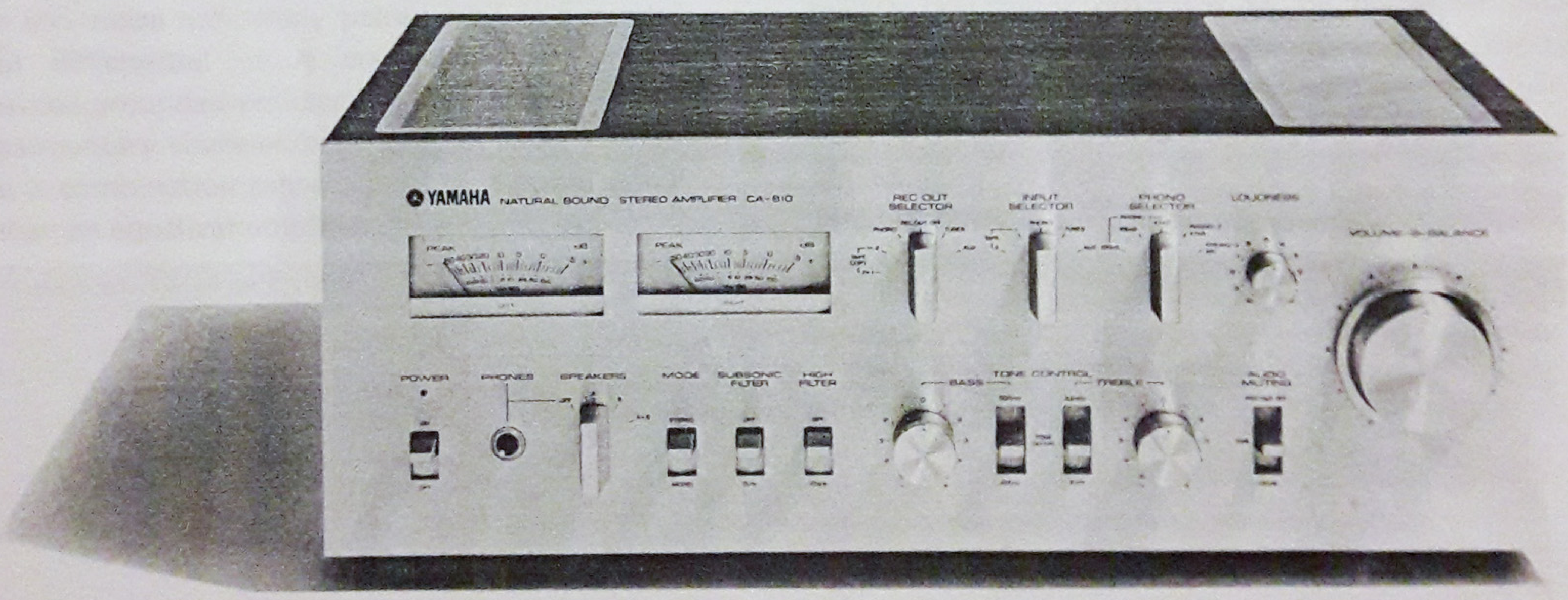
TECHNICAL REPORT

NATURAL SOUND STEREO AMPLIFIER

YAMAHA CA810



A TECHNICAL ANALYSIS OF THE CA-810

CIRCUIT CONFIGURATION

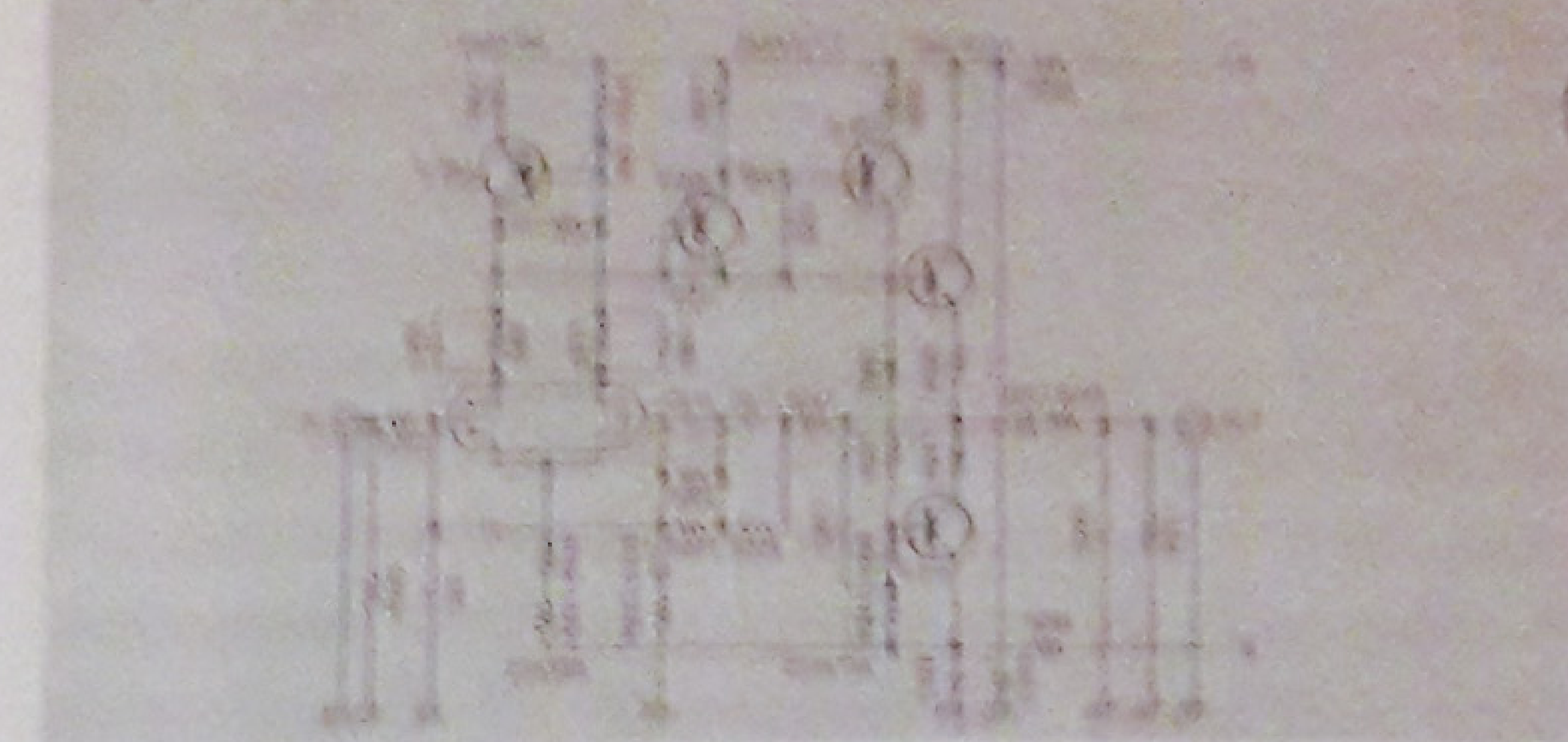
The basic circuit configuration, as will be clear from the block diagram, consists of the equalizer amplifier, buffer amplifier, tone control amplifier, power amplifier section, and a super low noise moving coil (MC) cartridge integrated circuit (IC) head amplifier. Each unit amplifier embodies special low noise, low distortion design, and performance characteristics set new standards both for the transient response and stability of individual units, and for the overall performance.

1. The Equalizer Amplifier

A low noise equalizer circuit with 95 dB signal-to-noise ratio (for rated 10 mV input) or −135 dB/V in terms of the input level.

The equalizer circuit uses a specially developed super low noise accurately paired FET in a current-mirror differential input stage, with Darlington-connected grounded emitter amplifier stage and fully complementary single-ended push-pull (SEPP) output stage, a combination more typical of a power amplifier than an equalizer amplifier.

Fig. 2 Equalizer Amplifier Circuit Diagram



The dual FET used in the first stage differential amplifier was developed specially by Yamaha for this low noise audio amplifier application. In comparison with conventional multi-use FETs, which are used in a wide number of different electronic circuits, it has a very large *gm* and despite this the two members of the pair have extremely closely matched pair characteristics. This is usually particularly difficult to achieve with high *gm*. It also has extremely low noise level levels (particularly in the suppression of 1/*f* noise). The first stage super low noise dual FET differential amplifier is built into a sub-assembly using current-mirror circuitry. The use of this circuit enables the input capacitor to be dispensed with (input-capacitorless: ICL) for direct coupling, and in particular the current-mirror circuit ensures fully adequate gain, also functioning much as a push-pull circuit does, cancelling out the even-harmonic distortion content.

Fig. 1 Block Diagram of the CA-810

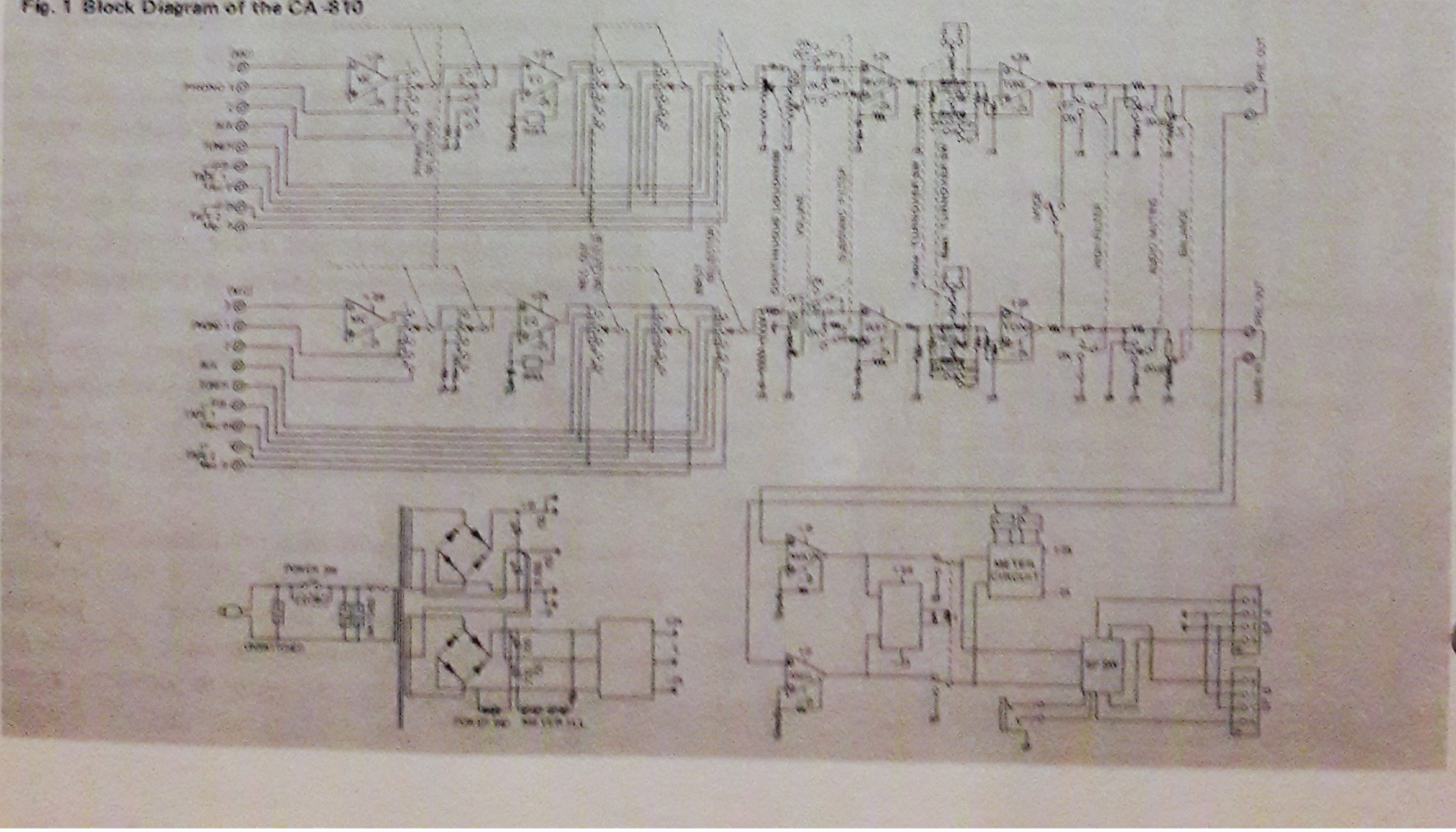
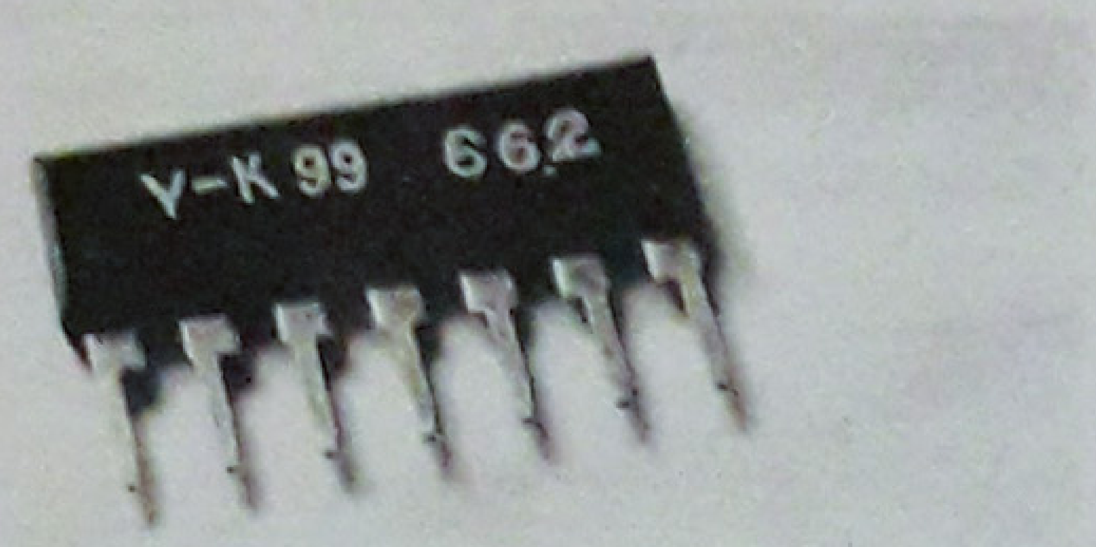


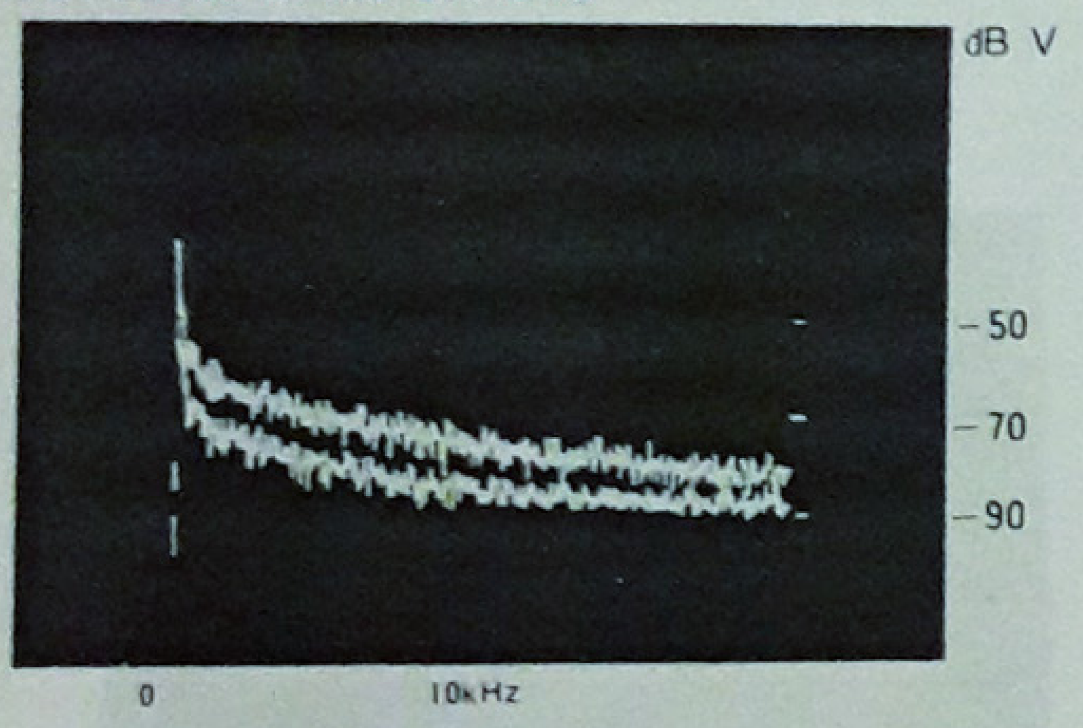
Fig. 3 The Super Low Noise Dual FET



The input impedance of the second stage is high, reducing the load on the first stage while ensuring adequate gain, by the use of low noise PNP transistors in a Darlington-connected grounded emitter configuration.

The load on the equalizer amplifier output stage consists of the level-setting volume control and the input impedances of the tape decks connected to the REC OUT terminals, etc. The low output impedance of 600Ω is achieved by the use of PNP and NPN transistors in a fully complementary SEPP configuration. As well as securing the very highest audio quality, this also assures fully adequate 'drive' of the later stages connected to the equalizer amplifier output.

Fig. 4 Spectral Distribution of Noise in the CA-810



Δf : 30 Hz
Upper trace:
5.1 kΩ short
Lower trace:
Short circuit

The utilization of super low noise paired FET and design constants directed at achieving the lowest possible noise in each individual section have resulted in a signal-to-noise ratio of 83 dB (IHF-A network) for an input sensitivity of 2.5 mV. This astonishingly high value means that records can be enjoyed against a velvet smooth, silent background. Just how great the achievement is can be seen by re-calculating the noise level in terms of input levels: the figure is −135 dB/V, putting the CA-810 right at the top of the state-of-the-art. This super low noise level is an improvement of anything from 5 to 10 dB over most of the competition (a reduction of from one half to one third!).

The justification for this unorthodox circuit configuration lies in the inevitable trade-offs and compromises of conventional equalizer circuit design. The negative feedback equalizer requires different gain at different frequencies, so that stable negative feedback cannot be applied, and imposing severe limits to the degree of improvement possible in distortion and transient response. Attempts to reduce costs by oversimplification of the circuitry reduce the open-loop gain of the amplifier (i.e. the 'raw' performance before negative feedback is applied) at low frequencies, so that adequate NF cannot be applied, and distortion increases. In the high frequencies, too, the degraded frequency response means that gain is inadequate, and the circuit elements responsible for generating the NF themselves add to the load on the amplifier, resulting not only in increased distortion, but also in a greatly reduced dynamic margin. The latter shows up as distortion for high input levels . . . a 'blurring' of peak sound levels.

In the CA-810 these problems have been solved by the use of current-mirror circuitry, Darlington connection, grounded-emitter amplification, etc., giving an amplifier whose open-loop gain and frequency response are ideally suited for the application of optimum NFB, and resulting in exceptionally good distortion figures. For all frequencies from 20 Hz to 20 kHz, the distortion is no more than 0.005%. Dynamic margin, too, is abundantly adequate for high output level cartridges even with the latest high cutting-level discs. The figures show this very clearly (a typical example from a competitive product has been included for comparison).

Fig. 5 Total Harmonic Distortion from PHONO to REC OUT Terminals for the CA-810

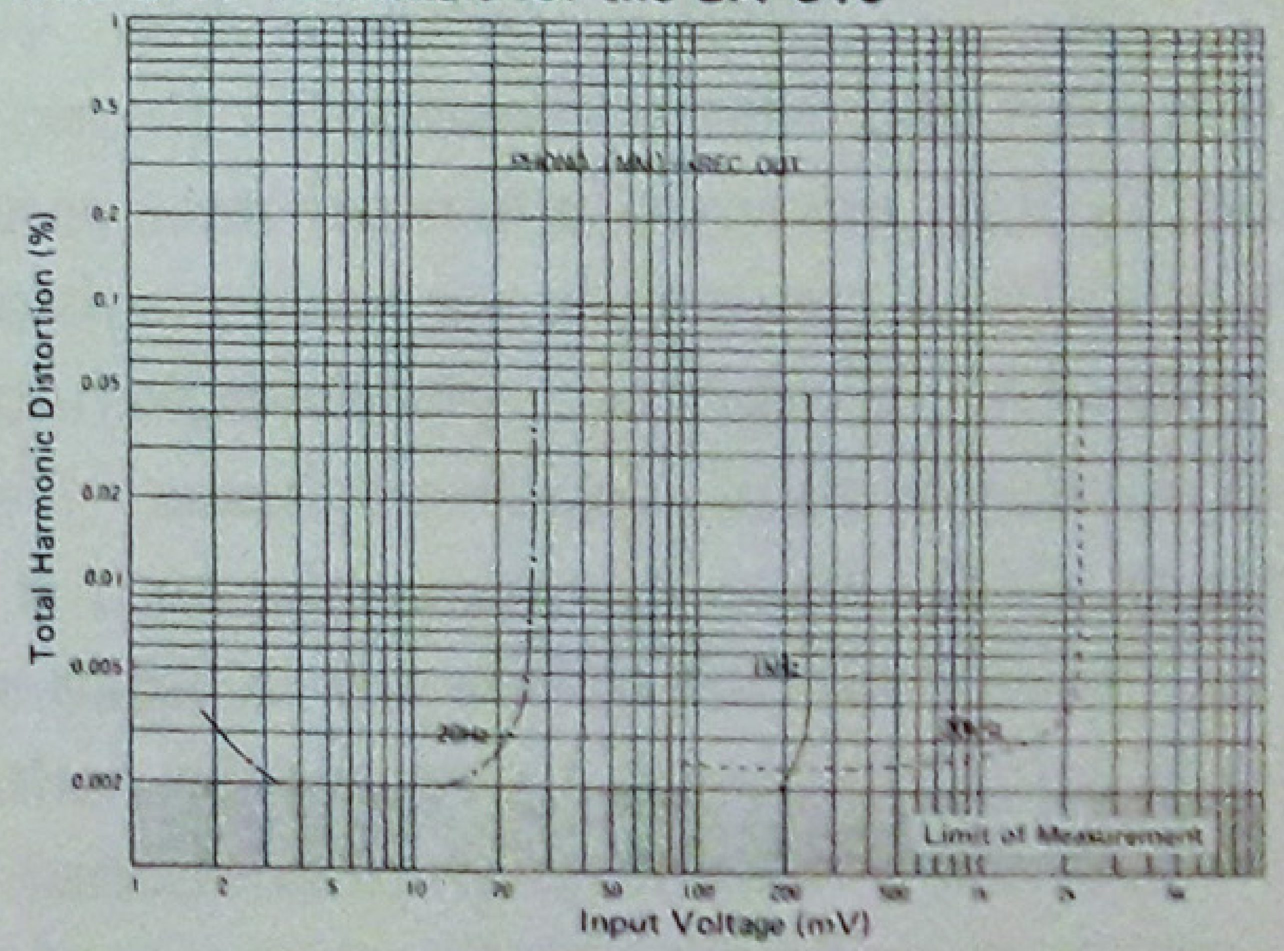
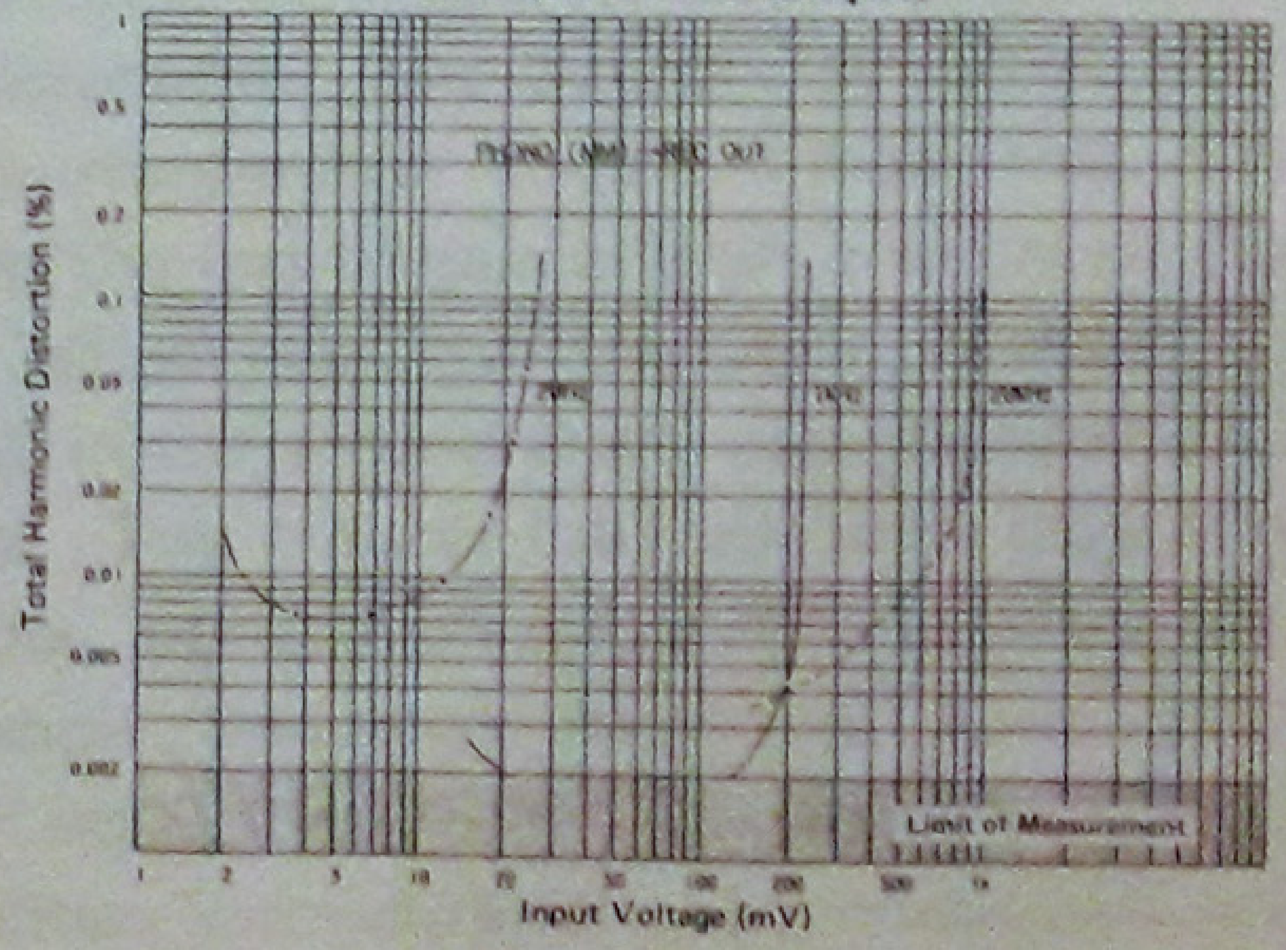
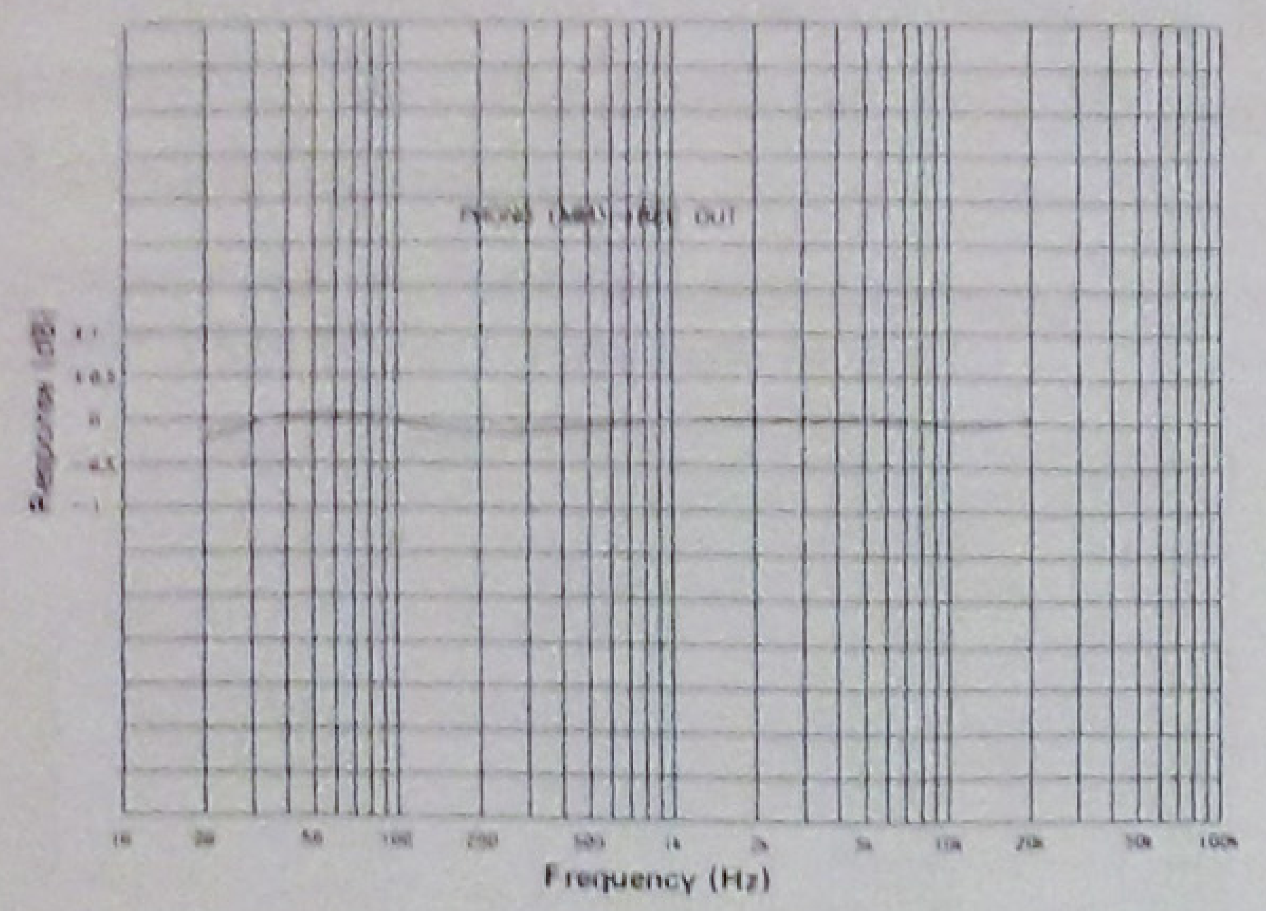


Fig. 6 Total Harmonic Distortion from PHONO to REC OUT Terminals (a Poor Example)



The RIAA deviation, too, has been reduced to no more than ±0.3 dB over the full frequency range by the use of ±1% tolerance metal film resistors and styrol capacitors.

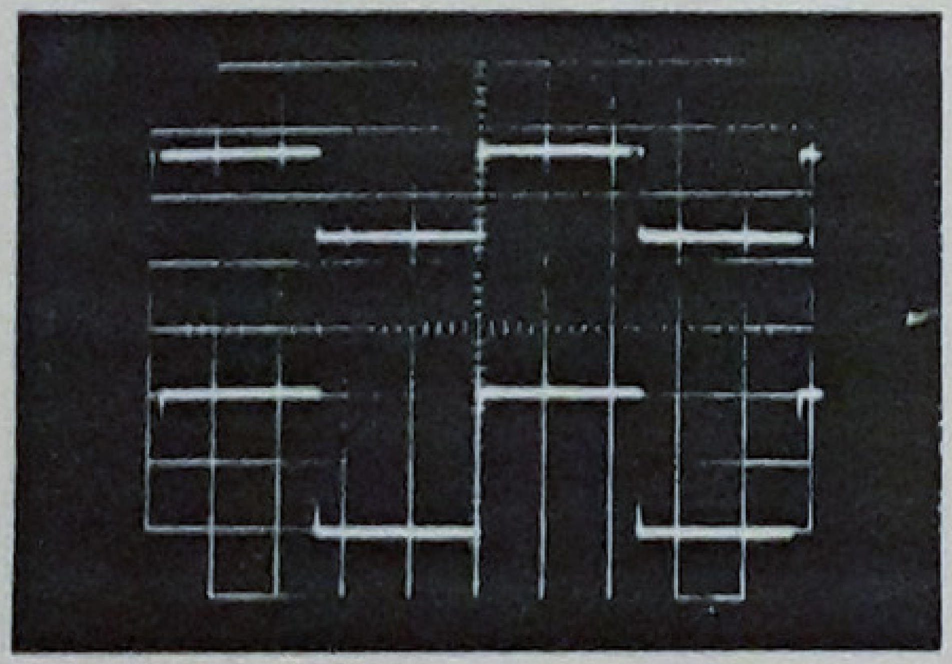
Fig. 7 RIAA Deviation



The equalizer amplifier also has an outstandingly good inverse-RIAA square-wave response. This square-wave response is shown at 1 kHz in Figure 8. Such a perfect reproduction of the original square-wave is proof of the wide dynamic range and the superior frequency response.

Fig. 8 Inverse-RIAA Square-Wave Response at 1 kHz, PHONO to REC OUT Terminals

Vertical Sensitivity:
Upper; 20 mV/div.
Lower; 1 V/div.
Horizontal Sensitivity:
0.2 ms/div.



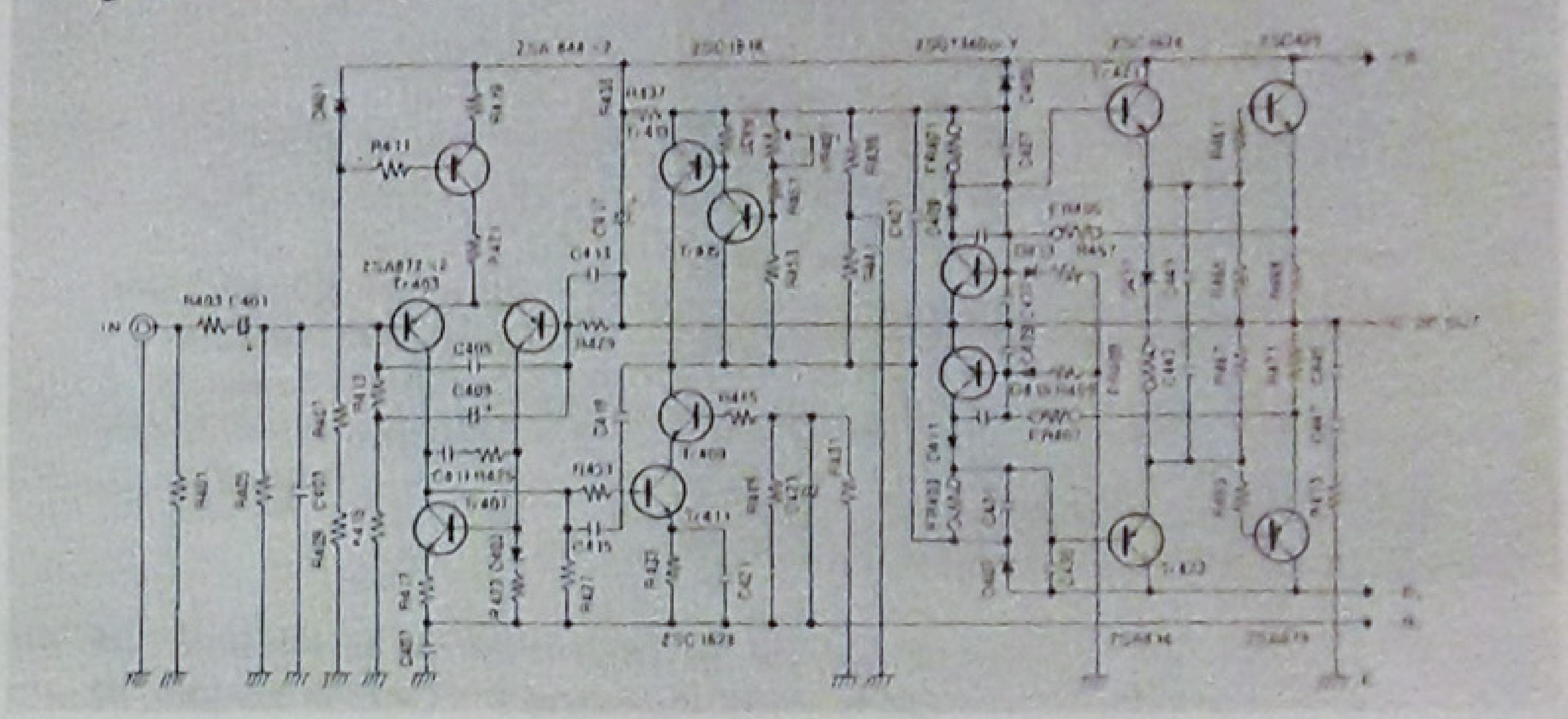
In the CA-810, attention has been given not only to the circuit design and the choice of components, but also to the physical location. In direct contact with the rear panel, the need for shielded wiring is eliminated. The pattern of the printed circuit board, too, has been specially developed for the minimum noise and distortion, and overall magnetic shielding of the individual functional sheets is further evidence of the Yamaha preoccupation with any detail which will result in better performance.

2. The Power Amplifier Section

Fully complementary output-capacitorless (OCL) single-ended push-pull power amplifier with 65 Watts minimum rms power per channel, both channels driven, with no more than 0.05% distortion from 20 Hz to 20 kHz.

The power amplifier section circuit configuration comprises a first stage constant-current bias current-mirror differential amplifier, a pre-drive stage with cascode-connected constant current load circuit, and a Darlington-connected fully complementary single-ended push-pull (SEPP) output-capacitorless (OCL) drive/output stage. It also features a potential-current (PC) limiter transistor protection circuit. The circuit diagram is given in Fig. 9.

Fig. 9 Power Amplifier Circuit Diagram



The first stage is specially designed for adequate gain and low distortion by the use of a pair of PNP transistors with closely matched electrical characteristics, forming a differential amplifier in a sub-assembly with constant-current bias and current-mirror circuit. Constant-current bias means that the impedance seen from the common emitter looking at the electrical power supply source is virtually infinite, with correspondingly negligable influence from changes in supply voltage. Supply voltage rejection (SVR) is thus exceptionally good. (SVR is explained in more detail at the end of this section.)

Another advantage of the current-mirror circuit is that it functions in much the same way as a push-pull circuit does, to cancel out harmonic distortion, forming a differential amplifier with high gain and equally low distortion. The output impedance of the first stage current-mirror circuit is high, and in order to prevent the loss of gain at high frequencies due to the Miller effect via the transistor feedback capacity (*Cobo*) in the second stage, cascode-type connection is used. This ensures fully adequate gain at high frequencies, and enables stable NFB to be applied across the whole frequency spectrum. The drive/power output stage uses SEPP OCL circuitry in a fully complementary configuration, and employing transistors with excellent switching characteristics in specially selected closely matching pairs. The result is a level of distortion which can only just be measured at the lower limit of detection on a high quality distortion meter. The benefits this pays in pure audio quality and that elusive sense of 'presence' must be heard to be appreciated, but the graph in Fig. 10 gives some idea of the performance.

Fig. 10 Output Power vs. Total Harmonic Distortion, MAIN IN to SP OUT Terminals (into 8 Ω)

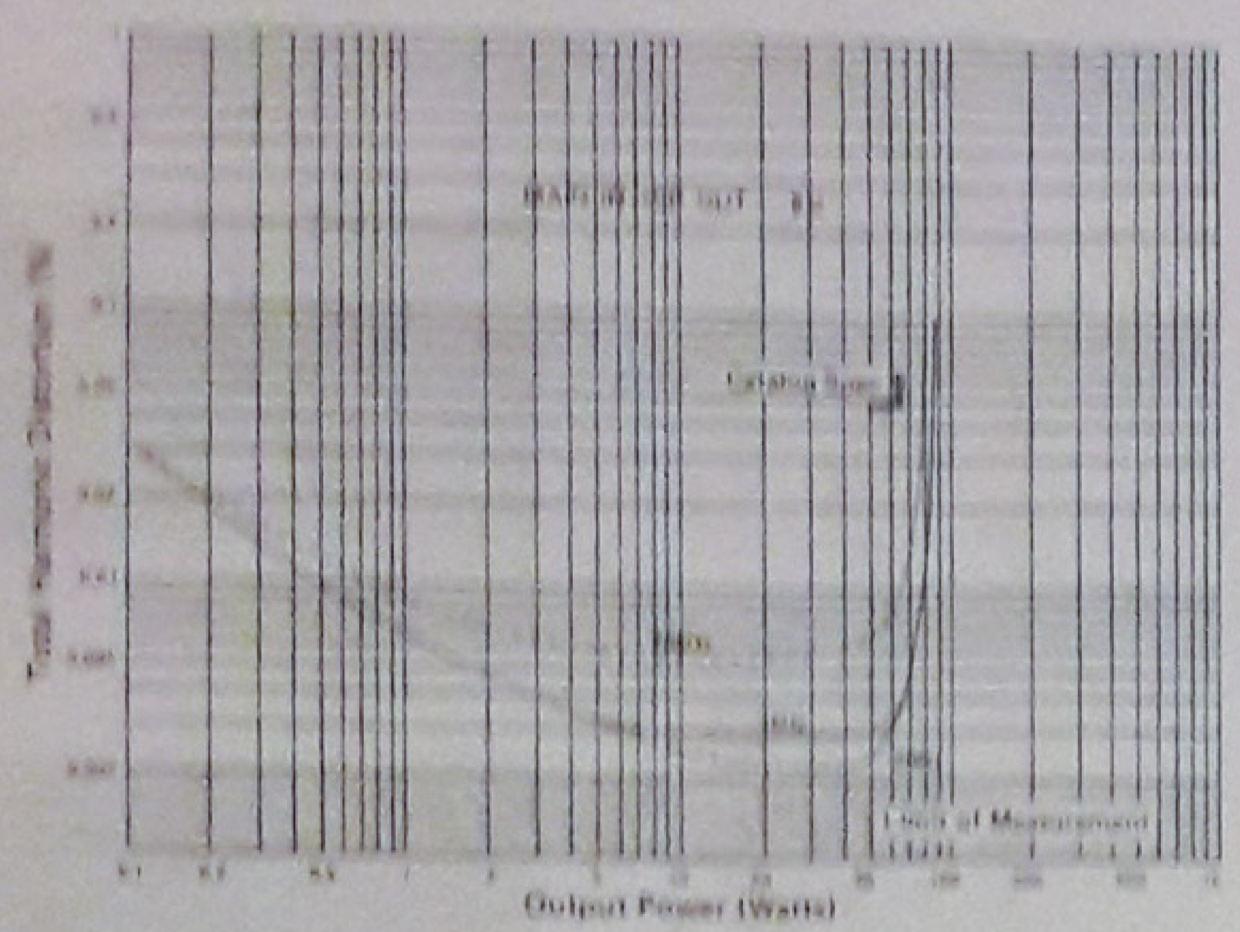


Fig. 11 Frequency vs. Total Harmonic Distortion, MAIN IN to SP OUT Terminals (into 8 Ω)

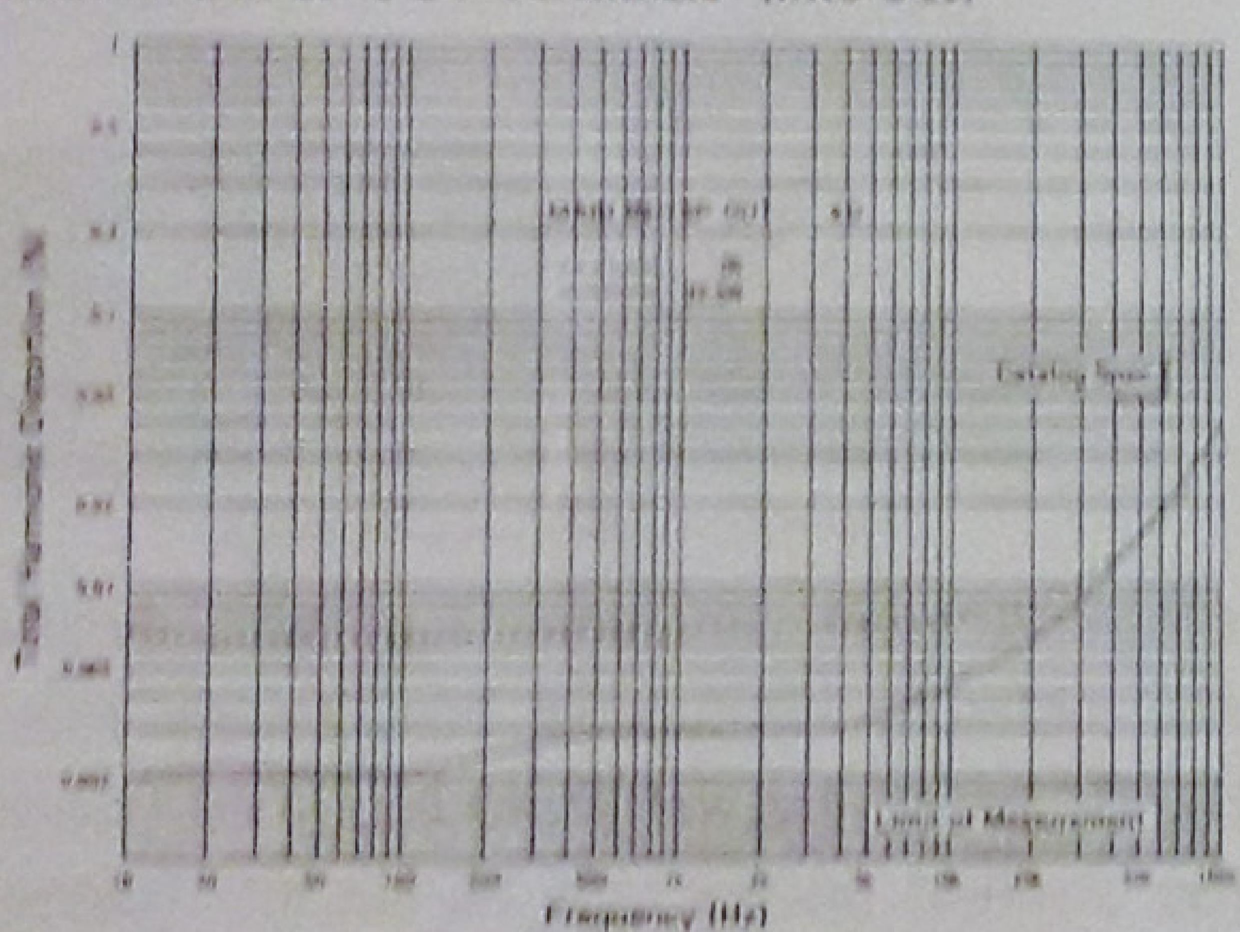
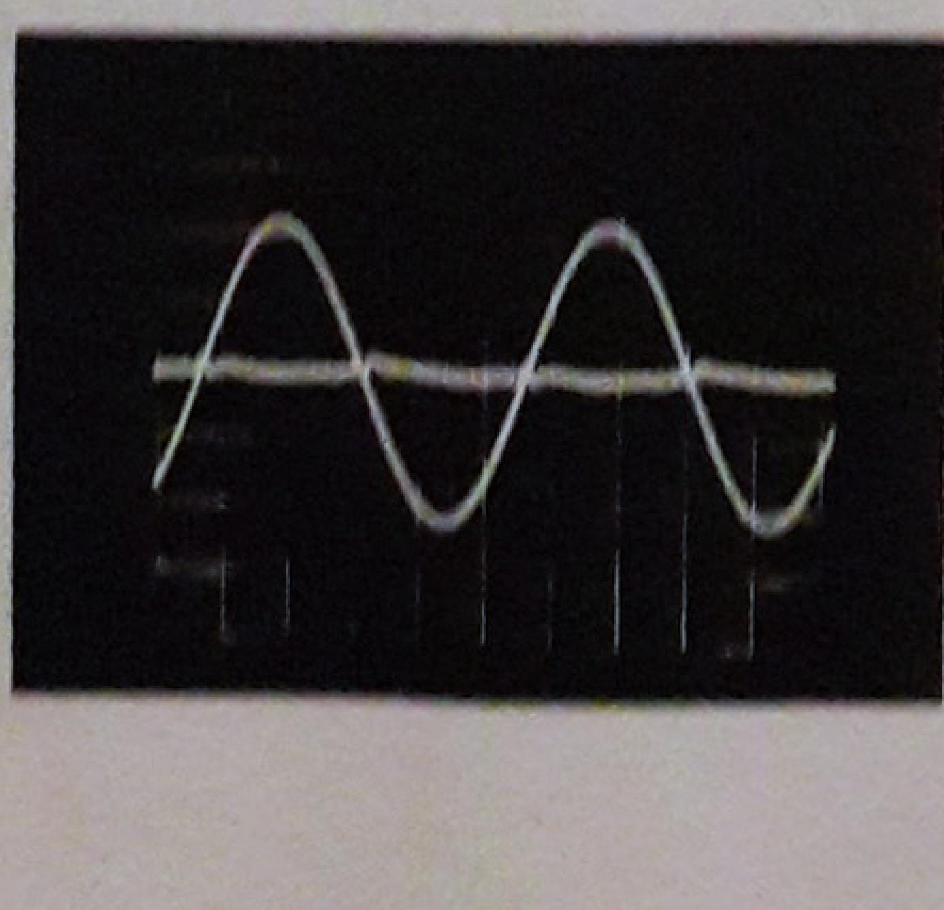


Figure 11 shows the comfortable margin by which a typical CA-810 exceeds the catalog specification at output powers of 1 and 32.5 Watts (the latter only 3 dB below full output power).

Fig. 12 Power Amplifier Section Distortion Waveform at 20 kHz, 32.5 W (into 8 Ω)

Vertical Sensitivity:
1 V/div.
Horizontal Sensitivity:
10 µs/div.
Distortion: 0.0067 %



Not only is distortion extremely low, the waveform is smooth and extremely beautiful. The almost complete absence of switching and crossover distortion makes the waveform good to look at — and even better to hear. The figure shows the waveform at 3 dB below full power, at 20 kHz.

Figs. 13 and 14 show the square waveform response at 10 kHz and at 40 Hz. In each case the original (input) waveform is the upper trace. Fig. 15 illustrates the complete stability of the CA-810 in the face of a capacitative load: even with 0.1µF across the normal 8Ω load there is absolutely no 'ringing' or instability.

Fig. 13 Square-Wave Response at 10 kHz, MAIN IN to SP OUT Terminals (into 8 Ω)

Vertical Sensitivity:
Upper; 0.5 V/div.
Lower; 10 V/div.
Horizontal Sensitivity:
20 µs/div.

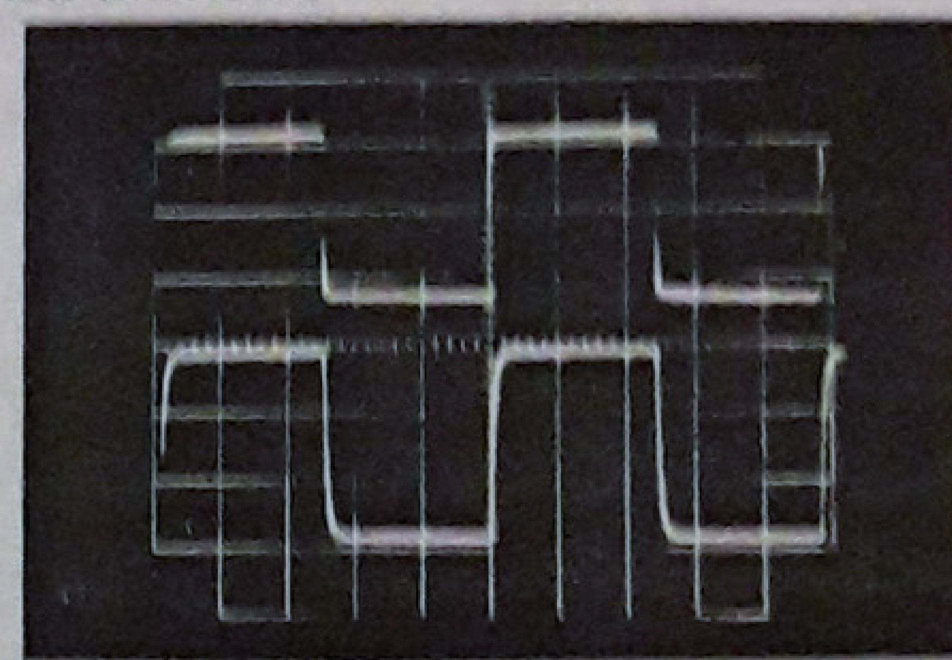


Fig. 14 Square-Wave Response at 40 Hz, MAIN IN to SP OUT Terminals (into 8 Ω)

Vertical Sensitivity:
Upper; 0.5 V/div.
Lower; 10 V/div.
Horizontal Sensitivity:
5 ms/div.

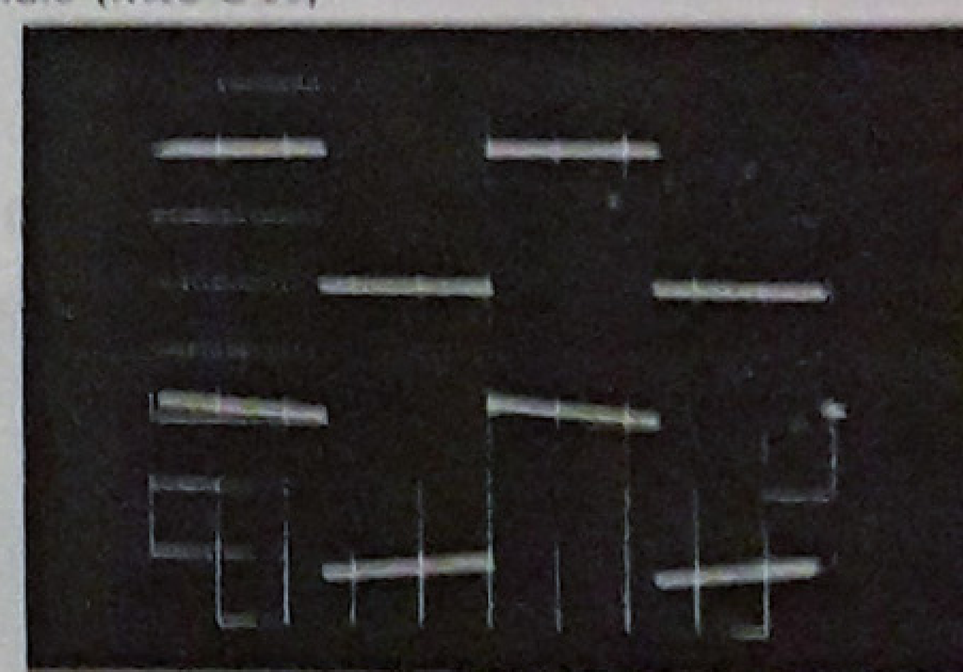
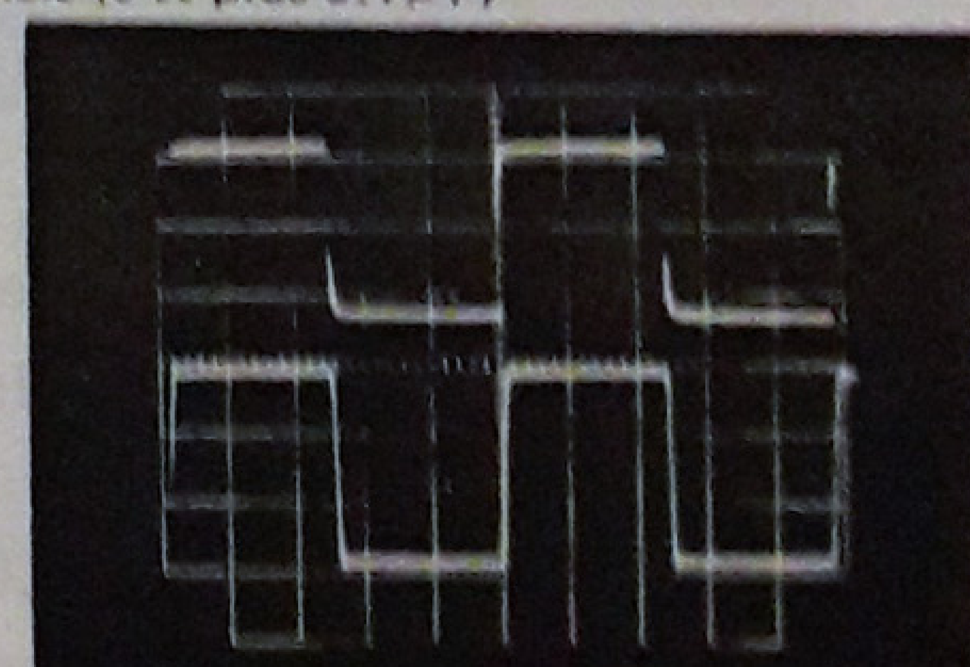


Fig. 15 Square-Wave Response at 10 kHz, MAIN IN to SP OUT Terminals (8 Ω plus 0.1 µF)

Vertical Sensitivity:
Upper; 0.5 V/div.
Lower; 10 V/div.
Horizontal Sensitivity:
20 µ s/div.

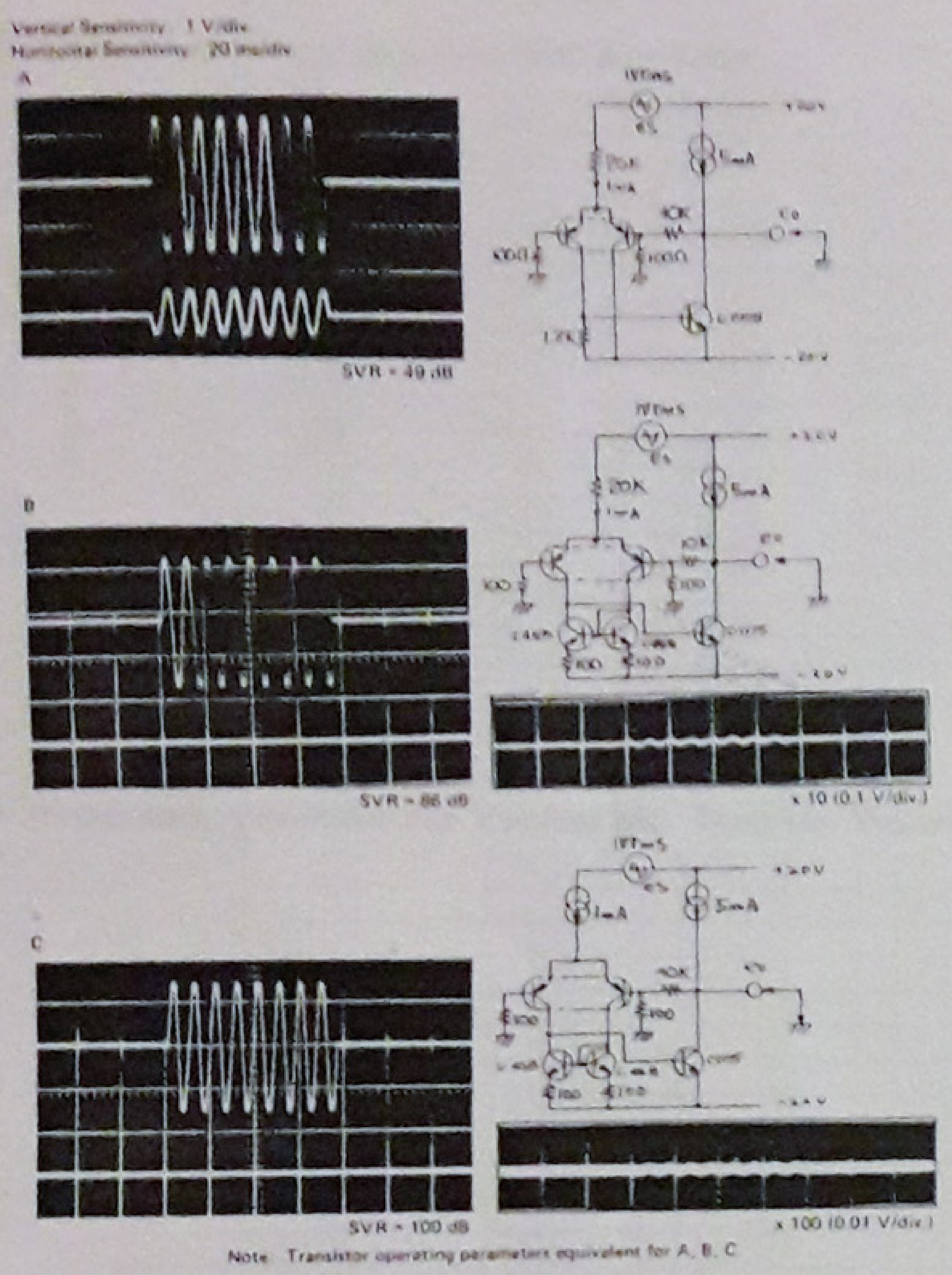


Supply Voltage Rejection (SVR) and Dynamic Cross-talk

SVR is a term which gives a measure of the extent to which amplifier performance is independent of power supply voltage variations. Expressed in dB, it is based on the change in the INPUT signal level to the amplifier which would produce the same change in OUTPUT level as that produced by a 1 V change in supply voltage. Fig. 16 shows three different circuits A, B, and C, and illustrates what the SVR ratio means are typical of those used in many competitive products: the CA-810, however, uses the type-C circuit, with clearly obvious advantages for the superior SVR.

Dynamic crosstalk, on the other hand, is a term which expresses the extent to which a signal in one channel influences the output from the other channel. In this it is the same as regular inter-channel crosstalk, but with dynamic crosstalk, the signal is generally a

Fig. 16 Various Circuits and SVR Ratios



more pulsive one (a tone-burst, etc.) than the continuous sine waves used for regular crosstalk measurements. Both forms of crosstalk are primarily affected by the actual details of the wiring layout, with the wiring carrying one signal inducing a corresponding signal in the wiring for the opposite channel, and by any impedances the two channels may have in common. While these two sources are responsible for by far the biggest percentage, the details of circuit design can also have an effect: for instance, if a pulsive signal in one channel causes a change in supply voltage, that change can give rise to a corresponding dynamic crosstalk signal in the opposite channel. In the CA-800, this effect has been virtually eliminated by making SVR as large as possible. Certain competitive amplifiers, however, separate power supplies for the two channels into two sections (the so-called dual power supply design). In the latter, however, the need to reduce costs can lead to the use of inferior components in the two power supplies which seriously curtails the dynamic range of BOTH channels.

3. Moving Coil (MC) Cartridge Head Amplifier

73 dB Signal-to-noise ratio (for 60 μV input sensitivity), −157.4 dB/V in terms of input level.

Moving Coil (MC) type cartridges, which generally have much lower outputs than Moving Magnet (MM) or other common types of cartridge, are catered for by this special head amplifier, which uses a Yamaha original super low noise integrated circuit (IC). For the rated input of 60 μV, the signal-to-noise ratio is a full 73 dB, (IHF, A network), similar to the S/N ratios quoted by many competitive amplifiers for the MM PHONO input! Re-calculate the S/N in terms of the input level, and the astonishing figure of −157.4 dB/V is achieved. Here, too, Yamaha's unique technology is advancing the state-of-the-art, making the superb performance of the best MC cartridges available at no extra cost to the user.

Fig. 17 The Yamaha Super Low Noise IC Amplifier

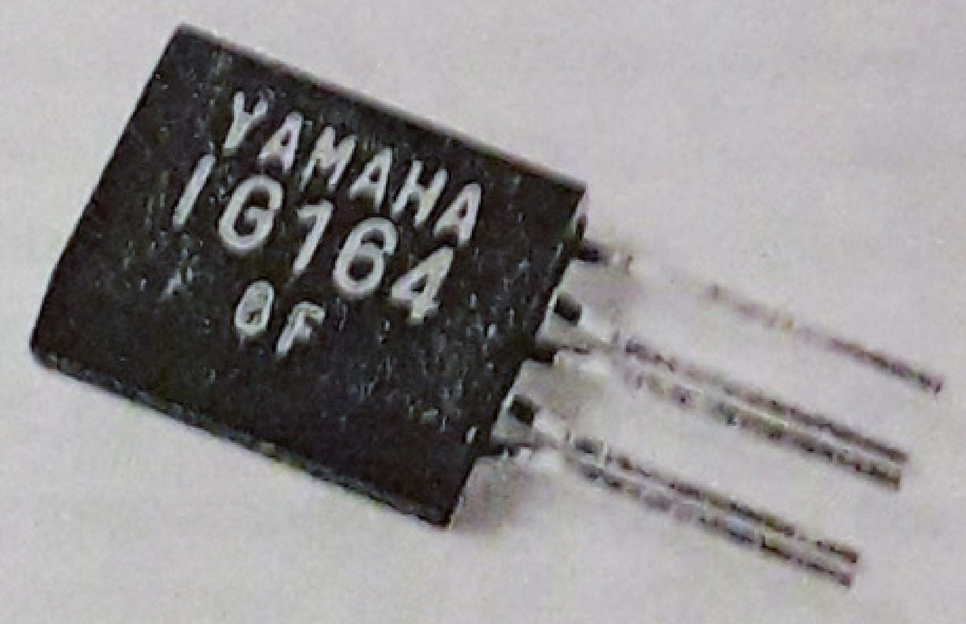
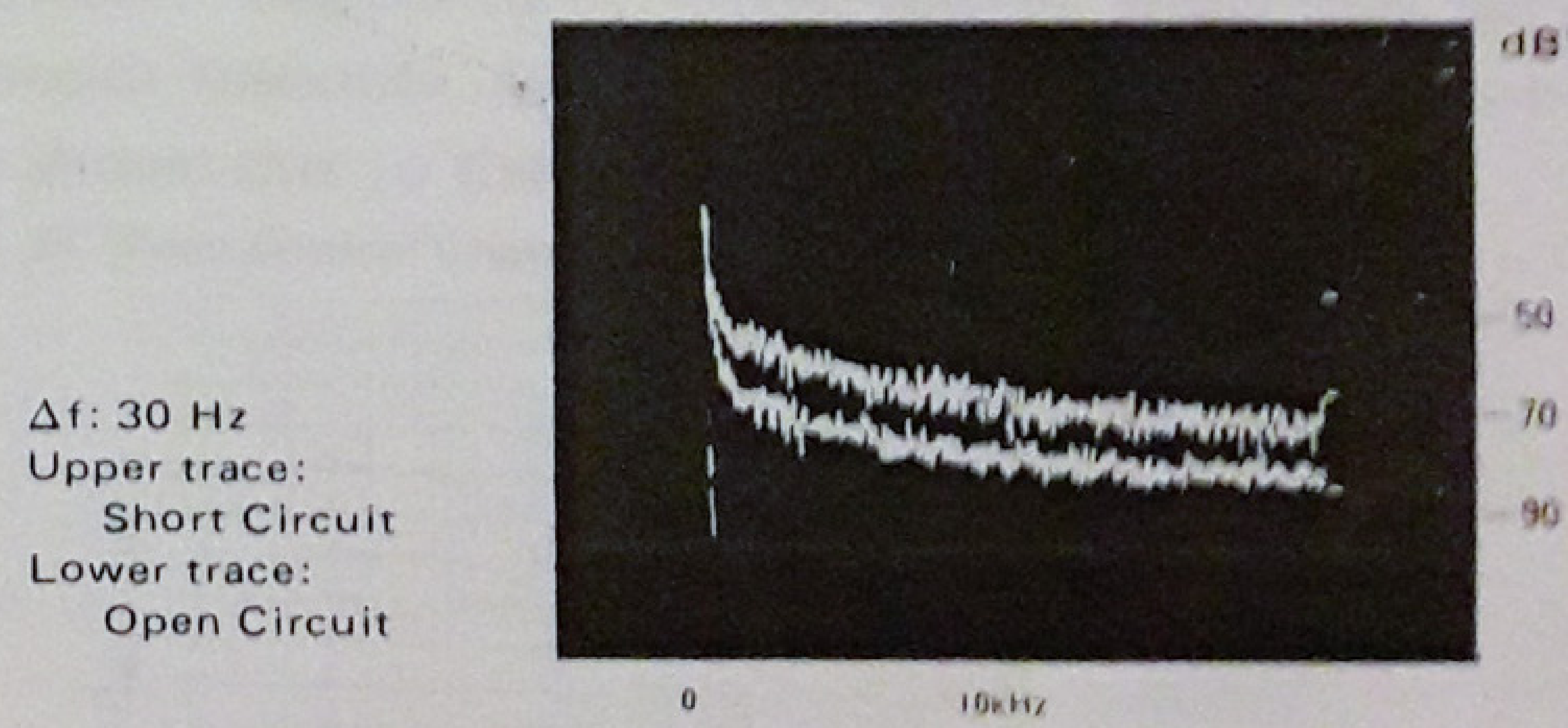


Fig. 18 Spectral Distribution of Noise for MC IN to SP OUT Terminals



In the past it was common for step-up transformers to be used with low output MC cartridges, due to the rather poor S/N of the head amplifiers then available (typically 55 to 60 dB). However, although the step-up transformer has a good S/N ratio, it is defective in terms of frequency response and distortion. Again, the impedances of the different makes of cartridge were different, and there are problems of impedance matching.

It is interesting to contrast the ruler-straight line of the MC amplifier frequency response with the corresponding graph for a typical step-up transformer. Note how the latter varies for different impedances, and how the response rapidly tails off near and beyond the top of the audio frequency spectrum.

Fig. 19 MC Amplifier Input Level vs. Total Harmonic Distortion

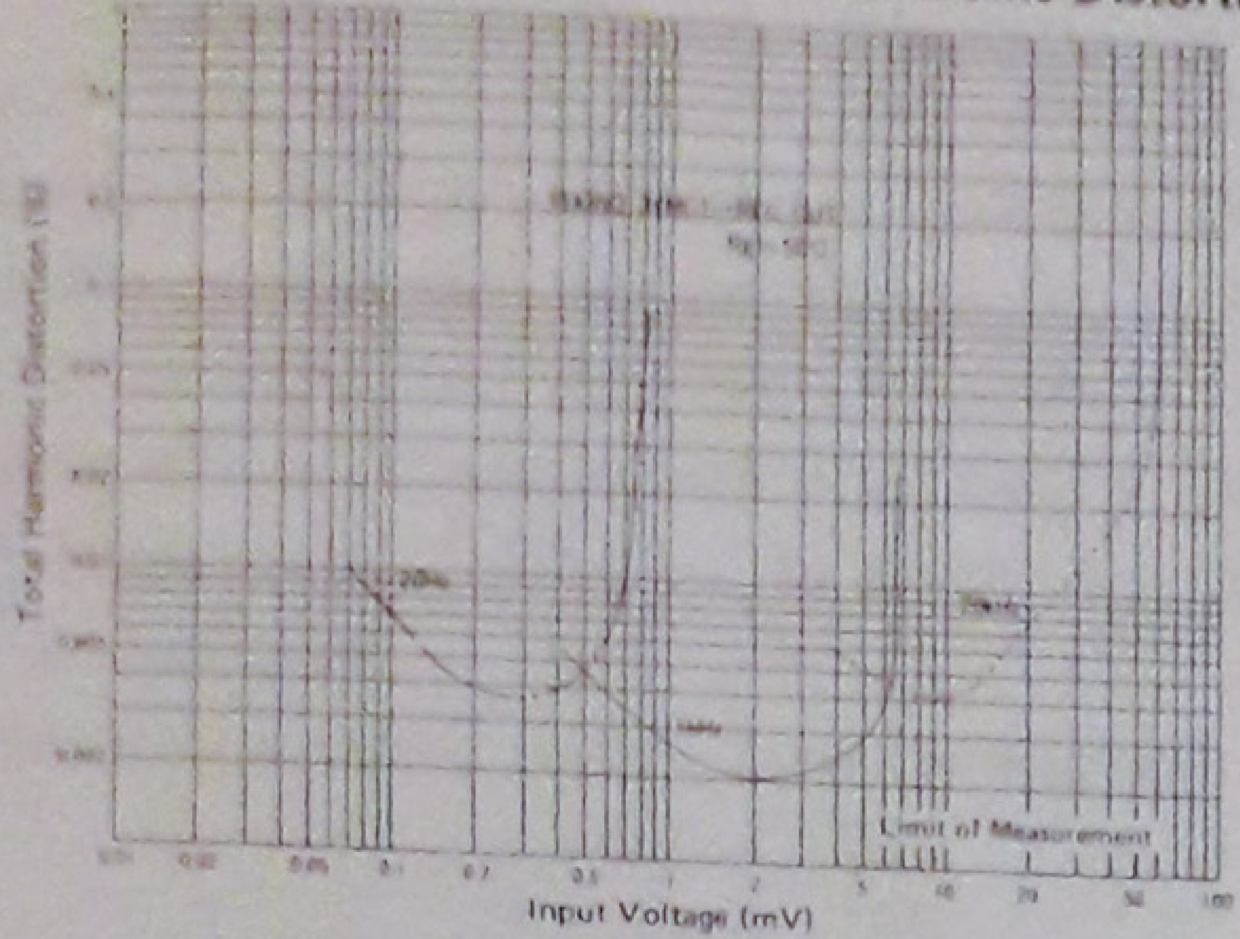


Fig. 20 Frequency Response of the MC Amplifier

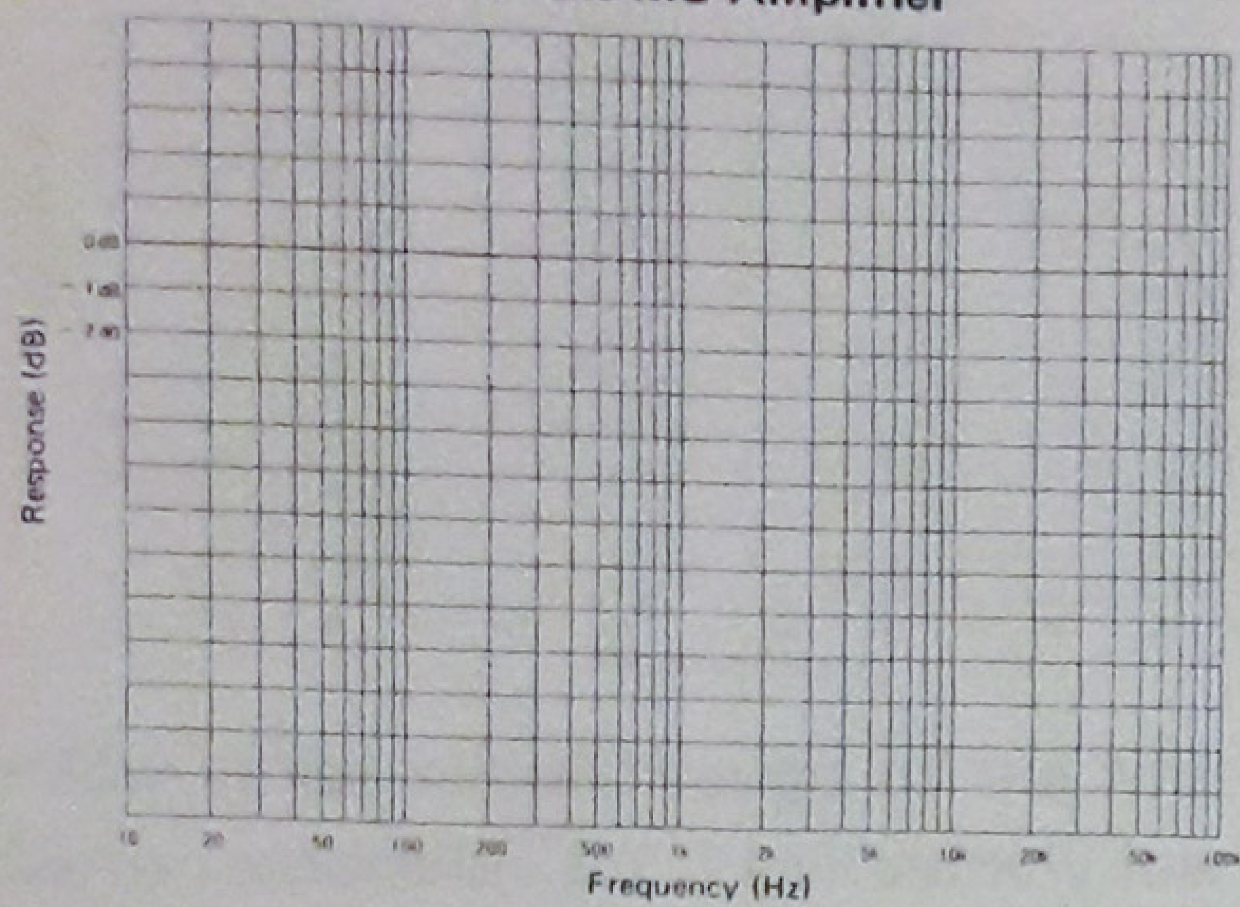


Fig. 21 Frequency Response for Typical MC Step-Up Transformer

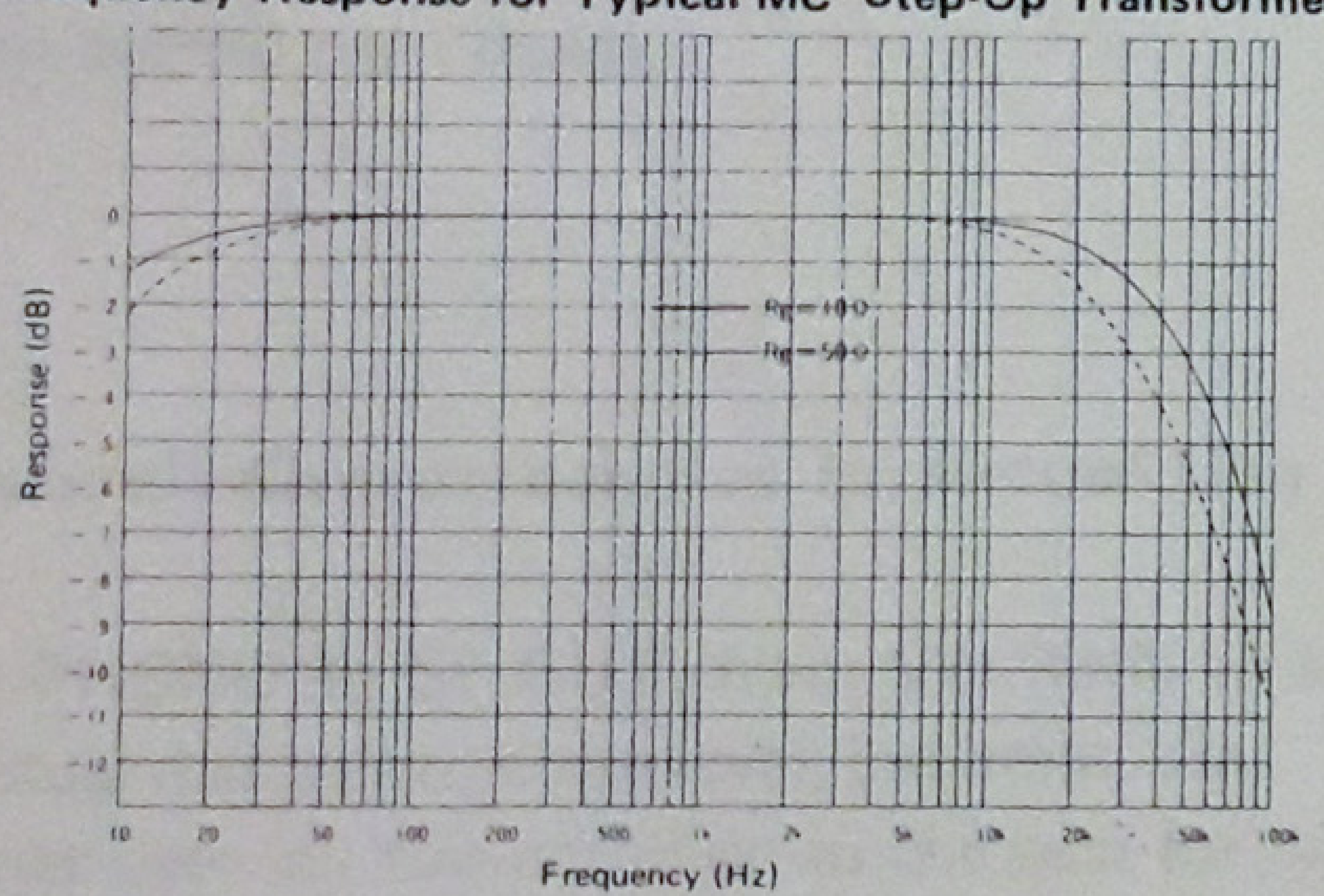


Fig. 22 Square-Wave Response at 10 kHz for the CA-810 MC Cartridge Head Amplifier

Vertical Sensitivity:
200 mV/div.
Horizontal Sensitivity:
20μs/div.

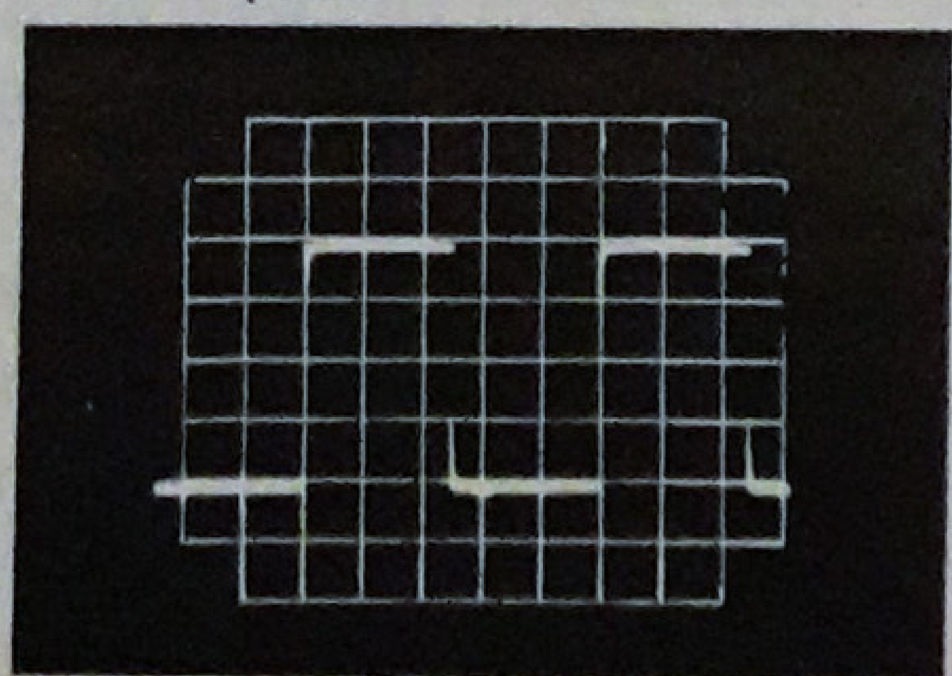
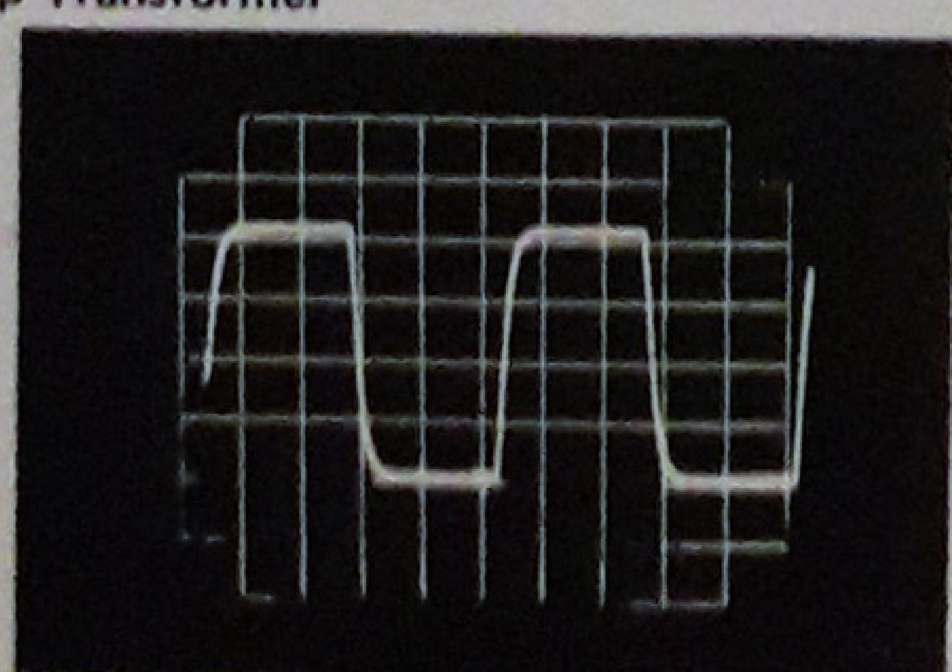


Fig. 23 Square-Wave Response at 10 kHz for an MC Cartridge Step-Up Transformer



Vertical Sensitivity:
200 mV/div.
Horizontal Sensitivity:
20 μs/div.

Since the big fall-off in response is well outside the audible frequency range, this might not appear such a disadvantage, but inspection of the square-wave response shows the inevitable degradation of the high frequency transient response this causes.

The MC head amplifier provided with the CA-810 has extremely high S/N ratio, and the frequency response is wide and flat (overall, from MC input to REC OUT terminals, the response is within ±0.3 dB). Distortion, too, sets new standards by being no more than 0.05% from 20 Hz to 20 kHz for a full 3 V output from the REC OUT terminals.

4. Tone Control Amplifier Circuit

Yamaha-type negative feedback tone controls with ideal characteristics

The circuitry used for the tone controls uses negative feedback to give smooth and precise control of tonal emphasis, with completely flat response in the defeat position (Note the separate defeat switches for Bass and Treble). Bass and Treble turnover frequencies are 125 Hz/DEFEAT/500 Hz, and 2.5 kHz/DEFEAT/8 kHz respectively. Continuous control up to a maximum boost and cut of ±10 dB is possible at 20 Hz and 20 kHz (with the 500 Hz and 2.5 kHz turnover frequencies). The figures show the very smooth response, but with finer gradations than can be shown due to the continuous control provided.

Fig. 24 Tone Control Characteristics f_{TO} 500 Hz and 2.5 kHz

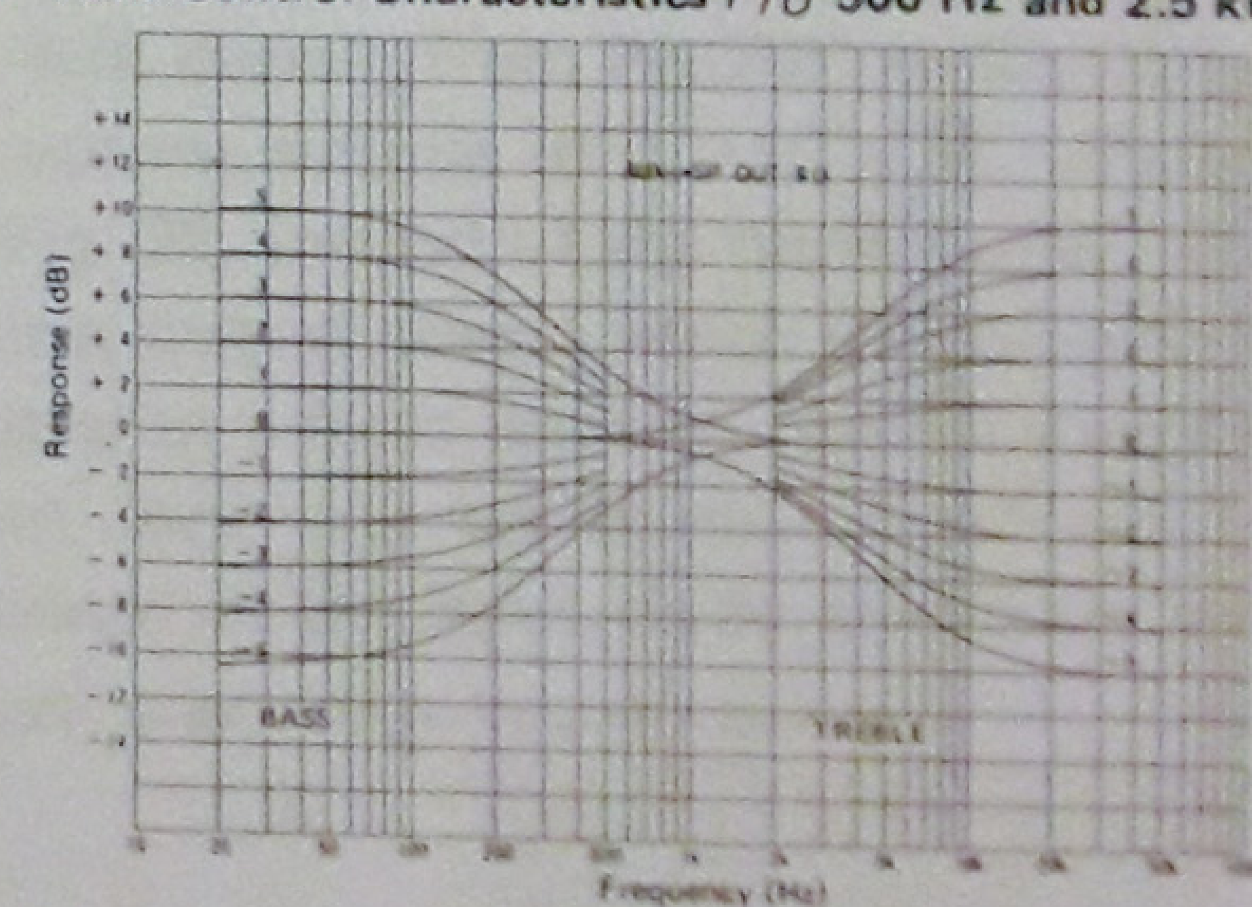
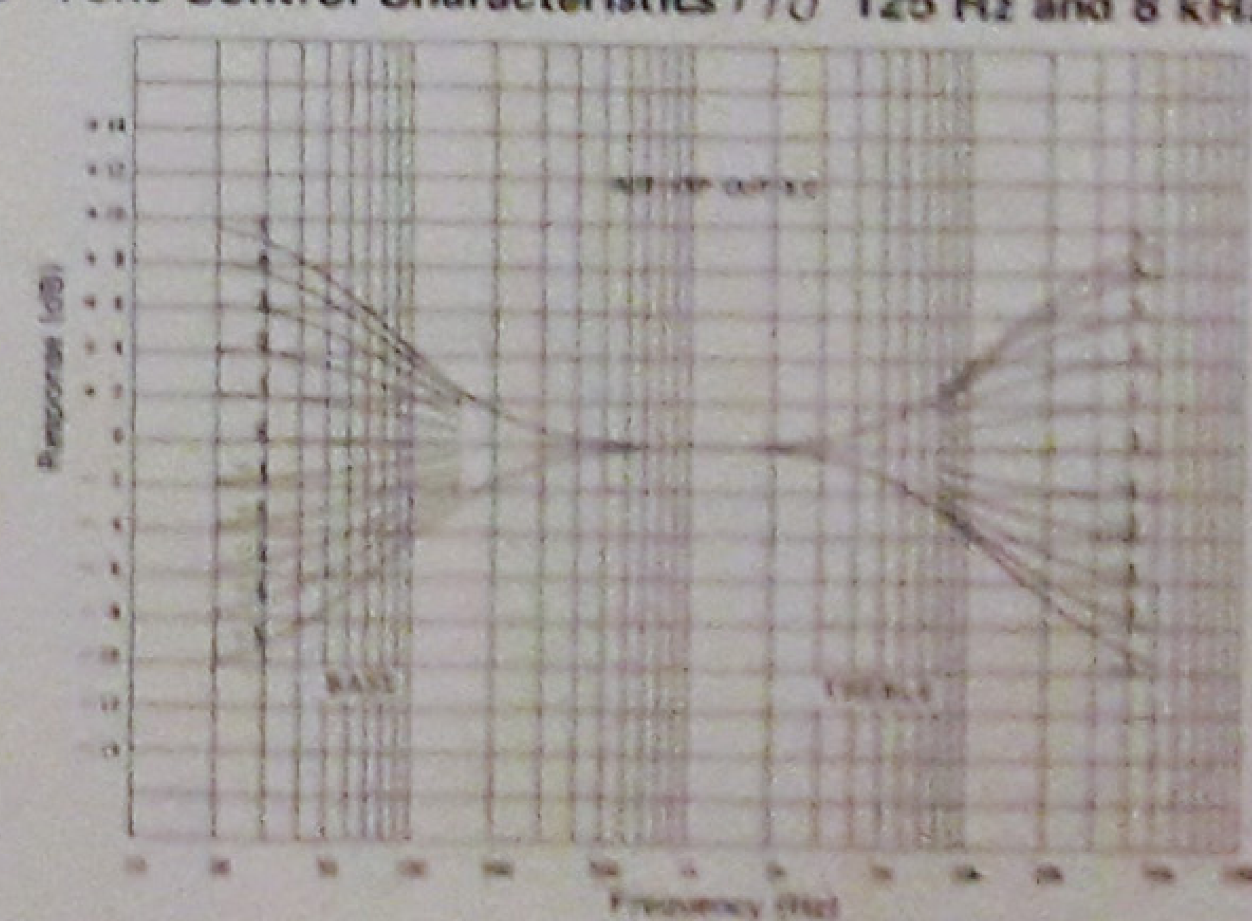
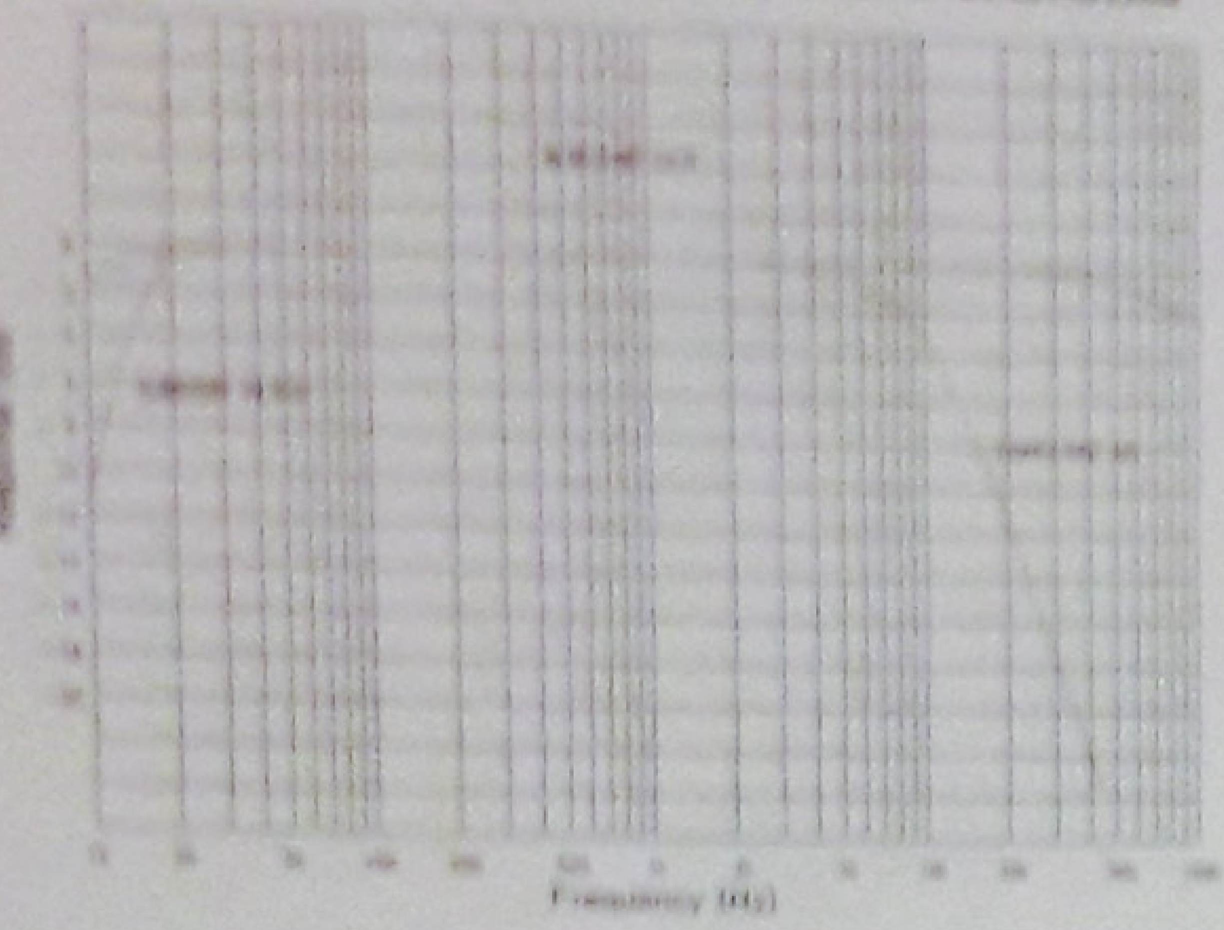


Fig. 25 Tone Control Characteristics f_{TO} 125 Hz and 8 kHz



The filters provided include a sub-sonic filter with a cut-off frequency of 15 Hz and sharp slope of 12 dB/octave to eliminate the unwanted sub-sonic frequencies which can be generated by warped or eccentric records, etc. The high frequency filter has a similarly sharp 12 dB/octave attenuation slope and cut-off frequency of 10 kHz to eliminate tape hiss, record scratch, etc.

Fig. 26 Sub-sonic and High Frequency Filter Characteristics



The low noise circuit design of the tone-control amplifier is responsible for the extremely low residual noise, only 0.2 mV at the SP OUT terminals with the volume turned right down.

5. Overall Characteristics in Actual Use

From PHONO to SP OUT, from Vol. MIN to MAX, the actual distortion, noise level, crosstalk, etc.

It has been all too common in the past for makers to confine their amplifier performance specifications to the individual sections (PHONO to REC OUT, and from MAIN IN to SP OUT, etc.). While these results are important, and they have been given fully here for the CA-810, of much greater importance for the listener are the overall performance characteristics.

It is absolutely untrue to claim that just because the individual performances of the different sections are good, the overall performance will also be good. The influence of the volume control and the tone control circuit, which are inserted, can have a dramatic effect on the overall performance characteristics. The reverse is much nearer the truth: good overall characteristics are the best guarantee that the performance of each individual section is outstanding. Again, conventional performance measurements are made with the volume in the maximum position, but in practical use the volume is always turned down.

For the CA-810 we have checked the overall performance characteristics for different volume setting positions, giving truly *overall characteristics* for actual use.

Fig. 27 Output Power vs. Total Harmonic Distortion for PHONO to SP OUT Terminals at 1 kHz

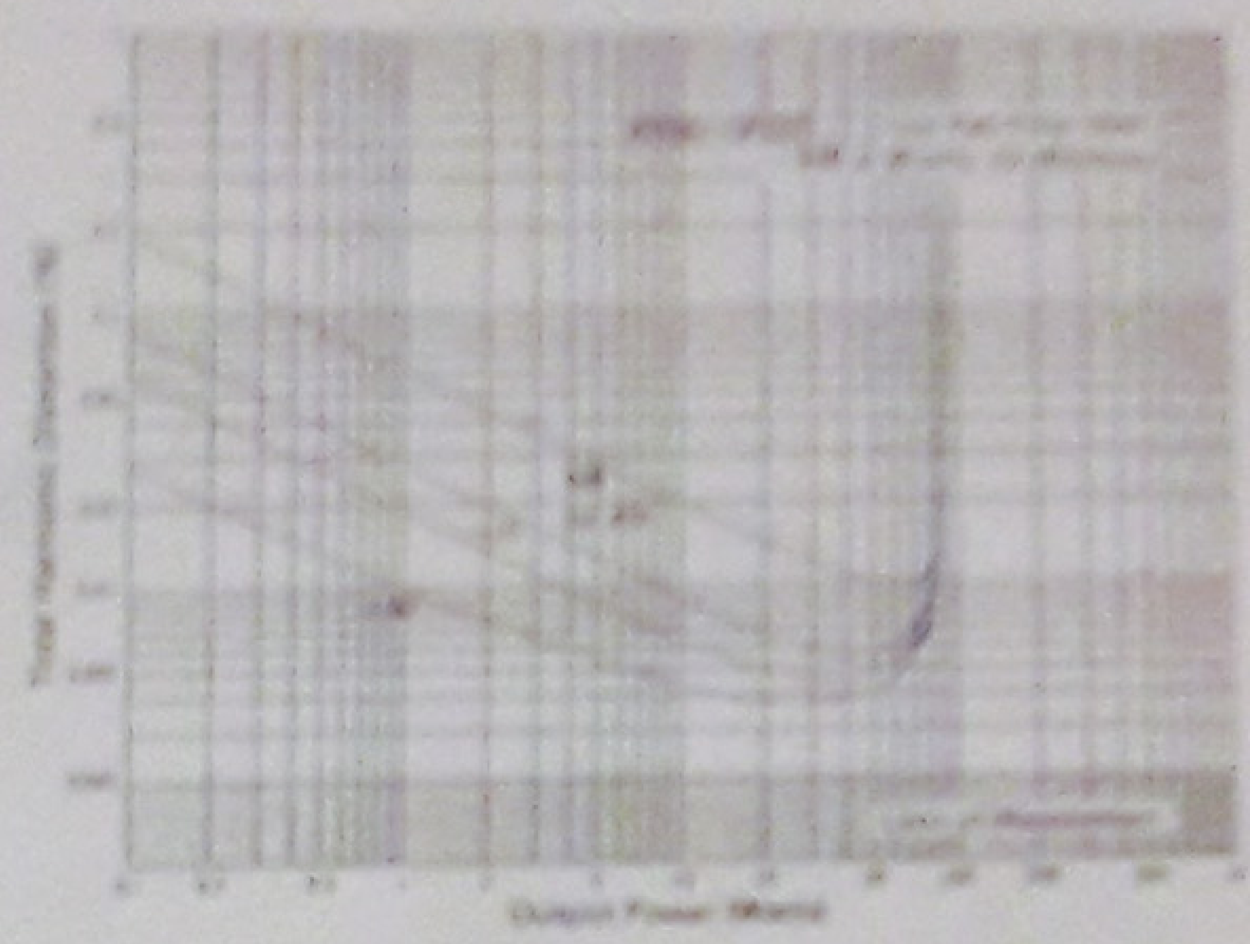


Fig. 28 Total Harmonic Distortion for Output Power for PHONO to SP OUT (Using Vol. Attenuation Setting)

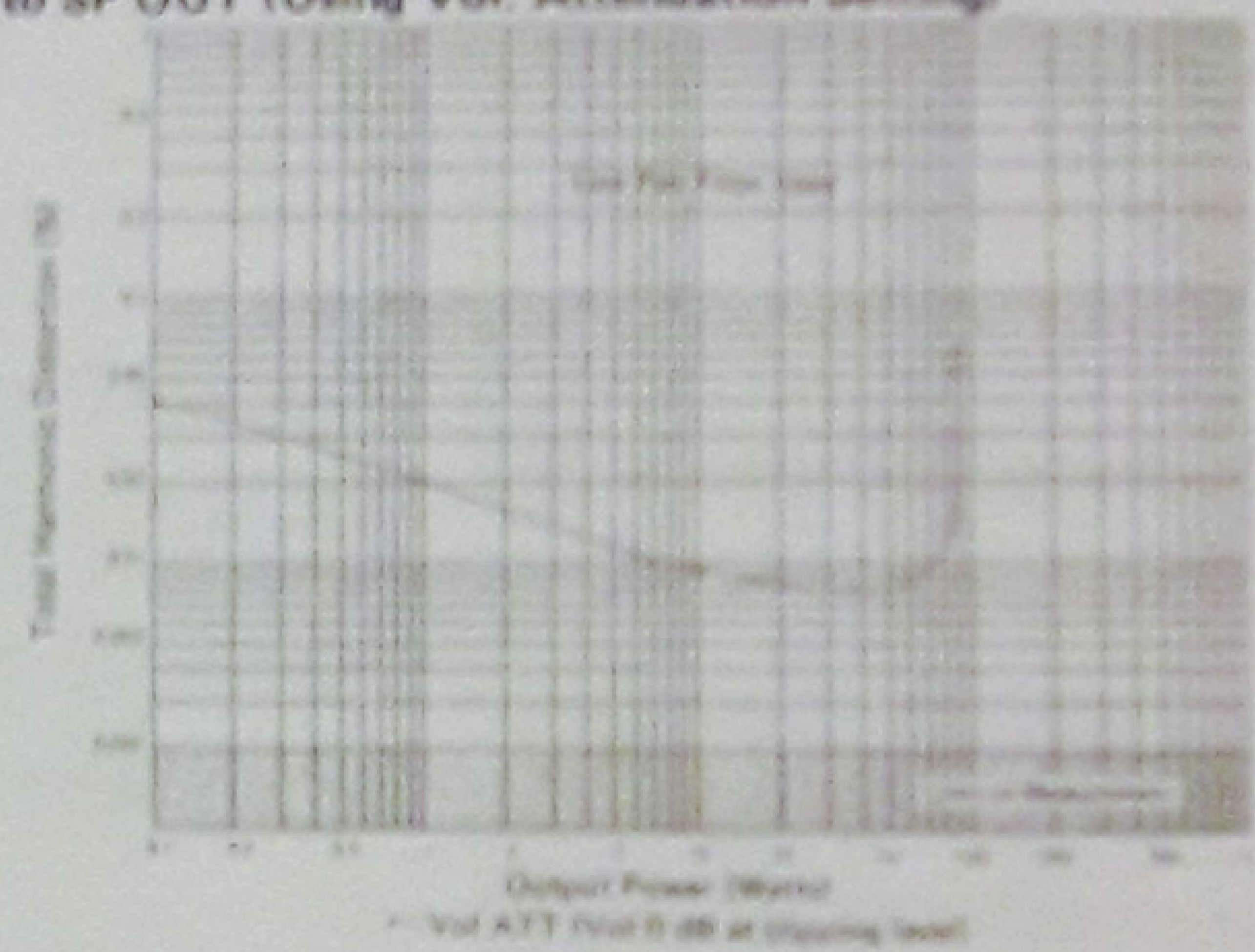
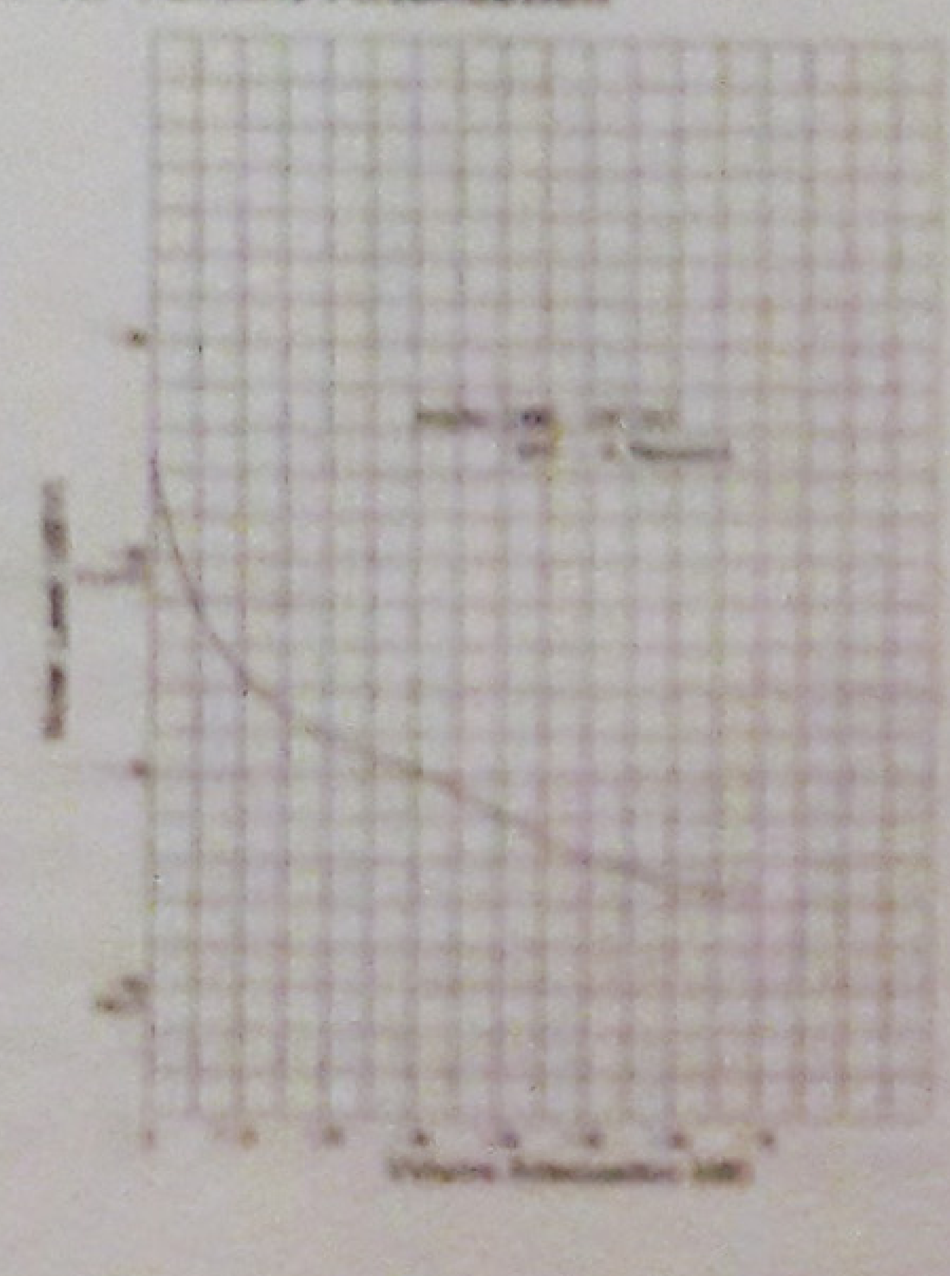


Fig. 27 gives the characteristic curves for the CA-810 overall, from PHONO to SP OUT terminals, for volume settings of 0, –10, –20, –30, and –40 dB. In Fig. 28, instead of the normal graph of distortion against output power, which is made with the volume control in a fixed position (almost always MAX), the input level was set so that maximum output was obtained at the MAX (fully clockwise) position, and

Fig. 29 Noise Level vs. Volume Attenuation



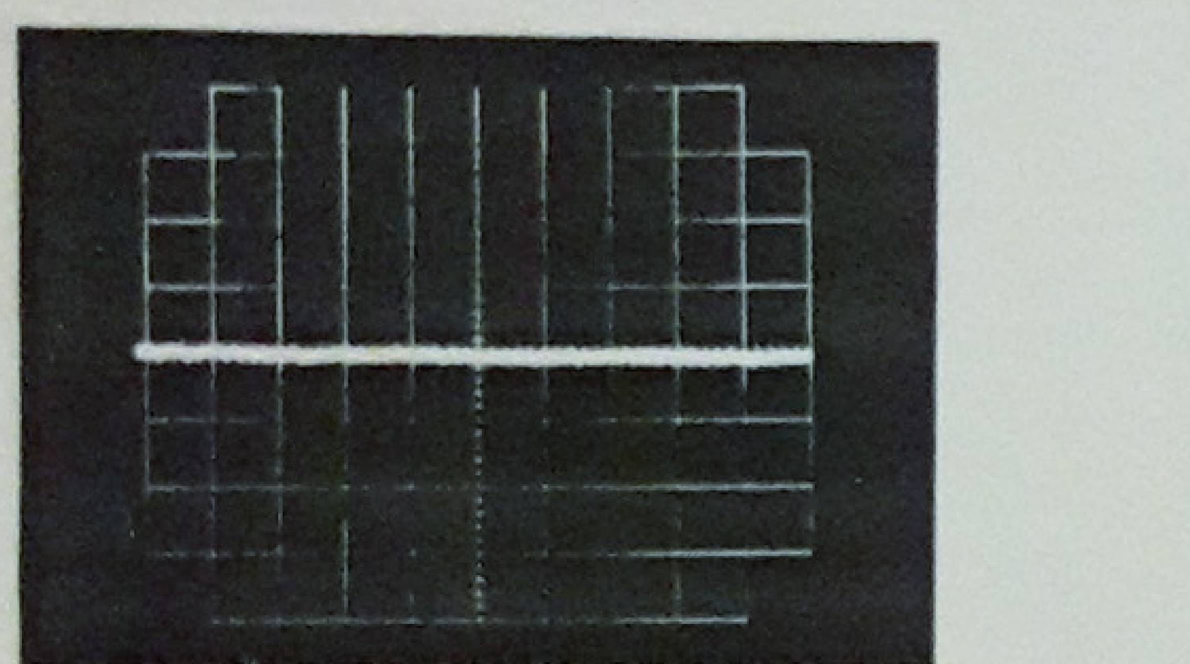
the power was reduced by turning down the volume control, exactly as would be the case in normal use. These two figures together show the outstanding performance, from PHONO to SP OUT, and from Volume MAX to MIN.

The change in noise level from PHONO to SP OUT as the volume is reduced is shown in Fig. 29. The extremely low noise levels at minimum Volume setting are a clear indication of the excellent S/N ratios for the equalizer amplifier, tone-control amplifier, and power amplifier sections of the CA-810.

Overall Dynamic and Regular Crosstalk

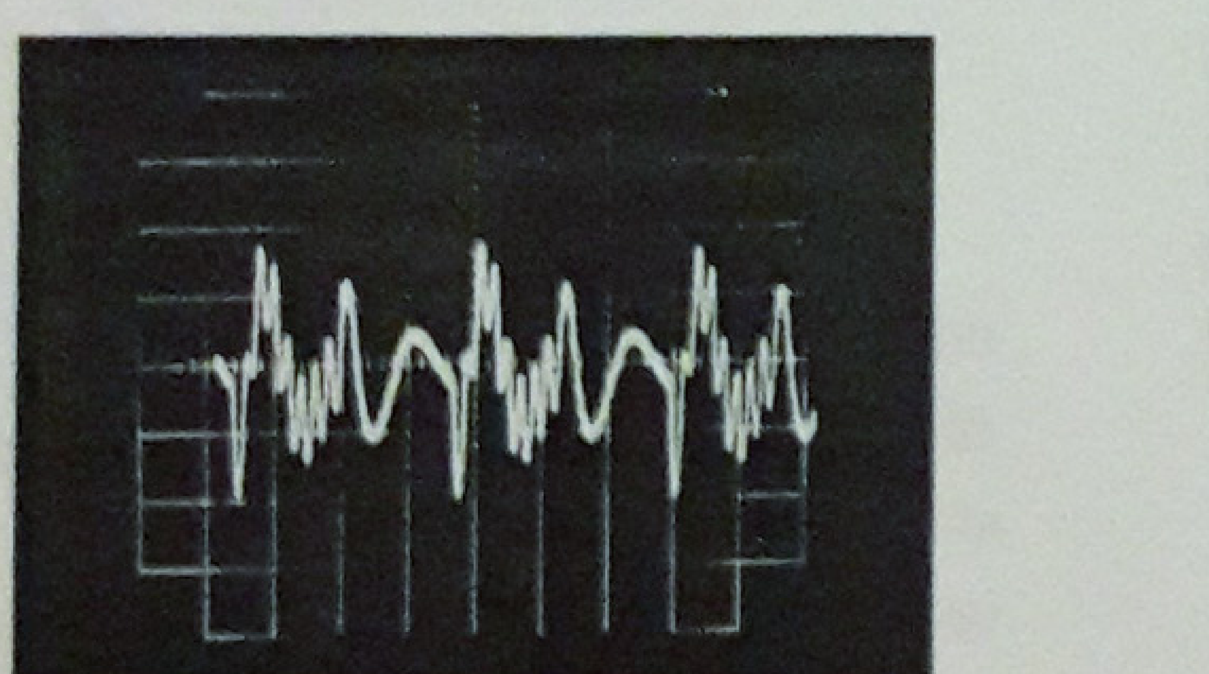
Rather than measure the crosstalk figures for individual sections, the overall figures should be obtained, from PHONO to SP OUT. Fig. 30 illustrates the actual dynamic crosstalk overall, with the volume set at −10 dB, where a 20 Hz tone burst is applied to the left-hand channel to give 10 V rms output at the SP OUT terminals of the CA-810.

Fig. 30 CA-810 Dynamic Crosstalk from PHONO to SP OUT Terminals



Vertical Sensitivity: 50 mV/div.
Horizontal Sensitivity: 0.5 sec/div.

Fig. 31 A Poor Example of Dynamic Crosstalk in a Competitive Amplifier



Vertical Sensitivity: 50 mV/div.
Horizontal Sensitivity: 0.5 sec/div.

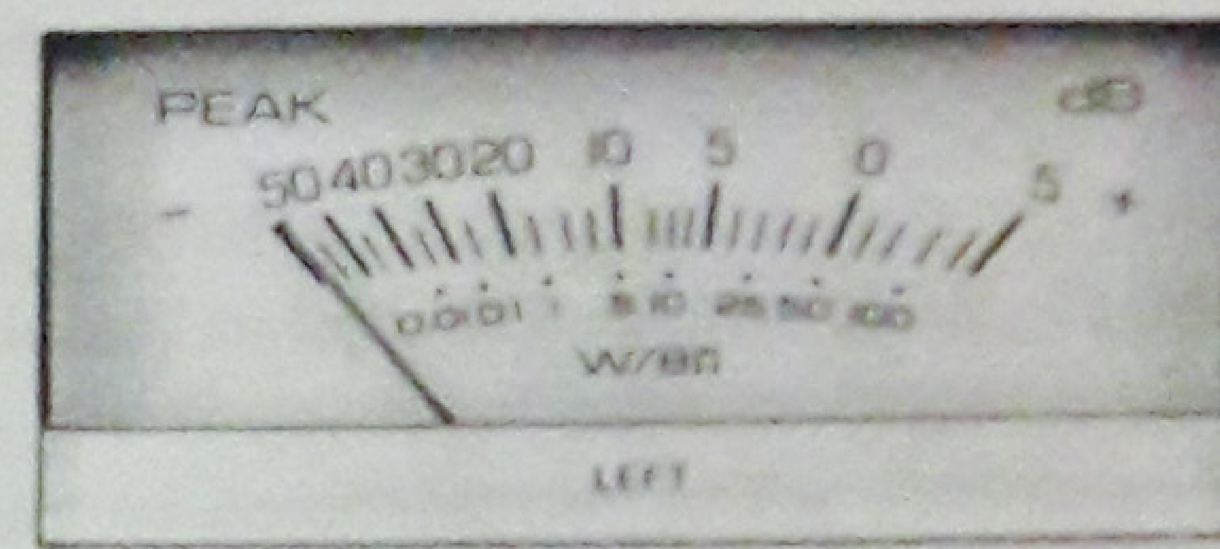
The effectiveness of the Yamaha approach is vindicated by the direct comparison with an amplifier which uses dual power supplies. The measurements were made under identical conditions.

6. Meter Circuit

High performance meters covering 0.5 mW to 158 W (for 8 Ω speakers, with 0 dB = 50 W)

Most VU meters have a range of display from −20 dB to +5 dB, a range which is too narrow for conveniently displaying musical signals which range from *pp* to *ff* (or *pianissimo* to *fortissimo*). They also suffer from the limitations inherent in a 300 ms rise time, too slow to follow pulsive sounds accurately. The peak level meters in the CA-810 have a logarithmic compression circuit and a peak hold circuit with gives the astonishing combination of a full −50 to +5 dB range (with 0 dB corresponding to 50 Watts output into 8 Ω speakers: that means a range from 0.5 mV to 158 W) with the ability to read peak levels accurately. Rise time is a mere 100 μs, so that even the shortest pulse of sound can be fully displayed. The meter scales themselves were specially developed to give the easiest and clearest reading.

Fig. 32 High Performance Peak Level Meters

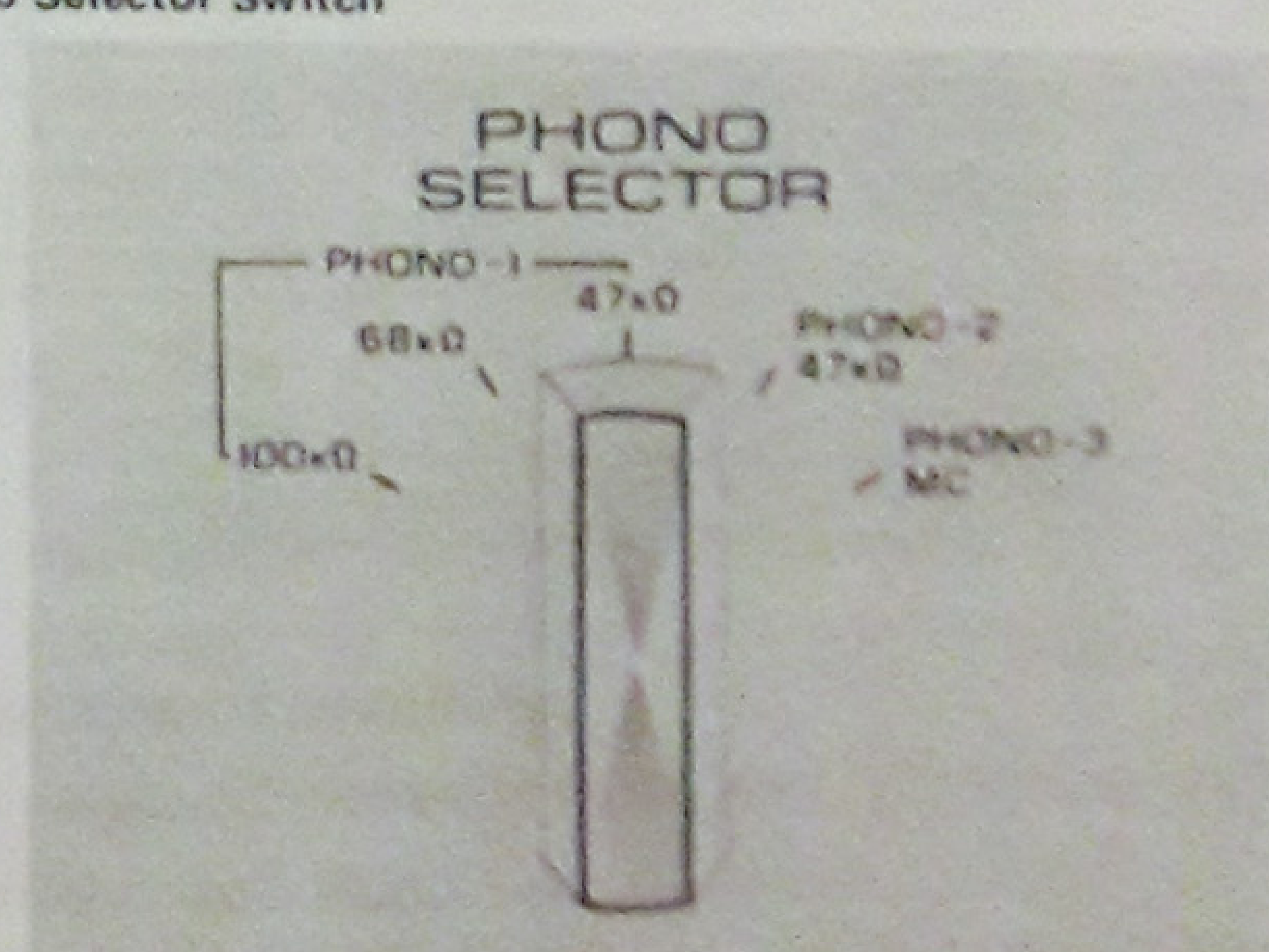


7. Special Circuit and Control Features

PHONO Selector Switch

In addition to the normal Input Selector, a special Phono Selector Switch has been provided. This offers a choice of 47, 68, or 100 kΩ impedances on the PHONO 1 position, 47 kΩ on PHONO 2 (both with 2.5 mV sensitivity), with a special PHONO 3 (MC) position for moving coil cartridges.

Fig. 33 Phono Selector Switch

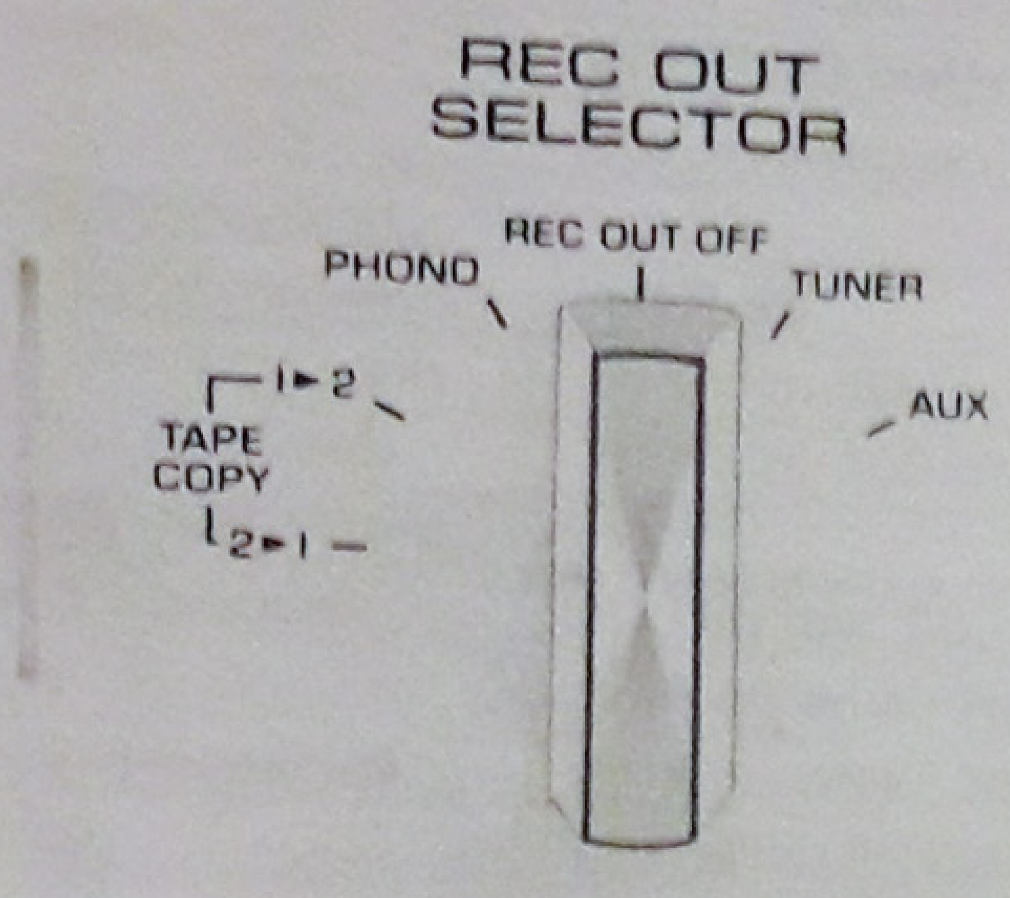


REC OUT Selector Switch

This switch enables any source connected to the amplifier to be recorded independently of the particular source which is being auditioned. It is hard to appreciate the extra convenience and enjoyment that this feature offers without having tried it. It means that a record can be taped while listening to an FM program, or record enjoyed while copying a friend's tape recording. Two tape decks can, of course, be connected, and simultaneous recording on both of them, and of dubbing from one to the other in either direction, is possible with the greatest of ease.

Again, the special REC OUT OFF position means that all sources connected to the CA-810 can be completely isolated from the tape decks when recordings are not being made, without having to unplug the tape recorder pin jack connections. This is particularly valuable when the tape recorders have been turned off, for their input impedances often drop abruptly when the main electrical supply is no longer connected, which could have unfortunate effects on signal reproduction quality.

Fig. 34 Rec Out Selector Switch



AUDIO MUTING

Although the high precision volume control of the CA-810 is of the continuous type, so that audio muting is not needed to make fine volume increments available at low listening levels (as is often the case with attenuator-type stepped controls), audio muting is provided for the convenience it offers in giving a swift, 20 dB cut in volume. This is useful when interrupting audition briefly for a telephone call, et. The Muting Switch also has a PRE OUT OFF position, at which the preamplifier section is completely isolated from the power amplifier section, enabling cartridges to be exchanged with the volume in the usual position but without the slightest danger of shock noise being transmitted to the speakers.

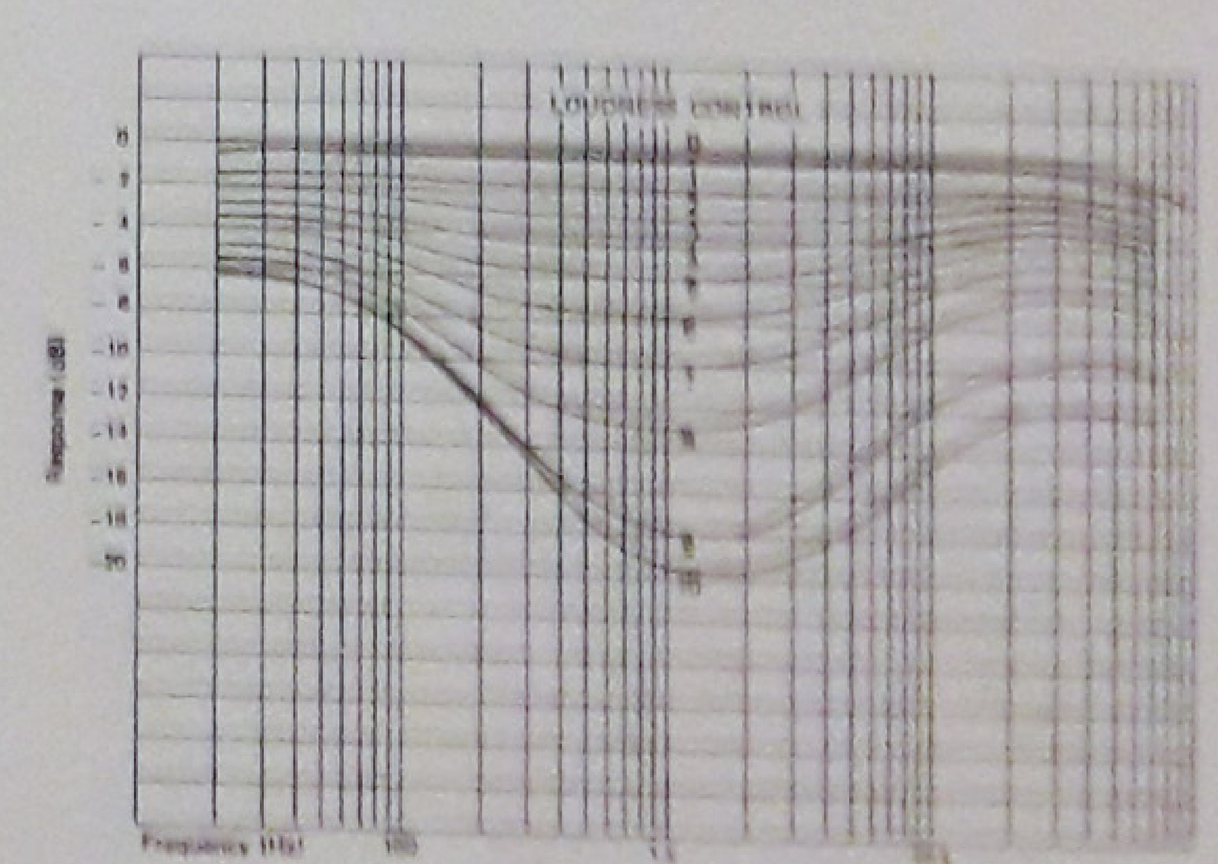
PRE OUT — Main In

Special coupling plugs on the rear panel connect the pre- and main amplifier sections, and these can be removed to give access to the two sections independently. This enables A/B tests of different amplifiers, and can also be used to derive a recorder input which has already been tone corrected (unlike the Rec Out signal, for which CA-810 tone controls are inoperative). It also enables the CA-810 to be used as part of a multi-amplifier system, in which separate amplifiers handle different frequency bands selected by an electronic crossover unit. It can also be used to feed the outputs of tuners or other audio equipment provided with suitable output impedances and level controls directly to the power amplifier.

Continuous LOUDNESS Control

Conventional switch-ON/volume-linked loudness controls in the majority of cases only give a certain fixed amount of compensation as the volume control is turned. The result is often a degree of compensation which does not result in a natural subjective listening impression. In the CA-810, however, a volume control has been provided for the LOUDNESS function, to that the ideal degree of compensation can be selected for the most natural listening impression to suit the listener's own hearing at all listening levels.

Fig. 35 Continuous Loudness Control Profile



Other Switched Functions

A full range of controls have been provided, including provision for operation of either or both of two independent pairs of speakers, and/or headphones. The Mode Switch offers choice of stereo or mono operation.

A-810 Performance Specifications

Minimum output power	
Continuous rms power (both channels driven at rated 0.05% harmonic distortion)	
20 to 20,000 Hz	65 + 65 Watts into 8 ohms
	80 + 80 Watts into 4 ohms
at 1,000 Hz	70 + 70 Watts into 8 ohms
	90 + 90 Watts into 4 ohms
Input sensitivity/impedance	
Phono 1	2.5 mV/47, 68 or 100 kΩ (MM)
Phono 2	2.5 mV/47 kΩ (MM)
Phono 3	60 μV/10 Ω (MC)
Tuner, Aux	150 mV/50 kΩ
Main In terminals	1 V/50 kΩ
Maximum input levels	
Phono 1, 2	230 mV (at 1 kHz)
Phono 3	6 mV (at 1 kHz)
Output level/impedance	
Rec Out terminals	150 mV/600 Ω (rated)
	14 V (maximum, at 1 kHz)
Pre Out terminals	1 V/2 kΩ (rated)
	3 V (maximum, at 1 kHz)
Frequency response	
Phono 1, 2, 3 RIAA deviation	± 0.3 dB
Main In to Sp Out terminals	10 Hz to 100 kHz +0, −1.5 dB
Tuner to Sp Out terminals	10 Hz to 100 kHz +0, −2.5 dB
Tone Control characteristics	
Bass turnover frequencies	125 Hz and 500 Hz
Bass boost/cut	± 10 dB at 20 Hz (for 500 Hz)
Treble turnover frequencies	2.5 kHz and 8 kHz
Treble boost/cut	± 10 dB at 20 kHz (for 2.5 kHz)

Filters and Loudness Control Characteristics	
Subsonic	*fc* = 15 Hz, 12 dB/octave
High	*fc* = 10 kHz, 12 dB/octave
Loudness control	Level-rated equalization
Signal-to-noise ratio (IHF-A network)	
Phono 1, 2 (MM)	95 dB (for 10 mV, shorted)
Phono 3 (MC)	73 dB (50 Ω short)
Tuner, Aux	100 dB
Main	115 dB
Residual noise	Less than 0.2 mV (at Vol. MIN)
Distortion 20 Hz to 20 kHz	
Phono 1, 2 (MM) to Rec Out	0.005% 10 V output
Phono 3 (MC) to Rec Out	0.05% 3 V output
Tuner to Pre Out	0.01% 3 V output
Main In to Sp out	0.01% into 8 Ω at 32.5 W
Tuner to Sp Out	0.02% into 8 Ω at 32.5 W
Noise-Distortion Clearance Range (NDCR) for 0.1% into 8 Ω	
Phono 1, 2 to Sp Out	0.1 W to 65 W (Vol. at −20 dB)
Damping factor at 1 kHz	Better than 30 into 8 Ω
Meters	
Rise time	100 μs
Decay time	0.75 sec
Meter range	−50 dB to +5 dB
	(0.5 mW to 158 W into 8 Ω)
General	
Power supplies	Models available for all supply voltages and frequencies.
Dimensions (W x H x D)	435 x 160 x 337 mm
	17-1/8" x 6-5/16" x 13-1/4"
Weight	12 kg (26 lb 7 oz)

SINCE 1887 YAMAHA

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