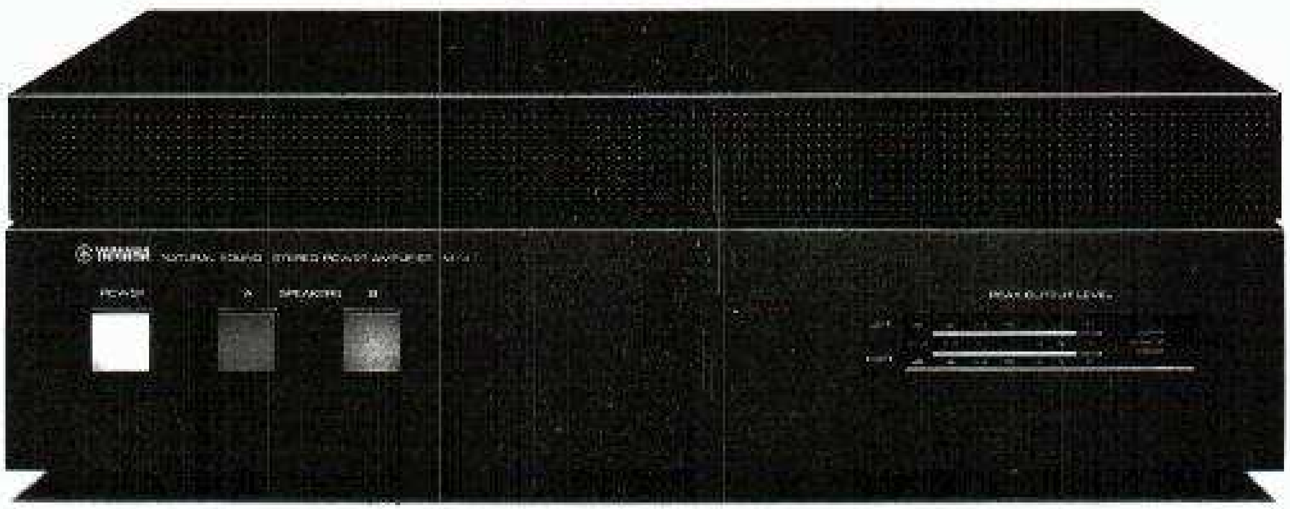
TECHNICAL REPORT

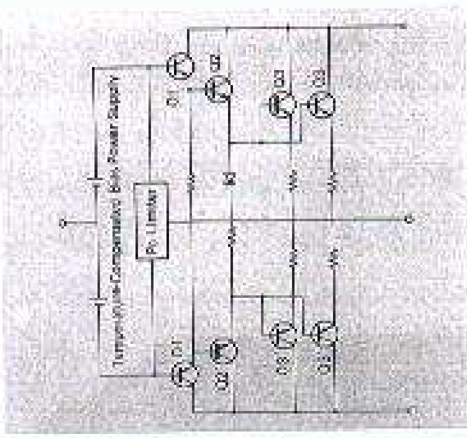
NATURAL SOUND STEREO POWER AMPLIFIER

YAMAHA M-4



YAMAHA M-4 POWER AMPLIFIER: OUTSTANDING HIGH FIDELITY FEATURES

Yamaha draws upon nearly a century of experience in making musical instruments to ensure that all our high fidelity products offer the finest in musical performance. New and original Yamaha techniques are employed to help the stereo power amplifier M-4 live up to this policy. The low-noise, low-distortion musical reproduction the M-4 achieves is a tribute to the effectiveness of Yamaha's in-house research and development. Serious audiophiles will be interested in employing the M-4 with the equally well-designed and produced C-4 stereo preamplifier. Together, they form a popularly priced "separates" team representing the best in state-of-the-art high fidelity equipment.



ADVANCED CIRCUIT CONFIGURATION

The basic circuit configuration of the Yamaha M-4 is one of the most advanced available today. It is a completely DC amplifier design that consists of a low-noise Dual FET first stage with a cascode bootstrap circuit, a Class-A predriver stage with a cascode-connected current-mirror circuit, and a parallel push-pull all-stage direct-coupled DC amplifier output stage with a three-stage complementary symmetrical emitter-follower circuit. Excellent transient response, broad frequency response and very low distortion are among its chief advantages.

NEW HIGH-f_T POWER TRANSISTOR

The M-4 benefits from the use of a newly developed output transistor in many significant ways. This is a bipolar transistor featuring a very high f_T (transition frequency) (90MHz for the NPN type, 70MHz for the PNP type), and offers a much higher breakdown voltage and much better h_{FE} linearity, the latter helping to reduce distortion. The current waveform of this new transistor amazingly shows no deterioration even at 100kHz at the output level of 120 watts.

DESIGN-COORDINATED SWITCHES

The three large, design-coordinated square switches on the Yamaha M-4 for POWER-ON, SPEAKERS A and SPEAKERS B add convenience and color. They contain illuminators which glow opaque orange (POWER) or green (SPEAKERS) to indicate the amplifier's operating status. However, when the power switch is turned on, the two speaker switches do not illuminate until after the amplifier stabilizes and the speaker relays are activated; they will also turn off whenever the speaker protection circuit is activated.

POWER-ON RELAY ELIMINATES "THUMP"

The power-on switch is backed by a muting relay to eliminate the annoying (and potentially damaging to your speakers) "thump" noise as you switch on the power to the M-4. The relay prevents transient switching noise from reaching the speakers by momentarily cutting them off the amplifier's outputs until the circuitry stabilizes.

TECHNICAL HIGHLIGHTS

CIRCUIT CONFIGURATION

The fundamental circuit configuration of the Yamaha M-4 is advanced and elaborate: it consists of a low-noise Dual FET first stage with a cascode bootstrap circuit, a Class-A predriver stage with a cascode-connected current-mirror circuit, and a parallel push-pull all-stage direct-coupled DC amplifier output stage with a three-stage complementary symmetrical emitter-follower circuit. Each of the amplifying stages is designed to provide optimal open-loop performance, which then is enhanced by employing advanced negative feedback techniques. Broad frequency response and low distortion are among its major virtues.

In developing the M-4, Yamaha found it difficult to measure the real performance characteristics of the M-4 with conventional measuring instruments because of the residual distortion, found in the instruments themselves. Hence we have introduced the HB-IB Audio Analysis System, combining an electronic computer and a spectrum analyzer, to measure and analyze all aspects of the M-4's performance.

This HP-IB System is capable of measuring various performance characteristics with extreme accuracy. High-order harmonic distortion components from the second to the tenth harmonic and higher, for example, can be measured with accuracy on the order of 0.00005%. Frequency response over 10MHz can be measured with accuracy on the order of 0.01dB. The carefully selected circuit parts of outstanding quality, the newly developed power transistor with its especially high f_T, the new performance-measuring system and Yamaha's advanced circuit techniques all combine to make the Yamaha M-4 an extraordinarily superior power amplifier.

AMPLIFIER CIRCUITS

Voltage Amplifier

First Stage

The first amplifier stage in the Yamaha M-4 power amplifier is a voltage amplifier combining a balanced differential amplifying circuit consisting of a low-noise Dual FET (Q1) source-follower

Fig. 1 BLOCK DIAGRAM

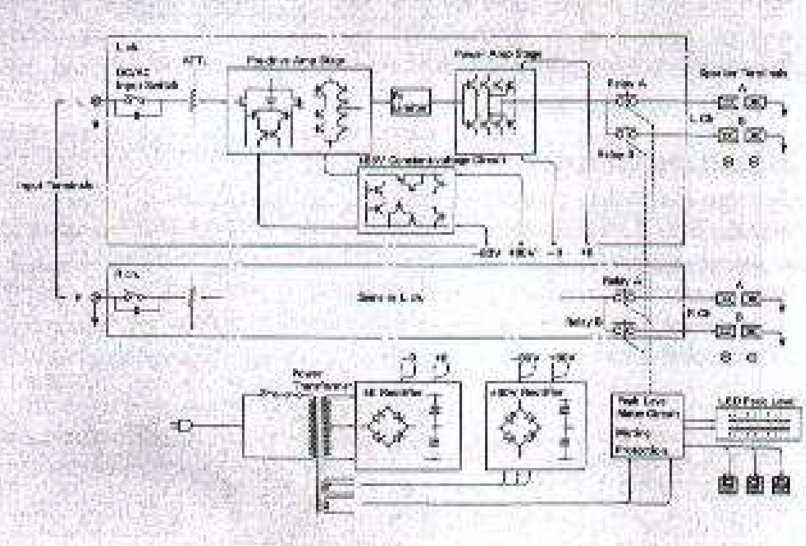
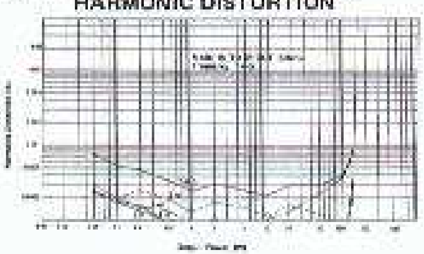


Fig. 2 OUTPUT POWER VS. TOTAL HARMONIC DISTORTION



and a cascode-connected Dual Transistor (Q2), with a cascode bootstrap circuit.

The Dual FET used contains a pair of FETs featuring low noise and high *gm* performance. The two FETs are carefully paired and matched in their electrical and thermal characteristics; they fully achieve the difficult pairing requirements called for in the first stage of a DC amplifier. As a result, the DC drift at the outputs is held to 0.0075V maximum over the ambient temperature range of 0°C — 50°C (32°F — 122°F).

This advanced circuit design enables the first stage to offer a much higher gain than a mere FET differential circuit. Since the cascode bootstrap bias circuit feeds a constant bias voltage (approximately 5V) from the common emitter of the differential amplifier to the FET, the distortion factor of the first stage does not increase significantly if the signal source impedance changes. This means that there is no restriction on the kind of equipment that can be connected to the M-4's inputs.

Predriver Stage

Because this stage is responsible for much of the power amplifier's overall gain, it has a significant influence over frequency response, distortion and other critical performance characteristics of the power amplifier as a whole. In the M-4, the predriver is in the form of a differential amplifier similar to the first stage, arranged in a cascode-connected current-mirror push-pull circuit. Its balanced input design means high CMRR (Common Mode Rejection Ratio) and SVRR (Supply Voltage Rejection Ratio), thus ensuring stable operation.

The current-mirror circuit permits Class-A push-pull operation, which helps to suppress even-order high harmonic distortion. At the same time, sufficient gain is created for the predriver voltage amplifying stage.

NEW, YAMAHA-DEVELOPED POWER TRANSISTORS OF HIGH f_T

The single most serious drawback of the conventional bipolar transistor used in Class-B operation is the switching distortion it creates. Reducing this switching distortion will mean improving the high-frequency response and reducing the possibility of thermal irregularities.

Needless to say, one way to obtain improved switching characteristics and high-frequency response is to use low-power transistors. Therefore, the new

Fig. 3 INPUT STAGE

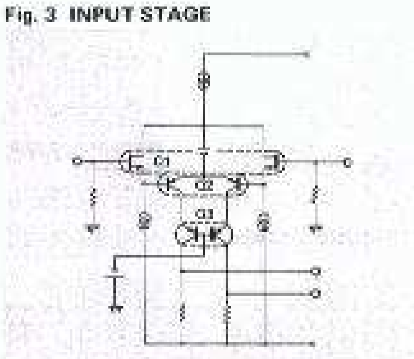


Fig. 4 PREDRIVER STAGE

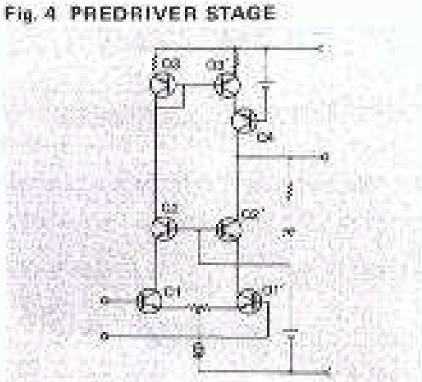


Fig. 5 CONSTRUCTION OF HIGH-f_T TRANSISTOR

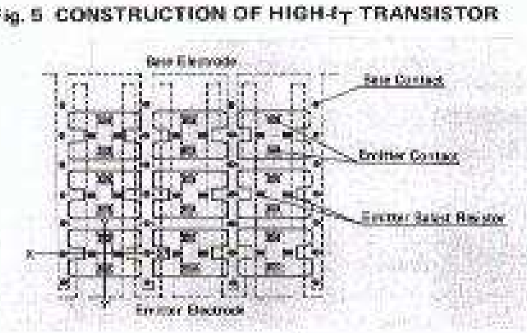


Fig. 6 X-X' CROSS SECTION DIAGRAM

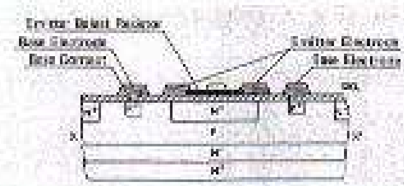
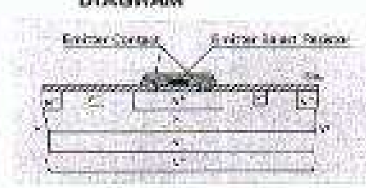


Fig. 7 Y-Y' CROSS SECTION DIAGRAM



power transistor, especially developed for high fidelity amplifier applications, has a unique EPR (Emitter with Poly-Silicon Balanced Resistor), whose construction is given in Fig.5.-7. As shown, a large number of low-power transistor units featuring high breakdown voltage and superior high-frequency response characteristics are combined on a single silicon chip. Then, to render the emitter currents uniform, emitter ballast resistors are inserted into the different transistor units in series connections.

The high f_T transistor with the construction described above possesses the electrical characteristics shown in Fig. 8. Specifically, it has a P_C of 120 watts (IC 12A), which rates it as a high-power transistor. Yet its transition frequency (f_T) is extremely high: 90MHz for the NPN type (2SC2460), and 70MHz for the PNP type (2SA 1050). The insertion of the emitter ballast resistors has immensely improved the transistor's breakdown resistance. Still another reason the new transistor is an output transistor well-suited for use in a power amplifier is that, in comparison with the conventional transistor having a multi-emitter construction, the linearity of this transistor's h_{FE}, a factor which influences the distortion of the amplifier, is considerably improved over a broad range of currents.

Power Amplifying Stage

Output Stage

This is a three-stage complementary symmetrical emitter-follower parallel push-pull power amplifying stage using newly developed high-speed, high f_T transistors. The three-stage design using closely paired high f_T transistors achieves sufficient power gain over a broad frequency band. In addition, each of the three stages is specially designed to offer a very fast carrier discharge speed in the Class-B operating region. This not only helps to prevent the deterioration of the frequency response and distortion in the high frequency range, but, at the same time, provides excellent stability during no-load operation.

In order to derive maximum performance from the high-speed, high f_T transistors in the output stage, a diode and a resistor with a very low 33-ohm resistance are connected in series between the emitters of the transistors in the driver stage. This suppresses the discharging impedance of the transistors in the base region, render-

Fig. 8 ELECTRICAL CHARACTERISTICS OF HIGH-f_T TRANSISTOR

Model	Max. Rating						Electrical Characteristics												Complementary Pair
	VCBO (V)	VCEO (V)	VEBO (V)	IC (A)	PC (W)	Tj (°C)	hFE	VCE (V)	IC (A)	VCE (V)	IC (A)	IB (A)	fT (MHz)	VCE (V)	IC (A)	Cob (pF)	VCB (V)	
2SA1050	−160	−140	−6	−12	120	150	R 55~110 O 80~160 Y 120~240	5	1	2.0 max	5	0.5	70 typ	−10	−1	250 typ	−10	2SC2460
2SC2460	160	140	6	12	120	150	R 55~110 O 80~160 Y 120~240	5	1	2.0 max	5	0.5	90 typ	10	1	130 typ	10	2SA1050

Fig. 9 COLLECTOR CURRENT VS. h_{FE}

2SC2460

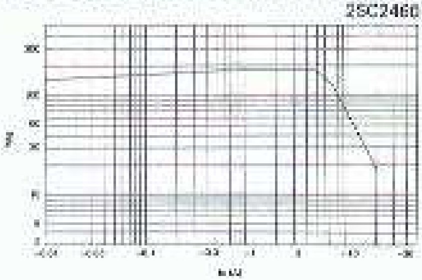


Fig. 10 COLLECTOR CURRENT VS. h_{FE}

2SA1050

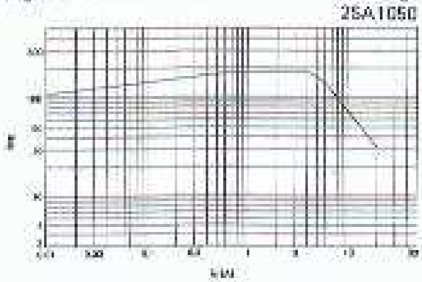
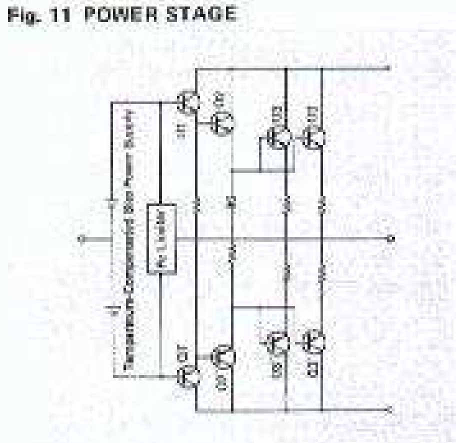


Fig. 11 POWER STAGE



ing the amplifier very fast in its rising and falling responses.

Finally, the high f_T transistors are securely mounted on sufficiently large heat sinks. Thermal resistance is very low, and heat dissipation is very effective, allowing the amplifier to deliver a high output of 120 watts per channel into 8 ohms at very stable junction temperatures.

Current Waveform of High-f_T Transistor

As mentioned before, a number of the newly developed high f_T transistors are driven at low impedance in a complementary push-pull circuit in the M-4's output stage. This design is so effective that the transistor exhibits no disturbance in its current waveform even under the severe operating condition of 120-watt output at 100kHz, as can be seen in Fig. 14a; nor is any increase of the vertical current observed. Fig. 14b shows the current waveform of a bipolar transistor tested under the same conditions: a great deal of disturbance is observed.

SUPERB PERFORMANCE CHARACTERISTICS

In the Yamaha M-4, the low-noise Dual FET in the first stage is driven at a constant low voltage (V_{DS}=5V), regardless of the input signal or output voltage. The output of this first stage is fed to a cascode-connected dual transistor predriver and on to the three-stage complementary symmetrical emitter-follower parallel push-pull DC amplifier output stage using the new high-f_T transistors. This explains why the M-4 is able to provide such outstanding all-around performance characteristics.

Presented in Fig. 15 are the power amplifier's open-loop frequency response and its closed-loop frequency response for comparison. As you can see, the amplifier has a frequency response reaching up to 22kHz before it drops −3dB, proof that its open-loop performance is particularly remarkable.

Within the audible frequency range, a sufficient amount (approx. 60dB) of negative feedback is stably applied; even at 100kHz, as much as 40dB negative feedback is applied with impressive stability. This has the effect of improving the frequency response to such an extent that, at 100kHz, it drops by as little as −0.7dB plus/minus 0.5dB. Intermodulation distortion is less than 0.002% at 60W

Fig. 12 IDLING CURRENT VS. TEMPERATURE CHARACTERISTICS

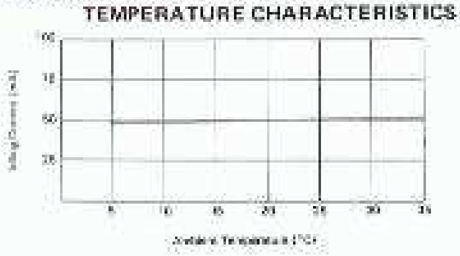


Fig. 14 CURRENT WAVEFORMS OF SWITCHING RESPONSE OBSERVED AT 100kHz/120W

(a) High f_T Transistor (b) Conventional Bipolar Transistor

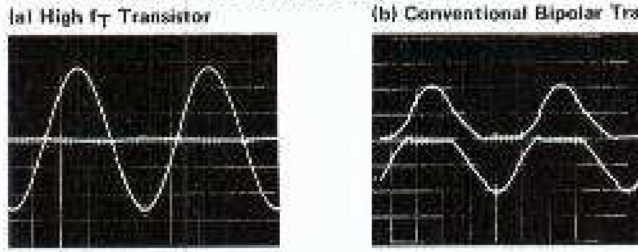


Fig. 13 M-4 HEAT SINKS

Fig. 15 FREQUENCY RESPONSE

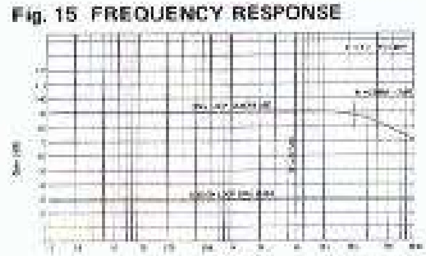
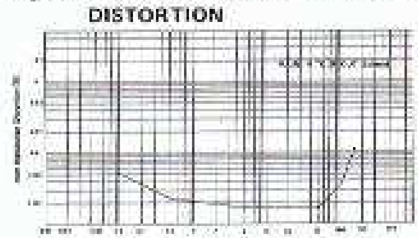


Fig. 16 OUTPUT VS. INTERMODULATION DISTORTION



output, and total harmonic distortion less than 0.005% (8 ohms, 60W output over 10Hz to 20kHz).

Figs. 17 through 20 show the amplifier's distortion waveforms at 20Hz, 1kHz, 20kHz and 100kHz. Hardly any switching distortion is discernible at very high frequencies through 100kHz. Fig. 23 demonstrates that the amplifier has a very accurate square wave response at 10kHz. However you measure the Yamaha M-4, it is a superior power amplifier in every way.

POWER SUPPLY CIRCUIT

The power supply circuit in an audio amplifier is just as important as its circuit design or the parts it uses. That's because the power supply plays the important role of supporting the stable operation of each amplifying stage by feeding energy to it constantly. In the M-4, the power supply circuit is constructed of a high-capacity transformer of superior regulation capabilities and a pair of 15,000μF/75V electrolytic capacitors. As a result, amplifier operation stability is ensured even at very low frequencies, which is very important for a DC amplifier such as the M-4.

In addition, the voltage-amplifying stages (the first stage and predriver stage) are provided with their own left/right-separate local constant-voltage supplies. This helps to minimize intermodulation distortion and crosstalk resulting from common impedances.

Moreover, Yamaha's advanced amplifier design know-how has successfully reduced the occurence of current loops as much as possible; the inductance in such loops is thus reduced in turn. The result is that the source impedance is kept sufficiently low through very high frequencies, so that the transient response of the amplifier as a whole is measurably bettered.

PROTECTION CIRCUITS

P_C Limiter

Should the speaker terminals be shorted and an overload occur, or should speaker systems of a 4-ohm or less impedance be connected to an amplifier, the P_C (collector power dissipation) of the power transistors would increase sharply and cause them to break down. To prevent this, the M-4 has a unique P_C limiter which operates by detecting the load impedance. It is activated the moment the load impedance goes down below 2 ohms.

Fig. 17 OUTPUT WAVEFORM AT 20Hz/60W RMS (Main in — Sp Out, DC operated)

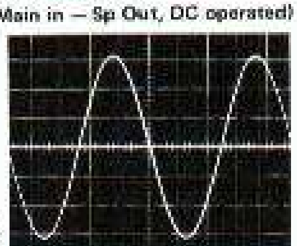


Fig. 18 OUTPUT WAVEFORM AT 1kHz/60W RMS (Main in — Sp Out, DC operated)

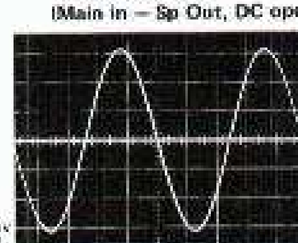


Fig. 19 OUTPUT WAVEFORM AT 20kHz/60W RMS (Main in — Sp Out, DC operated)

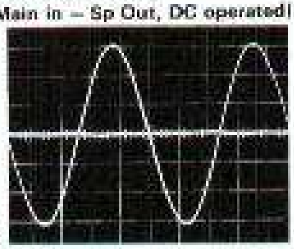


Fig. 20 OUTPUT WAVEFORM AT 100kHz/60W RMS (Main in — Sp Out, DC operated)

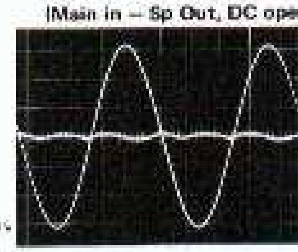


Fig. 23 SQUARE-WAVE RESPONSE AT 10kHz/40Vp-p (Main in — Sp Out, DC operated)

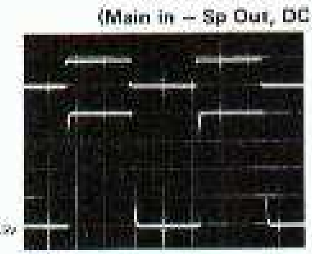


Fig. 21 OUTPUT VS. TOTAL HARMONIC DISTORTION

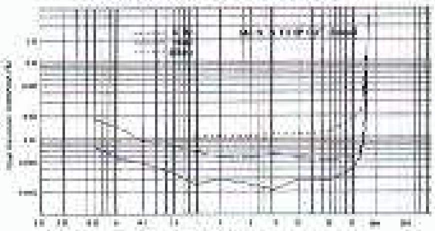


Fig. 22 FREQUENCY VS. TOTAL HARMONIC DISTORTION

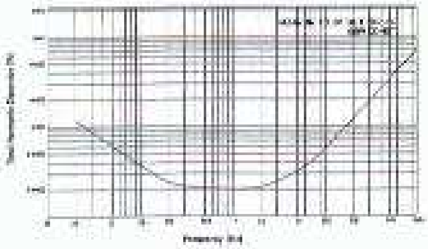
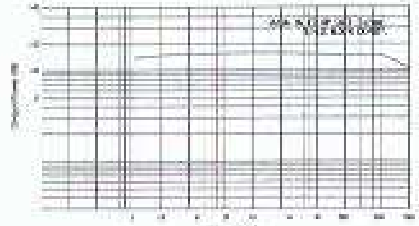


Fig. 24 FREQUENCY VS. OUTPUT



DC Detecting Speaker Protection Circuit

There is a relay in this circuit that instantly cuts off the speakers from the amplifier as soon as a DC voltage appears. Detection of the DC voltage is of course automatic.

This protection circuit also serves as a muting circuit to protect the speakers from the shock noise usually generated when the power switch is turned on or off. It does this by cutting off the speakers for a few seconds after the power is turned on, until the amplifier reaches normal operating conditions.

CONSTRUCTION & WIRING

When the performance level of an amplifier reaches as high as does the M-4's, it becomes ovbious that there is a limit to the improvement of amplifier performance through circuit techniques alone. This is important because the amplifier's performance has indeed reached that critical boundary stage where the influence of its construction, wiring accuracy and layout, and other factors which have normally been secondary, can no longer be ignored.

The construction of the M-4, we would like to think, is superb, reflecting the long accumulation of Yamaha's amplifier know-how. The results are evident: the inter-channel crosstalk is minimized, the overall current loop of the amplifier as a whole is reduced, and the magnetic properties of the chassis do not interact with the internal flux of the amplifier circuitry to exert undesirable influences on the signal paths.

Other instances of special considerations we have given to the M-4's construction are many. The output stage, through which a high current flows, is grounded to a piece of 1.5mm-thick copper plate to reduce the impedance. The circuit parts have been most carefully chosen in light of their influence on final tonal quality. These include the high-capacity electrolytic capacitors used in the power supply, induction-free wound emitter resistors, and speaker terminal coils of very low DC resistance using copper wire 2.3mm in diameter. In short, careful consideration has been given to every detail of the Yamaha M-4.

Fig. 25 FREQUENCY VS. DAMPING FACTOR

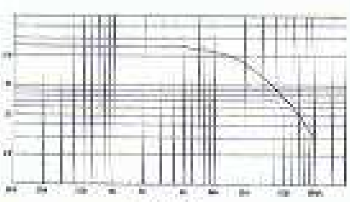
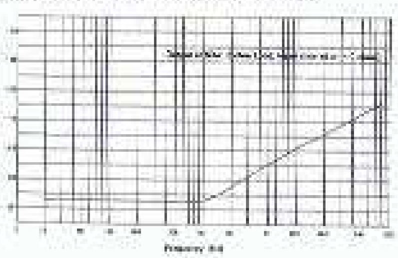


Fig. 26 CHANNEL SEPARATION



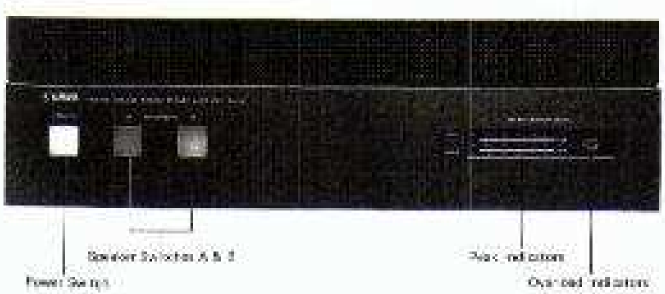
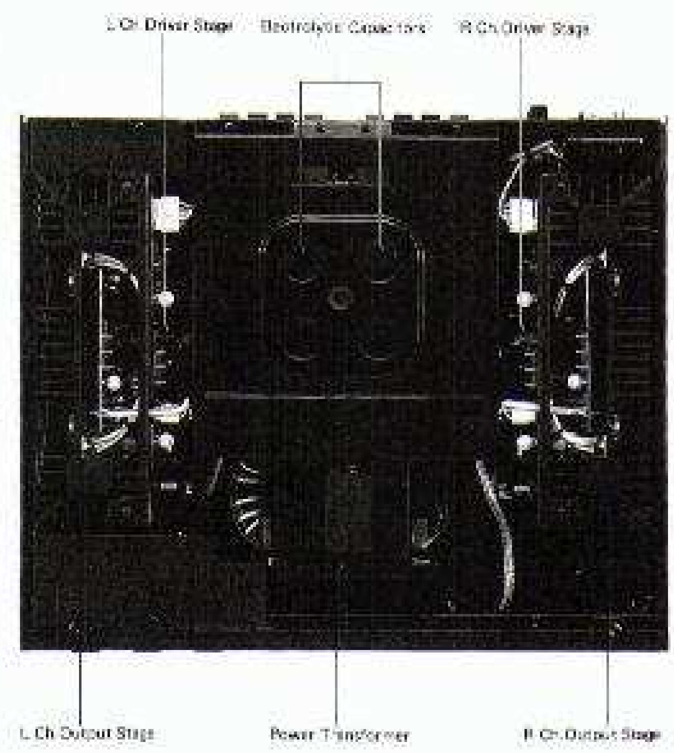


Fig. 27 INTERIOR VIEW



CONTROL FUNCTIONS

Peak Level Meter

The M-4 comes with an elaborate peak level display using a green LED array. This display operates off an exclusive level meter IC containing a special compression circuit, as shown in Fig. 28, to indicate the signal level from 0dB to −45dB in 12 steps of 5dB each. So it is very easy to read off the indication accurately. The 0dB level is set at 100 watts (into 8 ohms). The meter display's rise time is approximately 100µsec., and its fall time is approximately 1.2sec.

There is also an overdrive indicator circuit that lights red LEDs whenever the amplifier is saturated by an excessively high-level input or because of an overload. The indicators light up the moment the signal waveform is clipped (distortion approx. 1%), and remain lit for about one second. It is helpful for monitoring the dynamic range of the program source being played.

AC/DC Input Switch

Because the M-4 is a complete DC amplifier, it is capable of amplifying DC (0Hz) signals. This means that the built-in DC detecting protection circuit will be activated every time it detects a DC component in the preamplifier's output, thus rendering the M-4 inoperative.

To avoid this inconvenience, this AC/DC Input Switch is provided on the M-4's rear panel. When set to the AC position, it switches in a Mylar film capacitor in the M-4's input circuit to cut off signals below 6.4Hz and protect the amplifier from such DC content.

Speaker Switches

Two pairs of speaker terminals are provided on the rear panel to permit one-touch connection of up to two pairs of speaker systems. The self-lit speaker switches on the front panel select A, B or A+B.

Separate Left/Right Input Level Controls

Unswitched AC Outlet (100W max.) (UL and General models only.)

ELEGANT APPEARANCE

The external design of the M-4 is as elegant as its internal performance is outstanding. There are only three square switches, all beautifully illuminated when activated, plus a green LED peak level meter display glowing brightly in the darkness of the black front panel. The top panel and the upper half of each side panel use punched metal panels for the purpose of effective heat dissipation.

Fig. 28 BLOCK DIAGRAM OF PEAK OUTPUT METER CIRCUIT

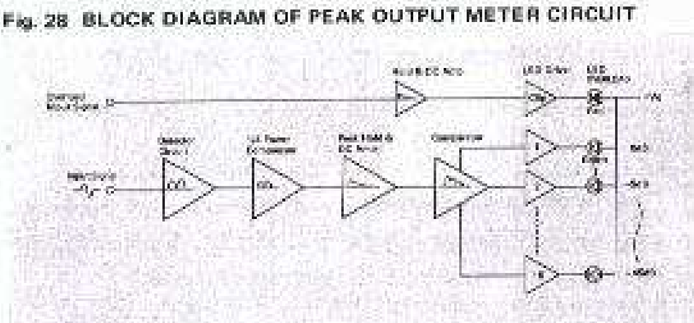


Fig. 29 PEAK OUTPUT METER/OVERLOAD INDICATORS

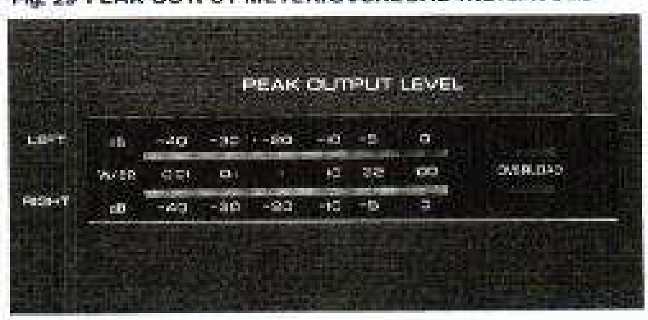


Fig. 30 DC/AC INPUT SWITCH
INPUT LEVEL CONTROLS

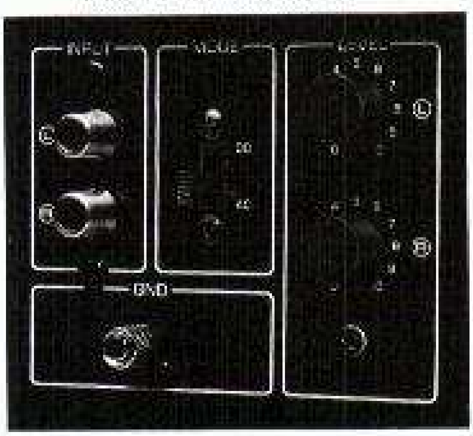


Fig. 31 FREQUENCY RESPONSE

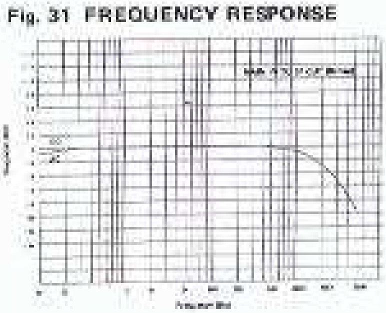
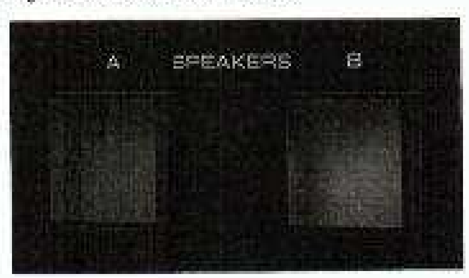


Fig. 32 SPEAKER SWITCHES



M-4 Performance Specifications

Rated Output Power	
U,C,R/ 8 ohms, 1kHz, 0.005% T.H.D.	150W+150W
4 ohms, 1kHz, 0.01% T.H.D.	215W+215W
8 ohms, 20Hz-20kHz, 0.005% T.H.D.	120W+120W
4 ohms, 20Hz-20kHz, 0.01% T.H.D.	170W+170W
E/ 8 ohms, 1kHz, 1% T.H.D.	135W+135W (DIN)
G,B,A/ 8 ohms, 1kHz, 0.005% T.H.D.	130W+130W
8 ohms, 20Hz-20kHz, 0.005% T.H.D.	100W+100W
Power Bandwidth	
U,C,R,E/ 8 ohms, 60W, 0.02% T.H.D.	10Hz-100kHz
G,B,A/ 8 ohms, 50W, 0.02% T.H.D.	10Hz-100kHz
Damping Factor	
8 ohms, 1kHz	200
4 ohms, 1kHz	100
Input Sensitivity/Impedance	1V (100W/8 ohms)/25k ohms, 500pF
Frequency Response	
MODE DC 8 ohms, 60W (U,C,R,E)/50W (G,B,A)	
10Hz	0dB
1kHz	0dB
100kHz	−0.7 ±0.5dB
MODE AC 8 ohms, 60W (U,C,R,E)/50W (G,B,A)	
10Hz	−1.5 ±0.5dB
1kHz	0db
100kHz	−0.7 ±0.5dB
Total Harmonic Distortion	
10Hz-20kHz, 60W (U,C,R,E)/50W (G,B,A), 8 ohms	Less than 0.005%
100kHz, 60W (U,C,R,E)/50W (G,B,A), 8 ohms	Less than 0.02%
Intermodulation Distortion	
U,C,R,E/ 8 ohms, 50Hz:7kHz=4:1, 60W	Less than 0.002%
G,B,A/ 8 ohms, 50Hz:7kHz=4:1, 50W	Less than 0.002%
Signal-to-Noise Ratio	
IHF-A Network, R_L = 8 ohms, 1k ohms	118dB
Terminated at Input Terminal	
Residual Noise	
IHF-A Network, 8 ohms, VOL. MIN.	32μV
Filter Characteristics	−6dB/oct., fc = 6.4Hz
Channel Separation	
U,C,R,E/ 8 ohms, 1kHz, 60W	90dB
8 ohms, 20kHz, 60W	70dB
G,B,A/ 8 ohms, 1kHz, 50W	90dB
8 ohms, 20kHz, 50W	70dB
Peak Indicator	
Indicator Reference	0dB=100W (8 ohms, 1kHz)
Indicator Level	0dB~ −45dB (−5dB step)
Attack Time	100μ sec.
Release Time	1.2 sec. (−45dB → 0dB)
Overload Indicator	
Indicator Level	1% Distortion (8 ohms, 10Hz-20kHz)
Power Supply	U,C: 120V AC, 60Hz
	R: 110/120V, 220/240V AC, 50/60Hz
	E: 220/240V AC, 60Hz
	G: 220V AC, 50Hz
	B,A: 240V AC, 50Hz
Power Consumption	
U: 350W, C: 580W, R: 350W, E: 900W, G,A: 450W, B: 500W	
Dimensions (WxHxD)	435x145.5x374.5mm
	(17-1/8"x5-3/4"x14-3/4")
Weight	
U	18.6kg (41 lbs.)
C,R,E,G,B,A	18.5kg (40 lbs. 12 oz.)

U: U.S.A., C: Canada, R: General, A: Australian, E: European, G: North European, B: British

Specifications subject to change without notice.

SINCE 1887 **YAMAHA**

NIPPON GAKKI CO., LTD. HAMAMATSU, JAPAN

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