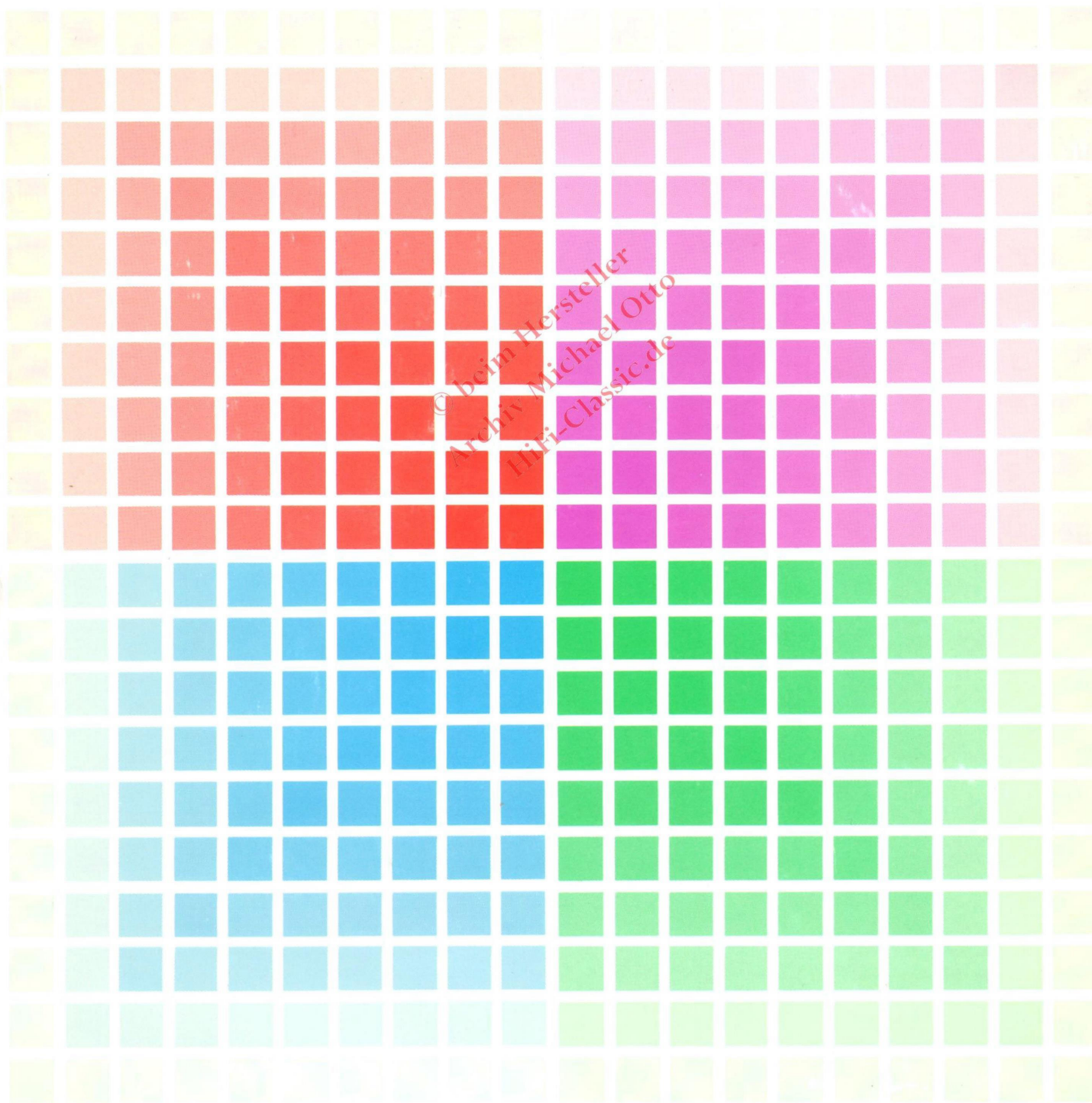


harman/kardon

Citation 16

professional power amplifier

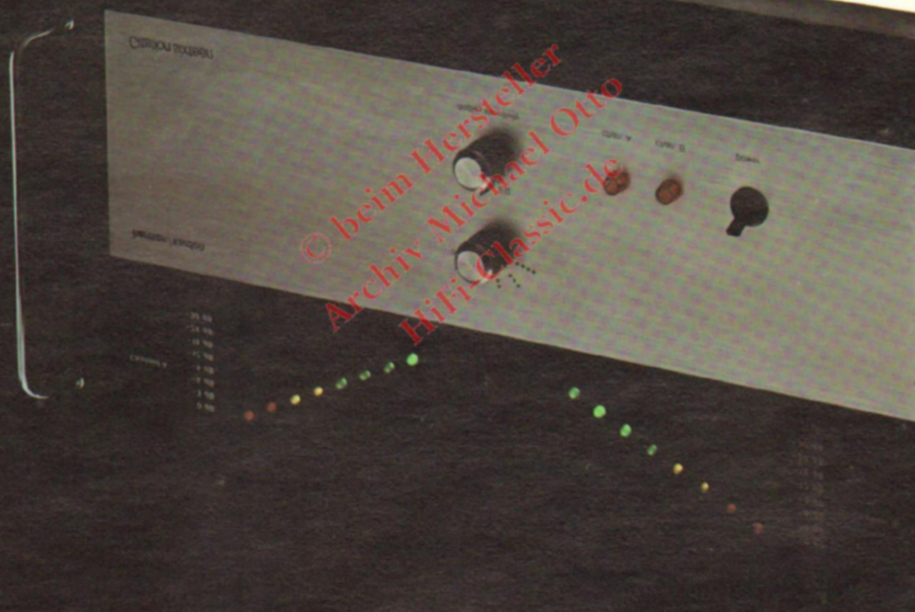


The desire to provide higher operant power levels in audio power amplifiers is based primarily on the belief that great power reserves enhance the amplifier's ability to replicate the wide dynamic range of live or recorded sound. At Harman/Kardon we believe this to be the legitimate rationale for the domestic use of a high powered audio amplifier.

The Citation 16 has the power output needed to meet the most rigorous dynamic conditions, but does not sacrifice sound quality in doing so. It is unique in satisfying the demands for high power, technological advancement, and, most important, the exceedingly high standards of sound quality set by its creators.

The Citation 16 is the careful synthesis of brute force, technical expertise and sonic sensitivity that were the goals of its designers.

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Power and Dynamic Range

Many people are surprised to learn that the increased power levels available in modern audio amplifiers do not necessarily imply increased loudness levels. A relationship between power and loudness does exist, but it is not an arithmetic one: twice the power capacity does not mean twice the apparent loudness. The real advantage of higher power capacity is the improvement of the amplifier's ability to accurately traverse the wide dynamic range of both live and recorded musical material.

In recent years, application of noise reduction and dynamic expansion techniques to the recording process, improvements in the quality of disc and tape recordings, and reduced noise in broadcast and playback equipment have dramatically increased the total dynamic range of musical material now available for domestic enjoyment.

Not long ago, truly effective use of high powered amplifiers was limited to driving speaker systems of extremely low efficiency or for use as power sources for sound reinforcement systems used to fill extremely large audience areas. Now, because of the recent improvements in the dynamic range of recorded material, almost every home audio system will draw demonstrable benefits from an increase in available amplifier power.

Naturally, higher power capacity should not be accompanied by increases in any factor that could destroy sound quality. So, while the Citation 16 offers very high output power, its design virtually eliminates all commonly known forms of distortion. But beyond that, the Sixteen circuit design effectively deals with forms of distortion we at Harman/Kardon have long and strongly believed to have great impact on good sound quality. Further, the 16 circuit is specifically designed to deal with a form of distortion that has only recently been identified.

Sound Quality

Since their identification, intermodulation distortion (IM) and total harmonic distortion (THD) have been viewed as the most important aberrations in audio amplifiers. These distortions have been virtually eliminated in the circuit design of the Citation 16: IM values fall in the range of 0.025% (a ratio of 1:4000) at

power levels between 1 and 150 watts, while THD values fall to as low as 0.005% (1:20,000) across this same range. These values are so small that specially designed and carefully calibrated test equipment is essential to make accurate measurements of them. What's more, the accuracy of the measurements can actually be influenced by radiation fields from power lines and other equipment in the laboratory.

Wide discussion of these common distortions as the principal disorders of high fidelity equipment has left many with the impression that these are the only distortions present in audio amplifiers and that elimination of them will result in perfection. This simply isn't so.

THD and IM are not the only disorders present in amplifiers. There are numerous others. The history of high fidelity technology is a chronicle of the discovery of a myriad of new problems upon the solution or amelioration of one or more of the older ones. As soon as they are unmasked, these new problems catapult into position as the most significant impediments to the perfection of high fidelity—this is the nature and process of all technological advancement.

It must therefore be remembered that harmonic and intermodulation distortion existed even before we knew they did, and it is almost certain that their elimination will reveal a number of new problems for circuit designers to solve.

The Harman/Kardon Philosophy

We began solving some of these problems in the design of our first Citation electronics series in the late 1950's. Although all the implications of our position were not clear to us at the time, we were certain that "wideband" design of our amplifiers and preamplifiers was a clear benefit in terms of the resulting sound quality. "Wideband" design is based on the belief that high fidelity devices, particularly amplifiers and preamplifiers, will deliver better sound across the range of human hearing (20Hz to 20,000Hz) if they are capable of reproducing frequencies both well below and beyond that region. At first glance, this seems almost ridiculous: "Why bother with frequencies we can't hear?" But deeper study shows the concept to be far from ridiculous. First, it must be understood that sensing sound involves more than just the ear. It is commonly known, for example, that almost any part of the human body can detect frequencies below about 500Hz. Since the ear is not the only avenue to our perception of sound, we cannot apply its limitations routinely. (This multiple perception path shouldn't surprise us. We often integrate responses to stimuli from our various sense organs. Flavor, for example, is a combination of both taste and smell.)

More important, the perception of sound is based on much more than our sensitivity to individual pure, steady-state sine wave frequencies. Even with single pure tones, the elements of pitch, loudness, volume, and density are factors that augment frequency and influence our perception. Curiously, pure tones are rarely found in nature, though they are present as the component parts of virtually all sounds. The complex sounds we hear are each the composite of a series of simple, pure sine waves. Each composite is a unique relationship determined by the number and frequency of the pure tones present, the distribution of energy between the tones, and the phase relationships between the tones. Any alteration of any kind in this delicate relationship, no matter how minute, changes the quality of the sound. Further, almost all musical sounds are composed of an initial instantaneous *transient* followed by a decay period. These transients play a significant role in music.

Second, we must remember that analog electronic circuits exhibit smooth, consistent, and predictable functions. Most of us are familiar with frequency response curves that show roll-off where the amplifier loses the ability to reproduce frequencies at uniform energy levels. Such curves are uniform in that the amount of rolloff at any point on the curve can be expressed mathematically. But more important, the nature of these smooth functions is that their effect always increases in one direction, and decreases in the other. Once we know that frequency response non-linearity exists at one point, we know that such non-linearity will exist at points below and beyond that point in greater or lesser degree. Most circuit designers appear to appreciate these factors as they apply to frequency response and linearity.

What is apparently not widely appreciated (or worse—not widely understood) is that these same smooth functional characteristics apply to phase linearity as well. Calculations indicate that phase relationships between frequencies cannot be accurately maintained unless the upper cutoff (-3dB down) frequency of the amplifier exceeds the highest desired frequency by a factor of 5, nor unless the lower cut-off frequency of the amplifier is at least one-fifth of the lowest desired frequency. Thus, to reproduce

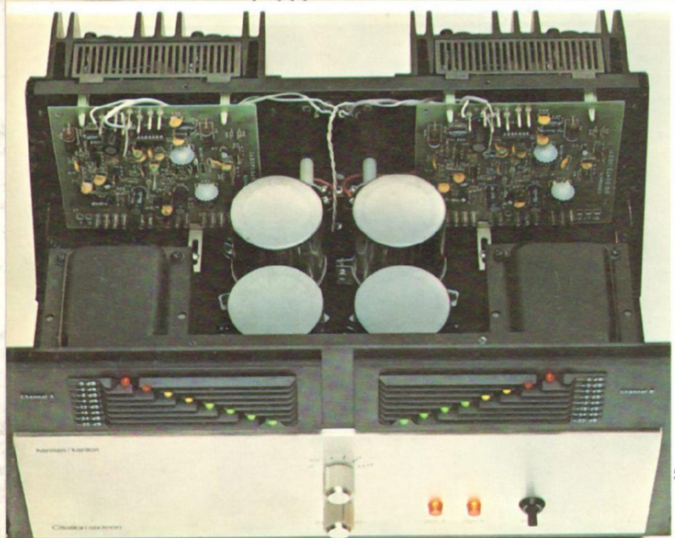
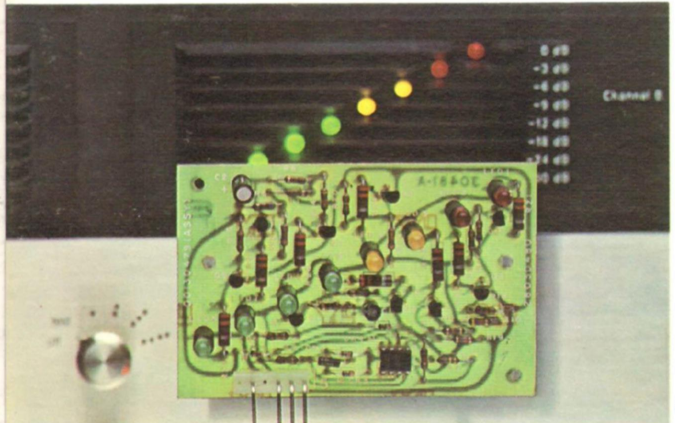
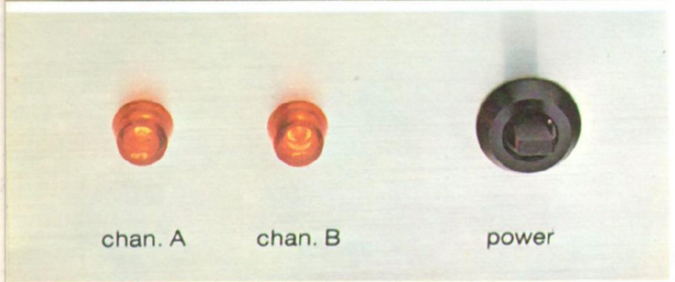
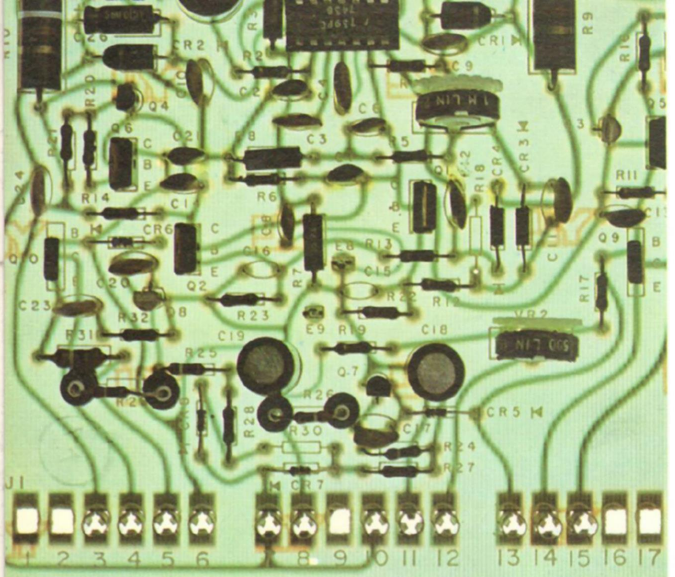
sounds with accurate phase linearity in the audible region of 20 to 20,000 Hz, the amplifier *must* have a minimum bandwidth of 4 to 100,000 Hz!

Since we know the important elements in musical sound are frequency content, specific frequency response relationships (energy distributions), and specific phase relationships, it becomes imperative that these relationships be undisturbed as their electrical analogues pass through the amplifier. No amplifier designed to the standard 20 to 20,000 Hz limits can hope to satisfy this basic requirement.

Surprisingly, even this is still not enough. The transient character of most sounds places an additional requirement on the designer. One must be certain the amplifier will accurately pass any transient it is likely to encounter. Transients are invaluable to the quality of all sounds: they are characterized by the movement from dead silence to high loudness levels in extremely small periods of time. All instrumental sounds possess some transient character—particularly the percussion instruments, i.e., piano, harpsichord, guitar and other instruments that are beaten, struck, or plucked. The precise length of transient periods in natural instruments is extremely difficult to measure. It is therefore difficult to use this behavior in natural instruments to set design goals. However, one entire family of instruments, the electronic synthesizers, can produce waveforms with measureable transient periods as short as a few millionths of a second. Only an amplifier possessing transient response equal to or faster than the transient period of the input signal is capable of passing such signals cleanly. Transient response is determined by the *square wave rise time* of the amplifier. Square wave rise time is inversely proportional to frequency response, i.e., faster rise times (better transient response) are achieved by increasing the high frequency cutoff points of the amplifier. This, of course, is the same as increasing the amplifier's bandwidth.

All of these factors confirm our attitude with respect to "wideband" design. The Citation 16 satisfies the basic requirements for phase linearity across the audible frequency region by exhibiting low and high frequency cutoff points of 0.1 Hz and 130,000 Hz, respectively. The high frequency cutoff also allows the Citation 16 a very fast 3 microsecond square wave rise time. Without "wideband" design, neither phase linearity nor sufficient transient response can be assured.

Citation 16



Technology

The Citation 16 is essentially a DC-coupled amplifier with a 0.1 Hz high pass network positioned at its input. This network offers protection against the amplification of any inadvertent D.C. inputs which would cause damage to speaker systems. Because it is an R-C type with a sharp cutoff characteristic, the input network provides the essential D.C. blocking protection *without* significantly affecting response above 2 Hz.

An IC differential input amplifier acts as the first gain stage in each channel and automatically balances the amplifier so there is virtually no D.C. offset potential at the speaker terminals. Apart from the role it plays in direct coupling at the amplifier's outputs, differential balancing permits the application of negative feedback across the entire frequency spectrum and offers the advantage of perfectly linear operation of even the most minute signal levels.

The drive circuit is notable for its symmetry. By using a complementary pair of class A drivers at the output of each IC differential amplifier, the entire driver stage is both symmetrical and complementary. The most important advantage of this arrangement is the resultant ability of the Citation 16 to slew at a rate of 30 volts per microsecond—far faster than the 8 or 10 volt-per-microsecond rates of other high powered amplifiers.

Slew rate determines the length of time the amplifier will be in saturation when it experiences a transient waveform. This saturation, and its associated hysteresis, are the prime factors in the generation of transient intermodulation distortion (TID). TID has relatively recently been identified and appears to be the element responsible for much of the stridency critical listeners have sometimes associated with solid state amplifiers.

An audio amplifier possessing feedback is actually driven by the difference signal resulting from the combination of the original input signal and the portion of the output signal used for negative feedback. If the response time, or slew rate, of the amplifier is less than that called for by a "step", or transient input signal, the output will lag behind the input, and the difference between the feedback and input signals can exceed the dynamic range of the input stage. A period of saturation results during which the amplifier's output bears no resemblance to its input. This condition persists until the amplifier's output "catches up" to the input signal.

(1) The driver board provides circuits for gain and drive and also includes circuitry which protects the amplifier from damage due to short circuits or overloads at the output.

(2) There are two heat sink assemblies. Each consists of eight TO-3 power output transistors, two TO-3 driver transistors and one Vbe multiplier. The chimney-type design promotes convection with great efficiency.

(3) Each channel has its own pilot light indicating each of the two power supplies in normal operation.

(4) The LED display is a faster, more responsive and therefore more accurate indication of dynamic range and power level.

(5) Each one of the massive power supplies (which account for much of the weight of the Citation 16), delivers two voltages: ± 60 VDC for the output stages and driver boards and ± 12 VDC for the LED display.



Improving the slew rate of the amplifier enhances the ability of the output to follow the input, in turn reducing the opportunity for saturation and the occurrence of TID. Thus, the Citation 16, with its 30 volt per microsecond slew rate, has a considerable advantage over other high powered amplifiers with respect to TID. In fact, half-power square wave outputs from the Sixteen cause no saturation in any of its amplifier stages whatever. It can therefore be said that the Citation 16 is essentially free of TID at average listening levels.

The Citation 16 may be the first all solid state amplifier to truly deliver on the promises made by transistorized equipment almost fifteen years ago.

Twin Power

The Citation 16 is "twin powered"—there are two separate power supplies, one for each channel's electronics. Two power supplies means two transformers, two rectifier bridges, and two sets of electrolytic capacitors. "Dual" power, the generation of both positive and negative voltages from one power supply, is often confused with "twin power." The availability of both positive and negative supply voltages makes direct coupling possible, but, while desirable, this is not new. The first Harman/Kardon design to use direct coupling, and therefore "dual" power configuration, was offered in the early 1960's. Each one of the power supplies in the "twin powered" Citation 16 is a "dual" configuration.

"Twin Power" is an integral part of the Harman/Kardon design approach, and we use it with good reason. Although it is possible to derive the voltages required for both channels with a single power supply, we believe an amplifier with two supplies can continue to deliver clean, well-separated sound, even when sustained, demanding musical material is encountered. Under conditions of extreme stress, a single supply offers a direct route for the supply demands of one channel to influence the needs of the other channel adversely. Great surges of power are generally demanded of *both* channels of a stereo amplifier *at the same time* rather than alternately.

The two channels must, in the case of a single-powered amplifier, draw great amounts of energy from the same supply in an attempt to satisfy these power output requirements. We don't feel a single power source for two channels can do nearly as well as a separate power source for each channel. "Twin Power" makes good sense in amplifiers intended to handle *all* the situations encountered in the reproduction of music because it avoids any possibility of channel-to-channel interference, while providing energy reserves to handle any demand made on the amplifier.

LED Display

Monitoring of output levels of the Citation 16 may be desirable in some applications. A clearly marked display, utilizing light emitting diodes (LED's) is provided with a control for four functional sensitivity ranges. A "test" position establishes that all LED's are opera-

tional, and an "off" position deactivates the display entirely. The LED's are arranged in a multi-color sequence rather than the usual single color strings.

In addition to the switch offering control of the LED display sensitivity, a switch is provided to calibrate the display activity to 4 or 8 ohm load impedances. At either impedance, full scale illumination of the display at the maximum range setting is equivalent to an output level of 160 watts.

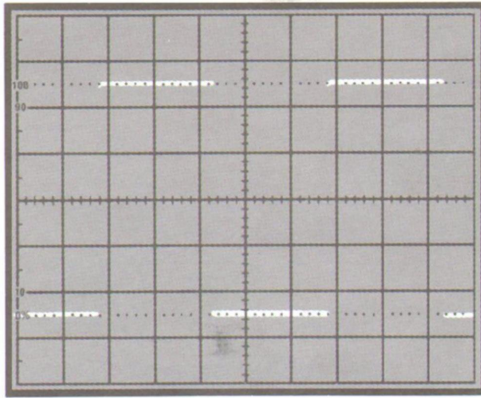
VU meters were rejected because of their inherent inaccuracies in indicating instantaneous power levels. LED displays have the capacity to indicate both dynamic range and power level more accurately than meters because of their speed. Neither the LED display, nor any of its control, affect the electrical performance of the Citation 16 in any way.

Protection Circuitry

Protection circuitry in the Citation 16 is of the "fold-back" type that allows the passage of full load current in the presence of load impedances higher than 4 ohms, but delivers progressively less current as the load impedance is reduced below 4 ohms. It can sense the presence of short circuits across the output terminals and reduces current to a point where thermal dissipation of the power output transistors falls within a safe level. In short circuit conditions, heat sink temperature is allowed to rise only to 90 °C. At that point the action of a thermal circuit breaker prevents any further temperature increase.

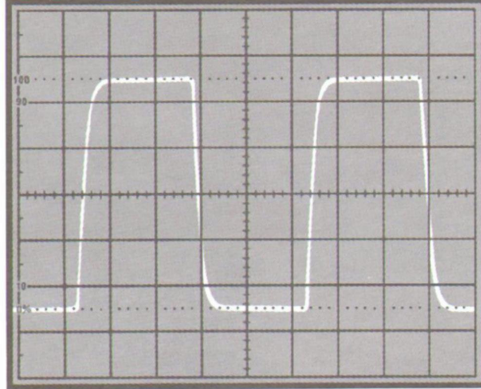
20 Hz Straight, flat and parallel tops and bottoms of square wave indicate virtually perfect reproduction of low frequency musical signals. Vertical leading and trailing edges of waveform are invisible because of long time base required to show several complete cycles.

H = 1/100 sec/cm
V = full power



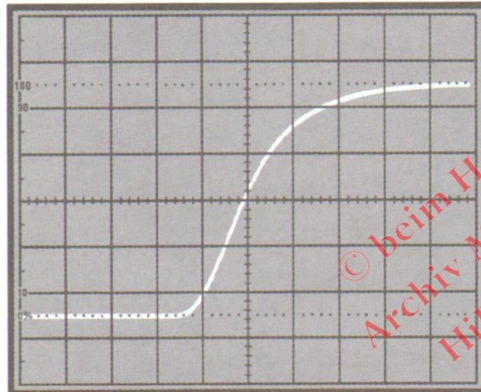
20,000 Hz Rounding of left hand corners of waveform indicate high frequency rolloff. Steepness of leading and trailing edges and small degree of rounding indicate rolloff to be at very high frequency (about 130,000 Hz).

H = 1/100,000 sec/cm
V = full power



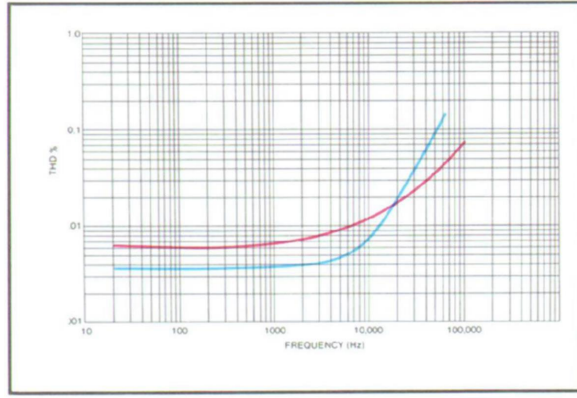
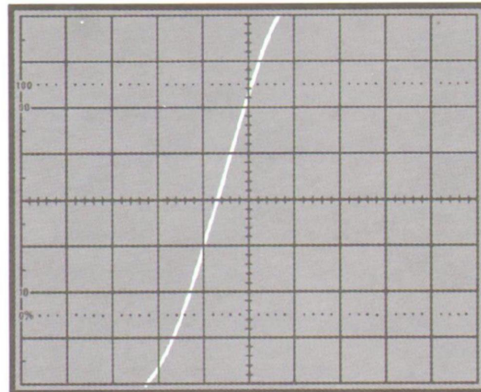
RISE TIME Measured from 10% to 90% displacement of leading edge. Time base has been expanded for more accurate measurement. Rise time is between 2.5 and 2.6 microseconds.

H = 1 microsecond/cm
V = full power



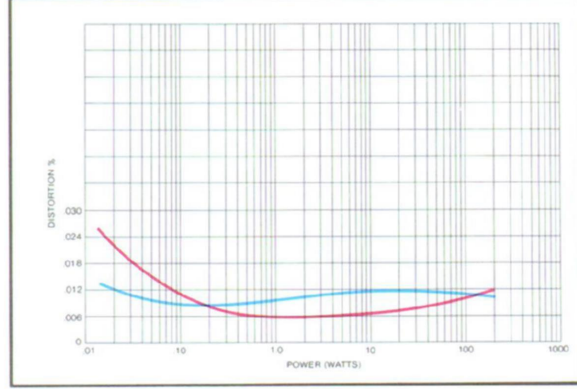
SLEW RATE Leading edge of square wave is perfect example of a "step" wavefront. Steepness of pattern indicates amplifier's fast slew rate (approximately 35 volts/microsecond).

H = 1 microsecond/cm
V = 10 volts/cm



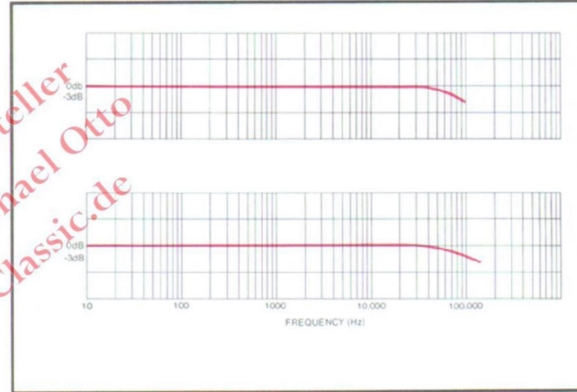
HARMONIC DISTORTION vs FREQUENCY

— 1 watt, 8 ohms
— 150 watts, 8 ohms



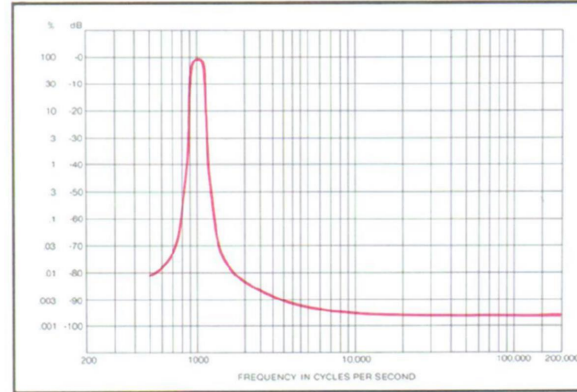
DISTORTION vs POWER (1 kHz)

— THD
— IM



POWER BANDWIDTH (per 0.5% THD, 0 dB = 150 watts)

FREQUENCY RESPONSE (0 dB = 1 watt)



SPECTRUM ANALYSIS (1 kHz input, 0 dB = 150 watts)

Absence of response at frequencies other than the input signal indicates harmonic distortion to be virtually nonexistent.

We use square waves in evaluating our circuit designs because they bear a remarkable resemblance to the complex musical waveforms with which the circuits must actually deal. Each square wave is a number of pure tones (a fundamental and its harmonics) where the arrangement of the energy levels and phase relationships of the pure tones involved result in the waveform's unique shape. Because of its delicate construction, any change in the number, relative energy, or phase of the pure tones making up the square wave will alter its shape, so there is a visual means of determining how well the amplifier will behave with musical signals.

Photographed at the Harman/Kardon engineering laboratory using calibrated test equipment. Citation 16 and eight ohm load.

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Citation 16 Specifications

- Power Output:** 150 WATTS MIN. RMS PER CHANNEL, BOTH CHANNELS DRIVEN INTO 8 OHMS FROM 20Hz TO 20kHz, WITH LESS THAN .05% THD.
- Power Bandwidth:** From 5Hz to 110kHz at less than 0.1% THD into 8 ohms, both channels driven simultaneously at 75 watts per channel.
- Frequency Response:** From 0.5Hz to 120kHz at less than 0.2% THD into 8 ohms, both channels driven simultaneously at 1 watt per channel.
- Square Wave Rise Time:** Better than 3 microseconds.
- Phase Shift:** Less than 0.5 degrees at 20Hz; less than 12 degrees and 20kHz.
- Slew Rate:** Greater than 30 volts per microsecond.
- Total Harmonic Distortion:** Less than .05% from 1 watt to 150 watts RMS, both channels driven simultaneously into 8 ohms from 0.5Hz to 20kHz.
- Intermodulation Distortion:** Less than .05% at .015 watts to 150 watts.
- Hum and Noise:** Better than 100dB below 150 watts.
- Damping Factor:** Greater than 300:1
- Input Impedance:** 10k ohms.
- Input Sensitivity:** 1.25 volts for 150 watts.
- Inputs:** One RCA type input terminal per channel.
- Outputs:** Instrument type binding posts. Accepts speakers from 4 to 16 ohms.
- Dimensions:** 9¼" H x 19" W x 14" D (complete with metal cage)
(23.5 cm. H x 48.3 cm. W x 35.6 cm. D)
- Weight:** 55 pounds (24.9 kg.)

This unit is internally bridgeable for monaural operation and provides 320 watts driven into 16 ohms from 20 Hz to 20kHz with less than .05% THD.

Information is available upon request with regard to commercial and sound reinforcement applications.

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