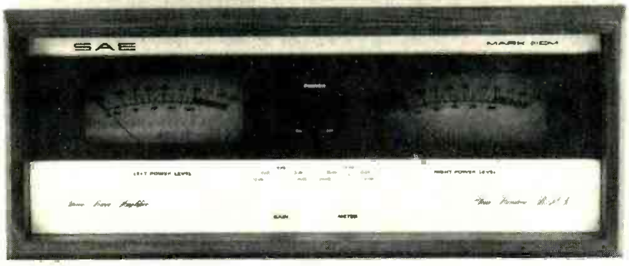
SAE Mk IIICM Basic Amplifier



MANUFACTURER'S SPECIFICATIONS

Power Output: 200 watts per channel, both channels driven into 8-ohm loads at any frequency from 20 Hz to 20 kHz with less than 0.1 percent total harmonic distortion; 300 watts per channel, both channels driven into 4-ohm loads at any frequency from 20 Hz to 20 kHz with less than 0.1 percent total harmonic distortion. **Intermodulation Distortion:** 0.05 percent at rated power output. **Frequency Response:** 1 Hz to 100 kHz ± 1 dB, 1 watt output. **Hum and Noise:** 100 dB below rated output. **Damping Factor:** 150. **Input Sensitivity:** 1.2 V rms for rated output. **Dimensions:** 17 in. W x 13½ in. D x 5¾ in. H. **Weight:** 60 lbs. **Price:** $1,000.00, with fan.

The SAE MK-IIICM is an attractive, well-made unit of unusual design. A MK-IIIC version is available with identical performance but without the front-panel meters. PC construction is used throughout, keeping the number of actual wires to a minimum. The bulk of the circuitry is on two boards which are an integral part of the heat sink which SAE calls their "UNISINK" concept. The heat sink works by heat

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expansion rather than convection. Hot air, generated at the base of the fins, expands and thus forces itself upwards creating its own chimney effect. Outside cool air is sucked in from the ends of the sink. The front panel has a five position gain-control switch, a five position meter-sensitivity switch, a dual-pushbutton power switch, and two meters with VU and power scales calibrated for 8-ohm loads. As meters go, these are most attractive, and having a power scale calibrated in watts is more meaningful than a VU scale alone.

Circuit Description

The circuit of the MK-IIICM is different from most high-power amplifiers in two respects. It is complementary push-pull from input to output, and the output stage uses series connected epi-base devices to attain the necessary safe-operating area. The result of this design philosophy allows the amplifier to drive resistive and reactive loads with equal ability in both the plus and minus directions. The safe area of the output stage is sufficient to drive a pure reactive 8-ohm load to 250 VA (volt-amps) without any limiting—a feat that few other solid-state power amps can achieve. A block diagram of the circuit is shown in Fig. 3, along with a circuit schematic, Fig. 4. Q3&4 form a NPN differential input amplifier whose output is coupled to the emitter of Q1, a common base stage that is acting as a level translator and relieves Q3&4 from having to stand off the 75-volt supply. The output of Q1 drives the Darlington-connected, common-emitter, inverting predriver stage pair, Q7&8. In a similar manner, transistors Q2, 5, 6, 8, & 10 are also driven from the input, and form a mirror-image circuit, ending up with a signal at Q10's collector that is the same phase and amplitude as the signal at the collector of Q9, but with even-order harmonic distortion products in opposite phase. These collectors are tied together through the bias regulator, which provides the necessary turn-on bias and temperature tracking for the output stage. Connection of the predriver collectors together is equivilent to standard push-pull operation in that signal currents are additive and even-order distortion cancels out (assuming circuit balance). The end result is a circuit that can drive the output stage in a symetrical manner with equal ease in the plus *and* minus directions.

The output stage itself amounts to a Darlington-connected complementary emitter-follower, with the composite output devices being a series connection of three Darlington power transistors. Q13&13 are the driver tran-

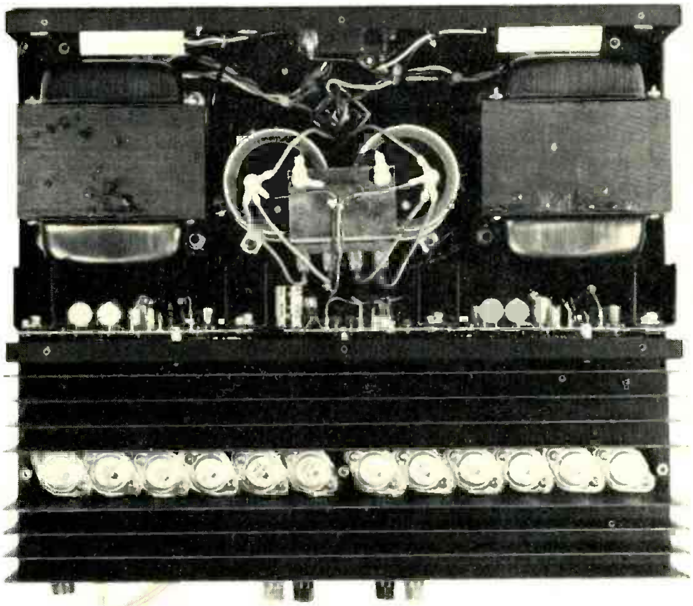

Fig. 1—Internal view.

Fig. 2—Back panel view.

sistors which are operated class A, and have their emitters tied together with a 62-ohm resistor. The composite output transistors, Q15, 16, 17 for the plus half cycle and Q18, 19, & 20 for the minus half cycle, are operated in class AB with a substantial idling current. Q17 is the plus half-cycle, control output transistor and is driven directly from driver Q13. The bases of Q16&17 are biased with voltage dividers from the plus supply to the emitter of Q17. These dividers cause the supply voltage to be divided equally across the three series-connected devices both under quiescent and signal conditions. Similar circuit action occurs for the negative half-cycle, composite output transistor, Q18,19,&20. The 62-ohm resistor connecting the bases of the control output transistors Q17&18 insures their rapid turnoff at high frequencies, as the *on* base is actively pulled in the *off* direction through the resistor as the opposite base is being turned *on*. This is in contrast to the usual quasi-complementary circuit where the stored base charge of the *on* device is passively discharged through the resistors connected from base to emitter of the output devices. This feature results in lower distortion and better efficiency at high frequencies due to the lack of common mode conduction where both devices are *on* for a fraction of the signal cycle. Another point of interest in the output stage is the use of rather large (0.39 ohm) emitter degeneration resistors, R39&40, for a power amp of this output power. In general, the larger these resistors, the more thermally stable the output-stage quiescent current becomes. However, the larger the resistors, the greater the power loss in them at high output powers. The MK-IIICM solves the power loss problem by shunting the resistors with Shottky rectifiers which are expremely fast and have a foward voltage drop of less than 0.6 volt at 20 amp but are essentially out of the circuit at quiescent conditions.

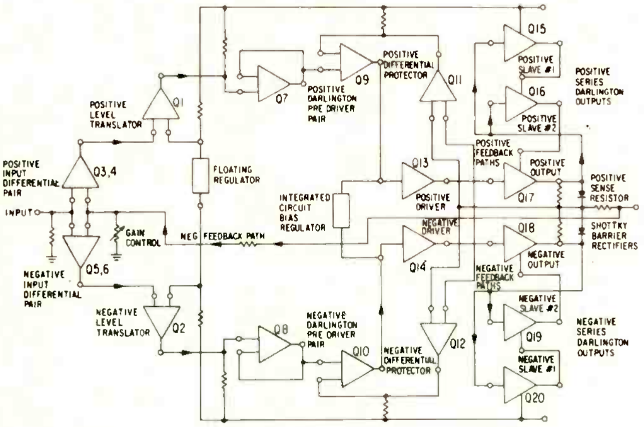

Fig. 3—Block diagram of output stage.

Protection circuitry for the output stage is of the volt-amp (VI) type, where both load voltage and current are sensed. Whenever the voltage and current levels are considered excessive, protection control transistors Q11 or Q12 will be turned on increasing the voltage drop across the emitter resistors of the predriver Q9 or Q10. This action will, in effect, reduce the conduction of the predriver affected and thus reduce the conduction of the corresponding output transistor. Further protection for the load is in the form of a circuit that controls a relay with contacts in series with the two hot output lines. This circuit provides a turn-on/off time delay upon application and removal of power to prevent thumps from getting to the speakers. Additionally, the circuit monitors the amplifier outputs for d.c., low-frequency subsonic energy and high-frequency supersonic content, and opens the relay when these factors are considered unsafe for the load. The circuit does not latch or stay on for an excessive time when triggered, recovering almost instantly except when the unsafe condition persists wherein the circuit "toggles" on and off until the unsafe condition is removed. A thermal output is mounted on the heat sink and is wired in series with the coil of the speaker relay. If heat-sink temperature rises above the cutout set point, the speaker relay is opened but power remains on in the amplifier. Protection of the amplifier and power supply in case of internal failure is provided by four 6-amp fuses in series with the power feeds to each channel.

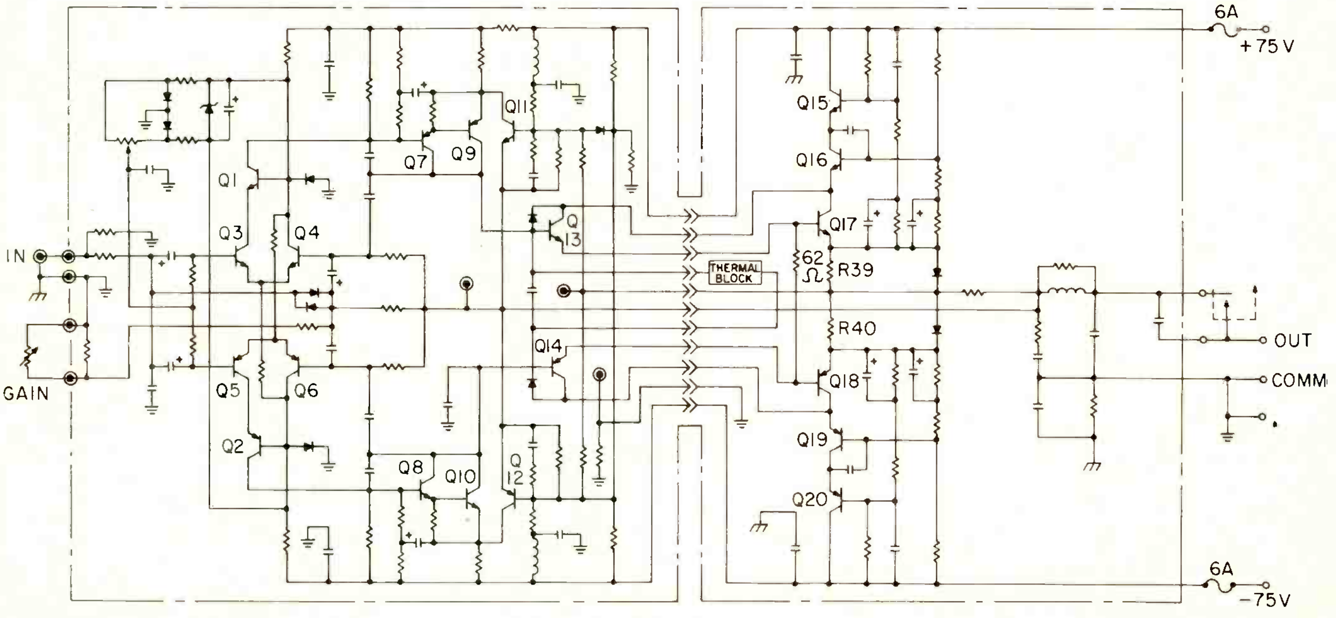

Fig. 4—Circuit schematic.

The input level control for this amplifier is in the form of a five-position 3-dB/step attenuator which does not control input attenuation per se but adjusts the shunt feedback resistor in the overall feedback loop of the amplifier. This results in controlling the closed loop gain instead. This permits essentially constant input resistance as a function of gain setting and eliminates the need for an input gain control buffer amplifier.

Meter circuit sensitivity is adjustable in 6 dB steps from 0 to −24 dB. Corresponding sine-wave power values into 8 ohms at 0 dB on the meters are: 200, 50, 12.5, 3.12, and 0.78 watts respectively. The meters are underdamped compared to standard VU meter ballistics and therefore respond more rapidly to power level changes.

Power-supply circuitry consists of two power transformers with secondaries wired in series to form a center-tapped source for the full wave rectifiers that generate plus and minus 75 V d.c. Filter capacitors are 10,000 μF at 80 volts.

Listening Tests

The MK - IICM was compared to a number of other power amplifiers over a several month period. The impressions were that it was quite clean and defined and generally sounded as good or better than the commercial amplifiers on hand during these listening tests. On a more absolute basis, when compared to the best amplifiers that this reviewer has ever heard which include several modified commercial products and a recently introduced commercial amplifier, the MK-IICM was found to have relatively more irritation and edginess but was comparable in terms of definition and low-end solidity.

Measurements

The gain of the MK-IICM is adjustable in 3 dB steps from 0 dB to −12 dB. Input sensitivity is speced at 1.5 V input for 200 watt output into 8 ohms. This would be a gain of 26.7/1 or 28.5 dB. Gain in both channels was measured at 1 kHz into a 8-ohm load as a function of the gain-control switch position with results shown in Table 1.

Table 1—Gain in both channels of the Mk-IICM.

Gain Setting	Gain, A	dB Difference
0	26.7x28.53 dB	3.05
−3	18.8x25.48 dB	3.21
−6	13.0x22.28 dB	2.8
−9	9.41x19.47 dB	3.04
−12	6.63x16.43 dB	
	Gain B	
0	26.8x28.56 dB	2.98
−3	19.0x25.58 dB	3.3
−6	13.0x22.28 dB	2.77
−9	9.45x19.51 dB	3.01
−12	6.68x16.50 dB	

Since this gain control method varies the amount of negative feedback in the amplifier, most measured parameters like frequency response, rise time, and distortion would tend to be better at the −12 dB position because of 12 dB more feedback. Accordingly, to represent worst case, all measurements were made at the 0 dB (max) gain position unless otherwise noted.

IM distortion is shown in Fig. 5 for a 8-ohm load, both channels driven. The dashed curve is the sum of the 5th and 7th harmonics in the IM residue and is representative of the more irritating components of the IM characteristic. There is no rise in IM at low levels in this amp and the sum of 5th and

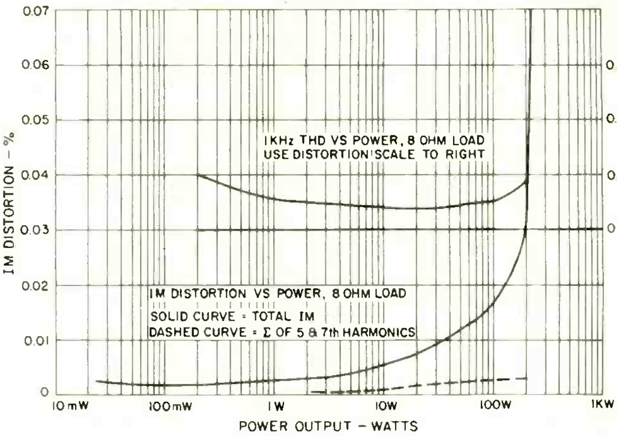

Fig. 5—Distortion versus power output.

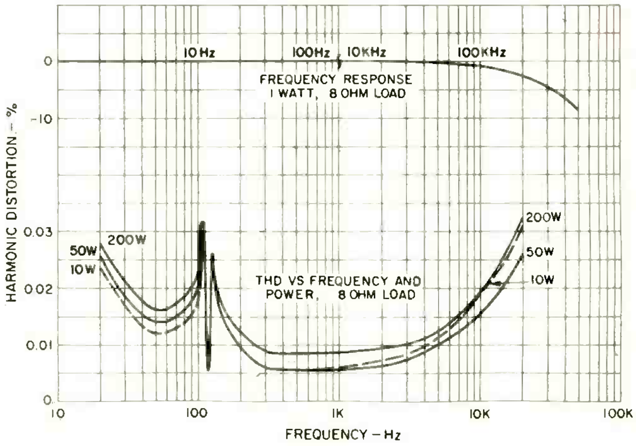

Fig. 6—Frequency response, and THD versus frequency for three power levels. Note break in upper frequency response scale.

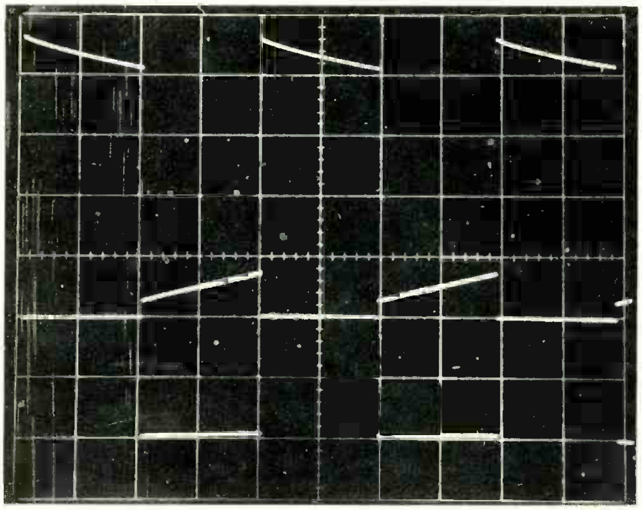

Fig. 7—50 Hz square-wave response at two power levels: top, approx. 200 watts, 8 ohms, 20 V/cm, 5 mS/cm; bottom, 3.12 watts, 8 ohms, 5 V/cm, 5 mS/cm.

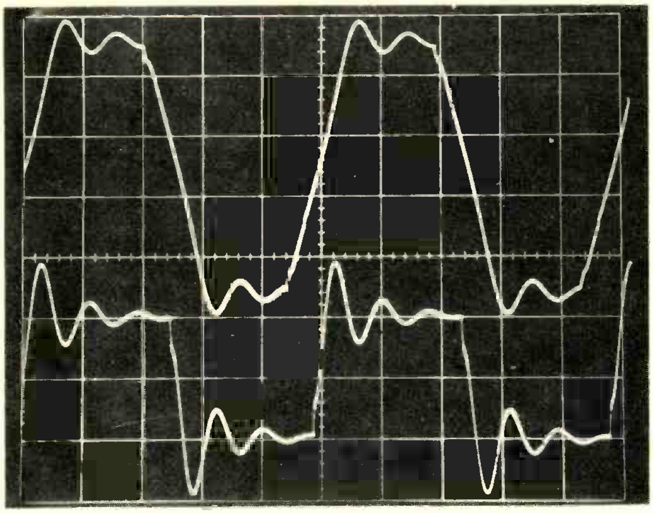

Fig. 8—10-kHz square-wave response at two power levels: top, approx. 140 VA, 2 μF, 20 V/cm, 20 μS/cm; bottom, approx. 2.5 VA, 2 μF; 5 V/cm, 20 μS/cm.

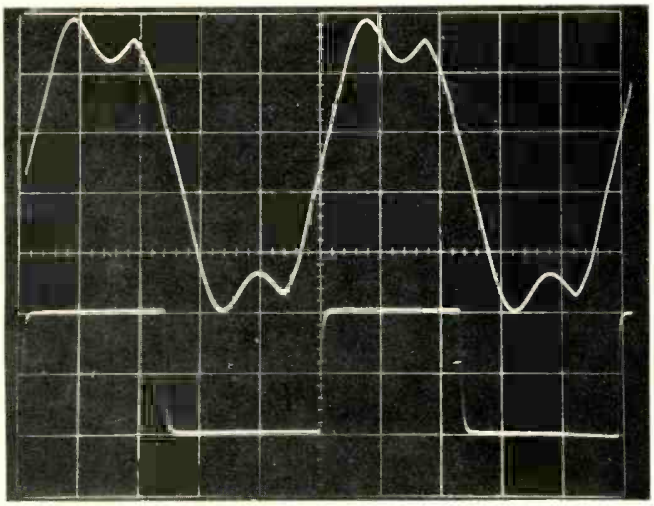

Figure 9—10- and 20-kHz square-wave response: top, approx. 140 VA output, 20 kHz, 1 μF, 20 V/cm, 10 μS/cm; bottom, 3.12 watts, 10 kHz, 8 ohms; 5 V/cm, 20 μS/cm.

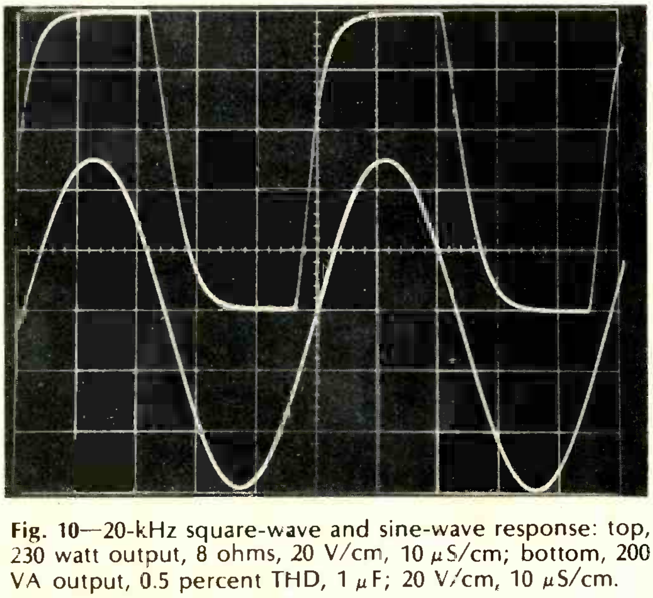

Fig. 10—20-kHz square-wave and sine-wave response: top, 230 watt output, 8 ohms, 20 V/cm, 10 μS/cm; bottom, 200 VA output, 0.5 percent THD, 1 μF; 20 V/cm, 10 μS/cm.

7th harmonics becomes unmeasureable below approximately two watts. From a measurement standpoint, these measurements are superlative. Harmonic distortion vs power at 1 kHz with 8-ohm loads is shown in Fig. 5 also. Harmonic distortion was measured with a Sound Technology 1700A, a new THD measuring set that is very good and fast to use. THD vs frequency and power is shown in Fig. 6. A word of explanation is order about the variation in THD near 120 Hz. In this amplifier and others to varying degrees, a beat frequency is generated—a first-order difference tone—between the test frequency and the 120 Hz power-supply ripple on the amp's power-supply lines. The difference tone seems to be the strongest when the test tone is nearest to 120 Hz. The value of the peak on either side of 120 Hz might be higher but would be limited in reading by the low-end subsonic response of the THD analyzer. The THD meter is reading the harmonics of the test signal plus the difference tone with the magnitude of the difference tone being dominant near 120 Hz. The audible effects of this phenomena might be spurious low-frequency thumps and tones when the musical spectra was strong near 120 Hz if the magnitude was large enough. It is doubtful that the magnitude exhibited here would be audible.

Frequency response at one watt into 8 ohms is shown in Fig. 6. Of interest is the superior low-frequency response, which is better than most a.c. coupled power amps. The MK-IIICM is a.c. coupled at the input and has several other LF rolloffs, the dominant one being in the overall feedback loop. The time constants are large enough to allow an extended LF response at the several watt power level. The 50-Hz square-wave response is shown in Fig. 7 for two power levels. The 10 V P-P level shows very little droop, which would be expected from the response shown in Fig. 6. The high-level response near full power exhibits more droop and is actually happening as a blown up 10 V P-P waveform at the same scope trace size as the one shown at high level has much less droop. This suggests that the LF amplitude and phase response is a function of signal level. This phenomena will be checked more closely on other amps and shown in future reviews where the effect is found to be significant.

The high-frequency square-wave response for a 10 kHz 10 V P-P level is shown in Figs. 8 & 9 for a 2 μF and 8-ohm load. An idea of the high-frequency capability of this amplifier can be seen in Figs. 8, 9 and 10. The upper trace of Fig. 10 shows the waveshape of a 20 kHz square wave at 100 V P-P into 8 ohm at a power level of about 230 watts. The lower trace shows a 200 VA sine wave into a 8-ohm reactive load at 20 kHz. The upper traces of Figs. 8 & 9 show the response to a 10 and 20 kHz square wave into 2 and 1 μF, respectively, which are both 8-ohm reactive loads at the fundamental frequencies indicated. The power levels shown are at about 140-150 VA.

The ringing on square waves with capacitive loads is usually caused by the low-pass filter formed by the parallel RL network that most solid-state amps have in series with the output leads and the capacitive load itself. Most manufacturers use such a network to prevent too low a load impedance at high frequencies with capacitive loads on the amplifier itself. Generally, the response inside the amplifier ahead of the RL network is relatively free of ringing and the ringing at the output is a result of protecting the amplifier with the RL network. With the above in mind, the square-wave behaviour of this amp into reactive loads is excellent and plus-and-minus half-cycle symmetry is evident in the waveforms. The specs for this amplifier state that it is not slew-rate limited in the audio range and that the full power rise time of a 20 kHz square wave is 2.5 μS. The amp is not slew-rate limited for a sine wave at full power up to 20kHz but some evidence of slew-rate limiting is present with square waves into resistive and reactive loads. A linear network will have a constant absolute value of rise time independent of level where a slew-rate-limited active circuit will have a rise time that increases with increasing level. Most transistor power amps will have a small signal rise time that is fast—in the order of a microsecond or so and at high levels will be much slower with a linear or straight-sided edge transition, indicating that some internal current source can only charge a necessary stability compensation capacitor so fast. The MK-IIICM is different in that the high-level resistively-loaded square wave has an exponential edge transition with a rise time of 6-7 μS where the low-level rise time is less than 1 μS. Since the rise time does increase with level, some equivalent of slew-rate limiting must be taking place. The full-power rise time at a −12 dB gain setting with a resistive load was very close to 2.5 μS. The above really represents some technical nit-picking and to be honest, this reviewer hasn't seen or measured any power amp that is as good as this one in delivering high-power, high-frequency square waves.

Power output at onset of clipping into 4-,8-,&16-ohm loads was 340, 230, and 125 watts respectively with both channels operating. Output noise with shorted inputs as a function of gain control setting and bandwidth is shown in Table 2. The rather large increase in noise voltages when measuring in a 20-20 kHz bandwidth was due to the noise being dominated by line harmonics. Note, however, that the S/N is better than 100 dB re 200 watts in a 20-20 kHz band at the highest gain setting.

Amplifier protection was seemingly foolproof as the worst that happened for such things as dropping pickups on records at full volume and tone bursting supersonic signals with large d.c. components, etc., was the speaker relay opening momentarily and then restoring operation after a short delay.

Damping factor was found to be greater than 200 from 20-1 kHz and decreased smoothly to about 25 at 20 kHz.

The Federal Trade Commission has stepped into the high fidelity area with a new ruling designed to eliminate false or misleading advertising of power output and power output versus frequency in audio power amplifiers. Legitimate high fidelity manufacturers generally rate their products honestly but nevertheless fall under the jurisdiction of the new FTC ruling. One particular requirement of this ruling makes it tough on most power amps. This is the requirement that an amplifier under test be preconditioned by simultaneously operating all channels at one third of rated power for one hour with a 1 kHz sine-wave test signal. This 33 percent of maximum power is close to the worst-case condition of about 40 percent of maximum power in class B and low AB power amplifiers. Most hi-fi power amps don't have adequate heat sinking to allow continuous operation with a sine wave near the worst-case conditions and consequently have thermal cutouts that shut the amp down when it gets too hot. This situation is realistic for most hi-fi use, as the average power output is about 1 to 15 percent of maximum power due to the high peak-to-average ratio of typical program material. A case in point; the MK-IIICM under review has a comparitively large heat sink and a thermal cutout that probably won't be activated with most usage in hi-fi systems. When operated continuously at one-third maximum power with a sine wave, it operates for 15 to 20 minutes before the thermal cutout shuts it down. It thus appears that many otherwise satisfactory power amps will have to be redesigned with consequent added bulk and weight and resultant increased cost to the consumer.

Table 2—Output noise versus gain setting and bandwidth.

Gain Setting, A	400-20 kHz μV	20-20 kHz μV	S/N, dB, re 200 W
0	80	240	−104
−3	50	160	−108
−6	34	110	−111.2
−9	24.5	79	−115
−12	18.5	57	−116.9
Setting, B			
0	83	230	−105
−3	57	180	−107
−6	44	140	−109.1
−9	32	105	−111.6
−12	23	77	−114.3

(Editor's Note: As is evident from Bascom's remarks in the "listening test" portion of this review, this particular amplifier was delivered to us in advance of the FTC's announcement of their new ruling. SAE tells us that all Mk-IIICM amps sold after November 1, 1974 include a small whisper fan, thus preventing premature action of the thermal cutout and meeting the FTC's preconditioning requirement. This fan is also available as a kit, costing $44.00, to update older Mk-IIICM amps.)

To sum up, the SAE Mk-IIICM is a well-made, esthetically attractive and reliable product that generally meets or exceeds its published specs. It is particularly well suited for driving inefficient and difficult loads and warrants serious consideration for anyone interested in a basic amplifier in this power class. *Bascom H. King*

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