A High Performance Manual-Tuned AM Stereo Receiver for Automotive Application Using MOTOROLA ICs MC13021, MC13020 and MC13041

INTRODUCTION

This article presents a high performance manual-tuned car AM stereo receiver design using MOTOROLA AM stereo ICs MC13021, MC13020 and MC13041. It is intended to provide radio design engineers with a good start in car manual-tuned AM stereo receiver design. The article consists of two parts. The first part describes all relative important principles of manual-tuned AM stereo receiver, and the other one details the car manual-tuned AM stereo receiver design.

PART I: THE CONSIDERATIONS ON MANUAL-TUNED AM STEREO RECEIVER DESIGN

The design of manual-tuned AM stereo receiver confronts several difficult problems, such as the phase noise, centre tuning, microphonics and RF mistracking.

PHASE NOISE Since the AM stereo is in AM/PM format, the phase noise created by frequency fluctuation becomes a noticeable problem which however does not cause serious affect on monophonic (MONO) receiver. Various factors cause frequency fluctuation, the major one being frequency drift of the local oscillator in mono-receiver with a conventional L/C oscillator. The frequency fluctuation is in the range of hundreds of Hz. But in stereo operation, it should be limited to a few Hzs because the 25Hz pilot tone with 4% phase modulation is equivalent to only 1.25Hz deviation. Any greater frequency fluctuation will cause interference to the pilot tone, and thus deteriorating the channel separation, signal to noise ratio (S/N) and distortion performances on stereo mode operation.

Besides the frequency stability requirement during operation, the center tuning during station tune-in and microphonics are equally important to the manual-tuned AM stereo receiver.

CENTRE TUNING In manual tuning, any small frequency deviation from centre will breed phase noise and subsequent tune-off from stereo mode or chartering in and out of stereo mode. Practical experience has shown that only a small amount (there are few Hzs) of deviation from centre frequency is allowed without seriously affecting the stereo performance. Obviously this is extremely difficult or even impossible to operate on a manual-tuned receiver unless some sort of AFC or centre tuning circuit is applied.

MICROPHONICS This effect is much more serious an AM stereo receiver. The drift of a typical variable capacitor tuner or inductance tuner is 1% or 3KHz respectively under vibration test according to a car environment. This introduces 17db higher impulse noise than the condition of 75% single channel, 400Hz modulation and / or 20db higher impulse noise causing by the 25Hz pilot signal. Even in a PLL synthesizer receiver, if a frequency drift caused by vibration is greater than the "Tracking Range", the receiver will lock off the stereo mode. This is obviously unacceptable in receiver operation.

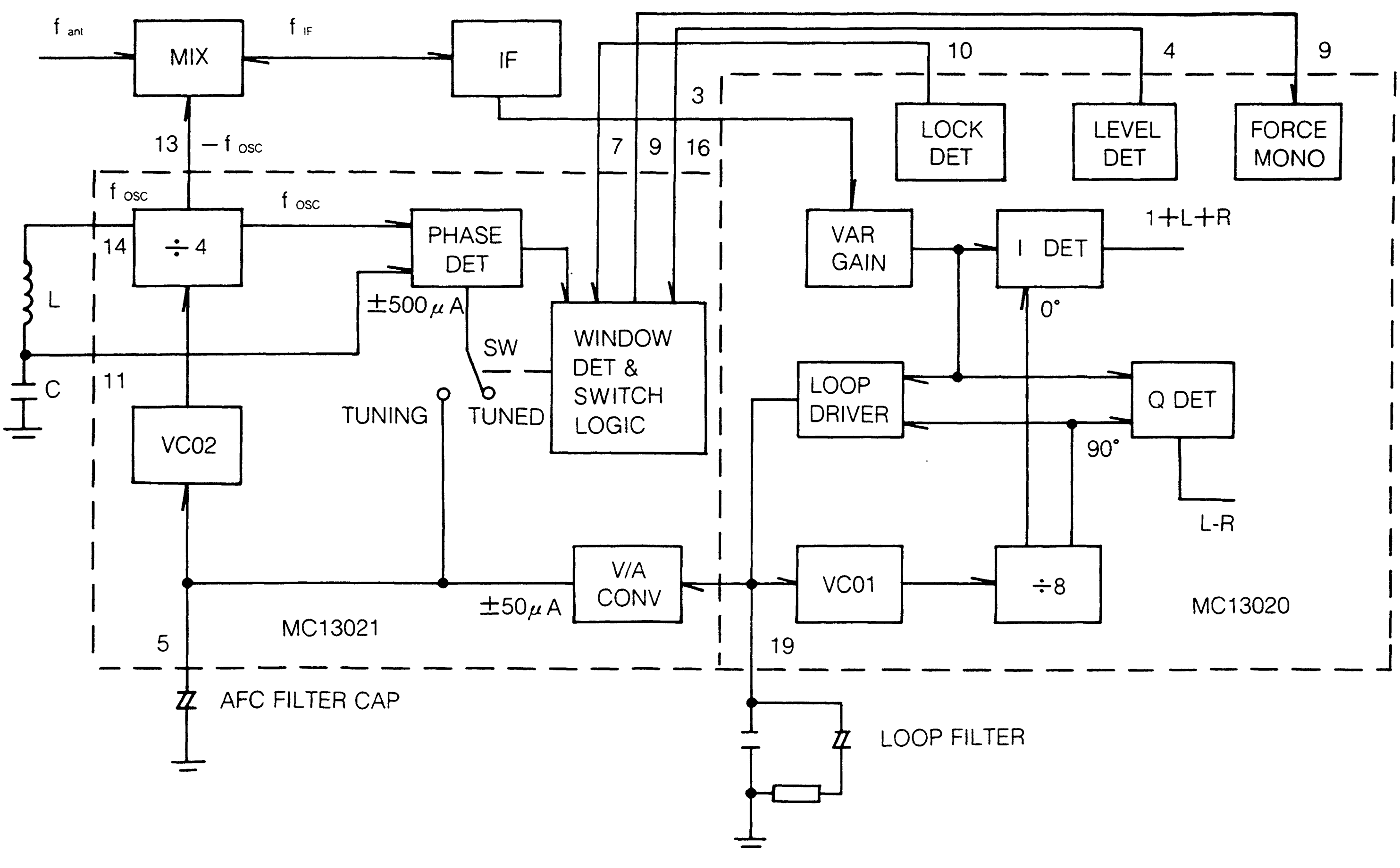


FIGURE 1. MANUAL-TUNED SYSTEM OF MC13020, MC13021.

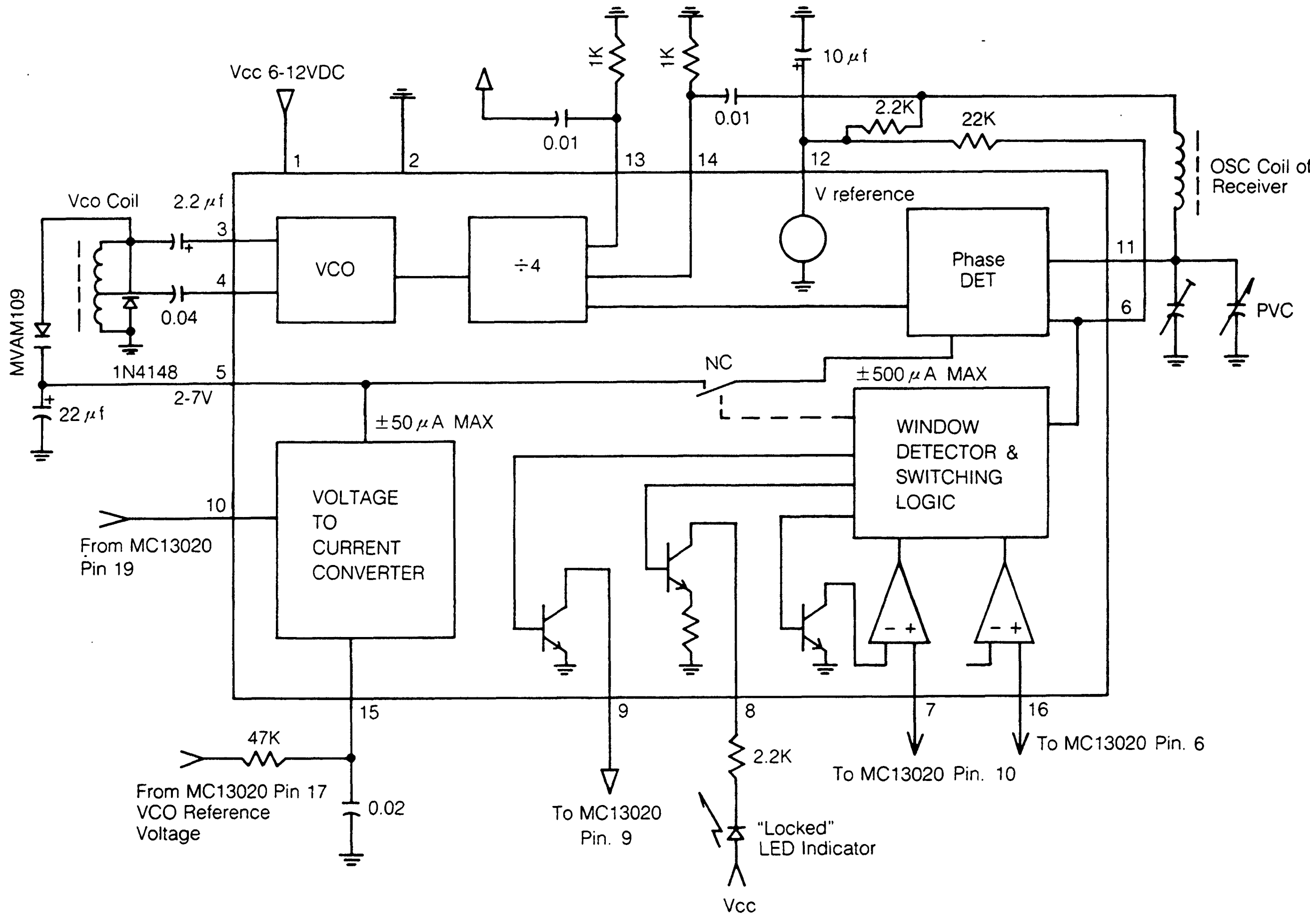


FIGURE 2. BLOCK DIAGRAM OF MC13021.

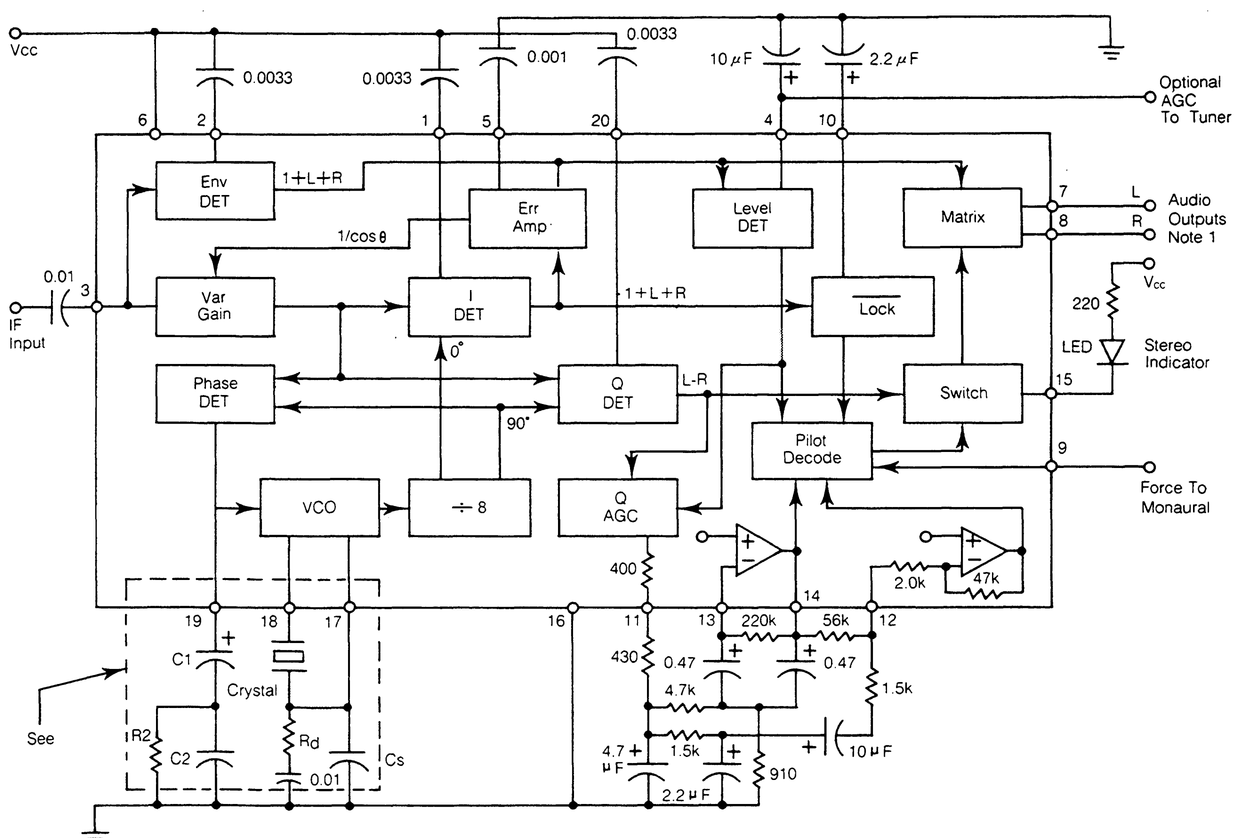


FIGURE 3. BLOCK DIAGRAM OF MC13020.

MOTOROLA has introduced the MC13021, interfacing with MC13020 decoder to solve those problems and obtained high performance in manual-tuned receiver. The combination of MC13020 and MC13021 provides a microphonics free manual-tuned AM stereo receiver with low noise oscillator, AFC and tuning aids.

The principle of the manual-tuned system of MC13021/MC13020 is described in figure 1, and figure 2 and 3 give the full circuit block diagram of the two ICs. The system operates at two different modes "Tuning" or "Tuned". The mode status is controlled by the window detector & switching logic circuit.

In the "TUNING" MODE, the system acts as a FLL (Frequency Lock loop) function. The VCO2 (Voltage Control Oscillator), operating at 4 times of receiver oscillator frequency, feeds to the divider (÷4) which has three outputs; the one with opposite phase goes to the local oscillator of receiver mixer stage, and the other two with the same phase go to the phase detector as a reference frequency and to the L-C local oscillator circuit. In the phase detector the reference frequency is compared with the frequency at the L-C junction which is derived from the reference frequency. If the resonant frequency of the L-C is tuned to the reference frequency and in phase, the output of the phase detector is zero. Otherwise it outputs a correction voltage to VCO2 until the divided VCO2 frequency equals to the L-C resonant frequency.

When a station is tuned into the lock range (Approximately +/— 2.5K) of the MC13020 AM stereo decoder, the decoder loop locks in, and pin 10 of the MC13020 goes high. Under this condition if the received signal is strong enough, the AGC voltage at pin4 of the MC13020 exceed the threshold voltage at pin16 of the MC13021, the phase detector of the MC13021 will be disconnected from the VCO2 by the Window detector & Switching circuit. Then, the receiver enters the "tuned" mode. The pin9 of the MC13021 goes high, this forces the decoder of MC13020 into "stereo" mode after detecting the 25Hz pilot signal.

The "loop driver" voltage at pin19 of the MC13020 is converted to the control current by the V/A (voltage to current) converter and pulls the VCO2 frequency into centre tuning frequency. Since the phase noise of the VCO2 is limited by the PLL loop in the "tuned mode", the receiver remains tuned in a frequency until the frequency drift, caused by tuning or microphonics, falls outside the window range of the MC13021 circuit. Then, the phase detector of the MC13021 triggers the window detector circuit and reconnect the phase detector to VCO2. Consequently the decoder goes out of "tuned" mode and pulls low at pin7 of the MC13021. The circuit is once again switched to the "tuning" mode.

The window width of MC13021 depends upon the Q value of the tuning L/C resonant circuit and the VCO2 Varactor gain. The two threshold voltages of the window detector are +/— Vbé (=0.7V) from the reference voltage at pin12. The resistor across the pins 6,12 of MC13021 is used to set the centre voltage of the window and has significant influence on the performance of microphonics elimination.

The relationship between the window width and the Q of the tuning L/C is as following figure 4:

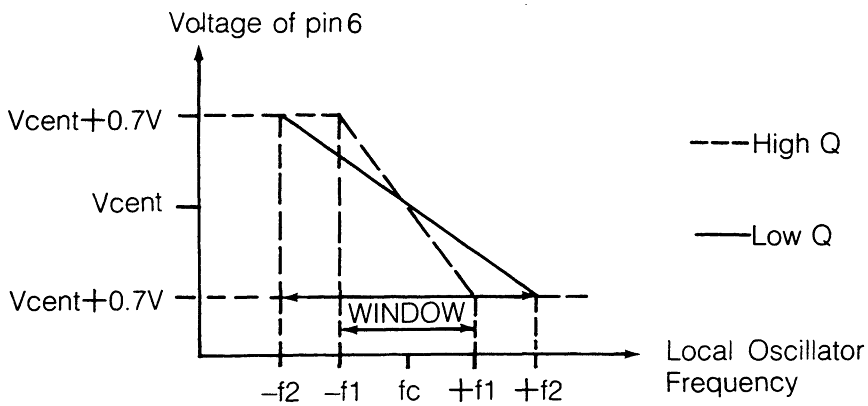


FIGURE 4. WINDOW WIDTH OF MC13021.

In general, the microphonics elimination (Electrical) of the circuit in figure-1 is almost effective by the following formula:

$$\text{Electrical Microphonics Elimination} = 20 \log_{10} \frac{fw}{fc} \qquad (1)$$

fw = Window Width.
fc = Loop Corner Frequency.

For example, if the loop corner frequency and window width are 10Hz and 10K respectively. Then the microphonics elimination (Electrical) is equivalent to 60db.

PART II: APPLICATION OF THE CAR MANUAL-TUNED AM STEREO RECEIVER

This part describes the manual-tuned car AM stereo receiver design and all the practical applications concerned. To avoid duplication, the discussion emphasizes on the microphonics elimination circuit and other concerned that did not included in the data sheets. The circuit diagram, PCB layout, components layout are shown in the figure 5,6,7.

RF SECTION of the circuit consists of 2 transistors and 1 FET. The transistors Q1, Q3 connect as a common base cascade RF amplifier which isolates the converter from input side. The FET is chosen on Q3 for better overload capability. Q2, driven by the MC13041 AGC output voltage of pin12, attenuates the input signal level under strong signal conditions. To obtain 6KHz RF bandpass for high fidelity while maintaining good selectivity for AM stereo reception, two tuned frequency selective circuits are being used. The first frequency selective circuit consists of L1-1, C2, CT2 and C3. Changing the ratio of C2 and C3 to matches the impedance of the antenna and Q3. The second frequency selective circuit consists of C11, CT1 and L1-2. The output of L1-2 secondary feeds the RF signal to the input of receiver IC MC13041 at pin18.

RECEIVER SECTION uses the MC13041 Car AM receiver IC. It has low phase noise, good phase linearity, wide dynamic AGC range performance, it is particularly suitable for automotive application. It also provides a buffered oscillator output pin13 for connecting to frequency synthesizer. The balanced mixer has high spurious rejection, with low phase noise IF signal output and low Intermodulation. The mixer output of pin19 couples to the recommended IF filter consisted of the IF transformer T4 and ceramic filter CRF1. The IF filter provides a quasi-parabolic bandpass with reasonably constant group delay. Changing the biasing resistor R20 can adjust the overall IF gain and affect the input impedance of the IF stage too. The IF output at pin8 goes to detector circuit pin7 through C23. Detector coil T3 is used as a peak detector as well as a phase shift coil for tuning error detection.

STEREO DECODER MC13020 is a well-known MOTOROLA C-QUAM stereo decoder IC. The important function of the PLL in MC13020 is to lock the phase of the divided VCO1 frequency into the input IF carrier. The manual-tuned AM stereo receiver uses a L-C (T5) circuit for VCO1, it has wider range of linear and symmetrical amplitude to phase characteristic and +/−2.5KHz "pull-in" range. A recommended coil of TOKO or MITSUMI MF2928CS-1349Z is used for T5. Since the loop driver is in current mode, the impedance at pin19 is very high so that the current leakage of the loop filter cannot be ignored. Experience has shown that to obtain less than 1% distortion, the leakage current of the loop filter capacitors C53 and C54 should be less than 0.5uA. The loop filter circuit of C53, C54, R36 is used to set the loop corner frequency at 8-10 Hz.

RECEIVER ALIGNMENT is slightly different from the normal one. Firstly, ground the pin10 of MC13020 to force the receiver into the "Tuning Mode". Then turn the L1-3, CT3 and T4 (padding inductor) to the desired receiver local oscillation frequency coverage. The VCO1 coil of the T1 does not need to be accurately adjusted, because the frequency range of the VCO2 has been designed with wider frequency coverage than the usual one. In manufacturing, the recommended VCO1 coil of T1 (Figure-5) can be pre-adjusted at the centre position, where the T1 has better anti-vibration performance.

THE "TUNING LOCK SENSITIVITY" is indicated by the tuning lock LED1. Its threshold voltage is controlled by the level detector output pin4 of the MC13020 and can be slightly adjusted by the voltage divider of R12 and R24.

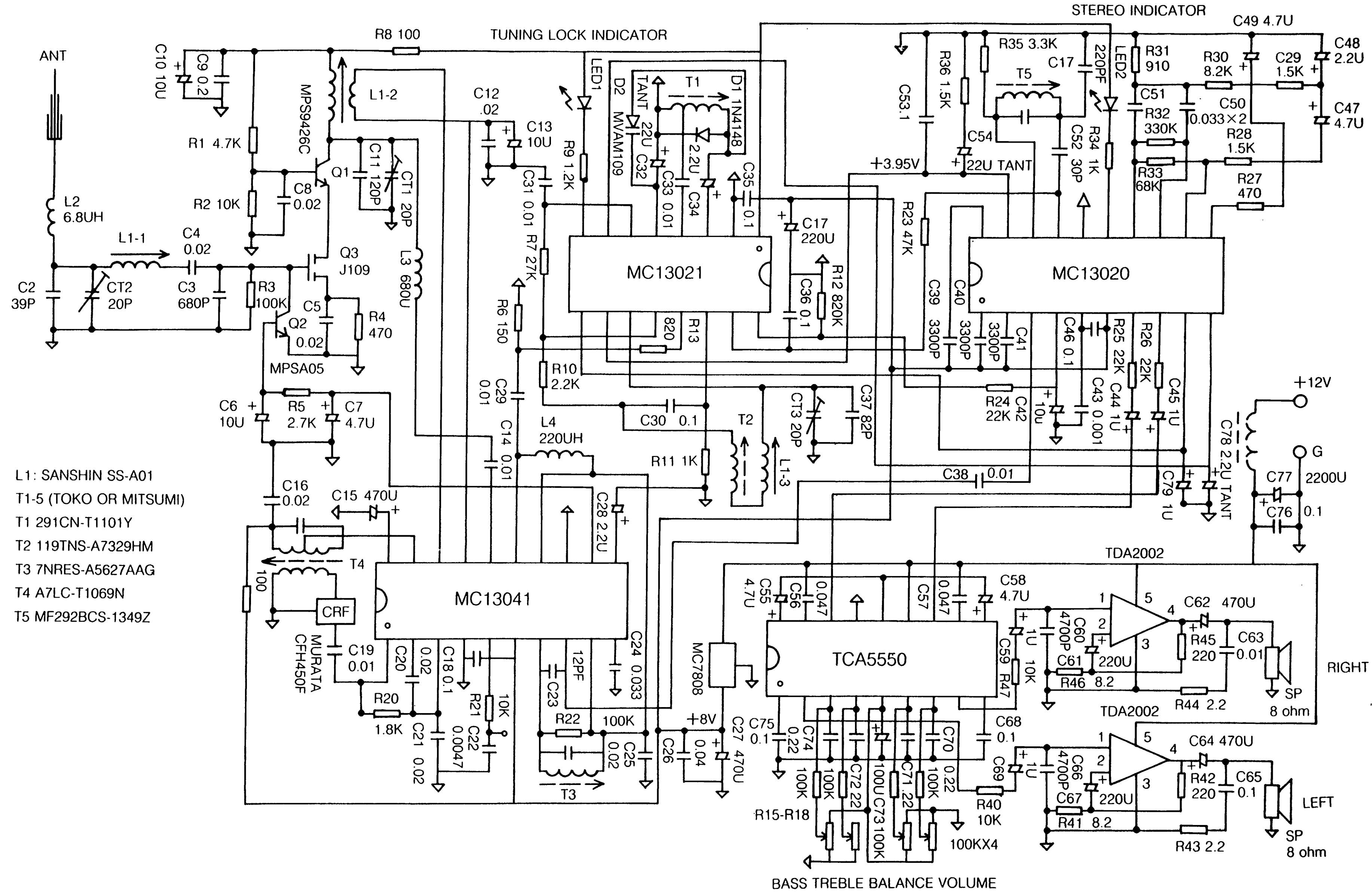


FIGURE 5. CIRCUIT DIAGRAM OF THE MANUAL-TUNED CAR AM STEREO RECEIVER

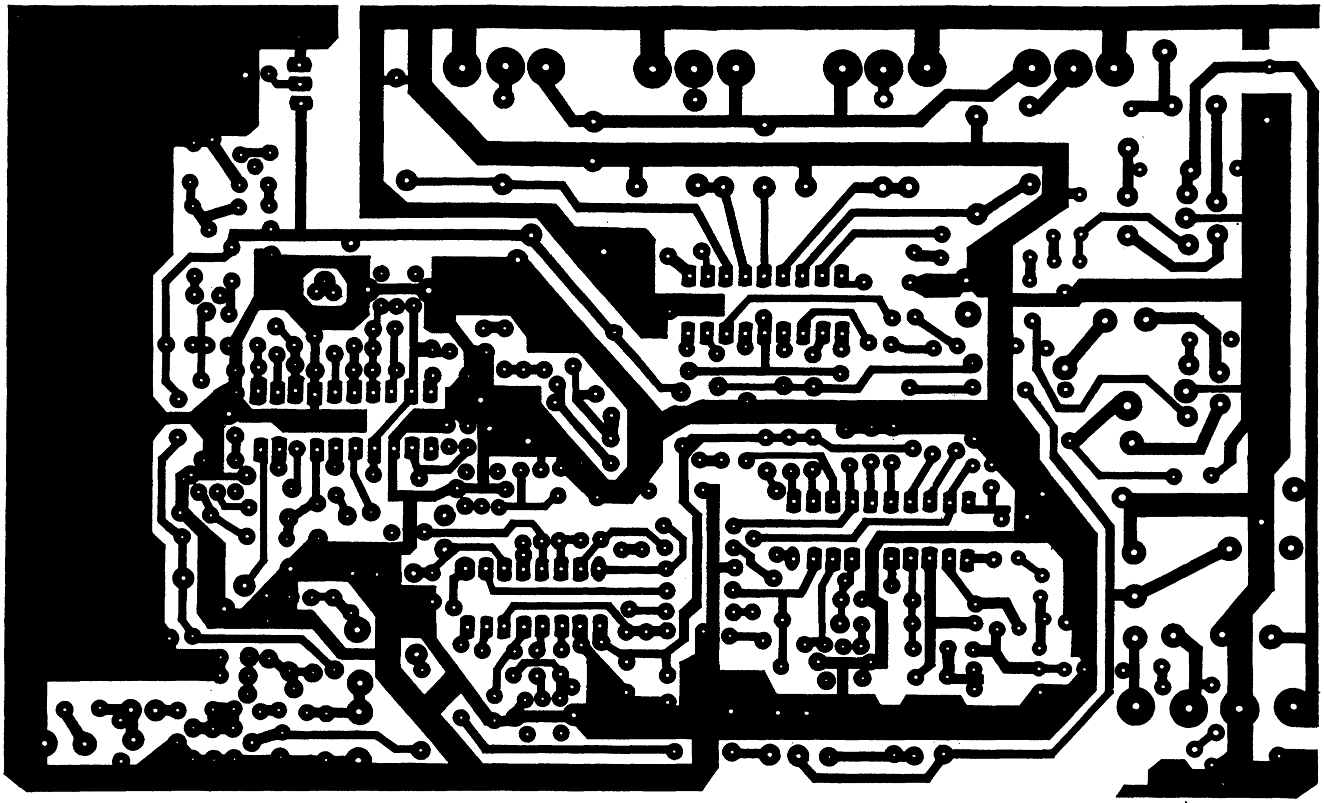


FIGURE 6. PCB LAYOUT

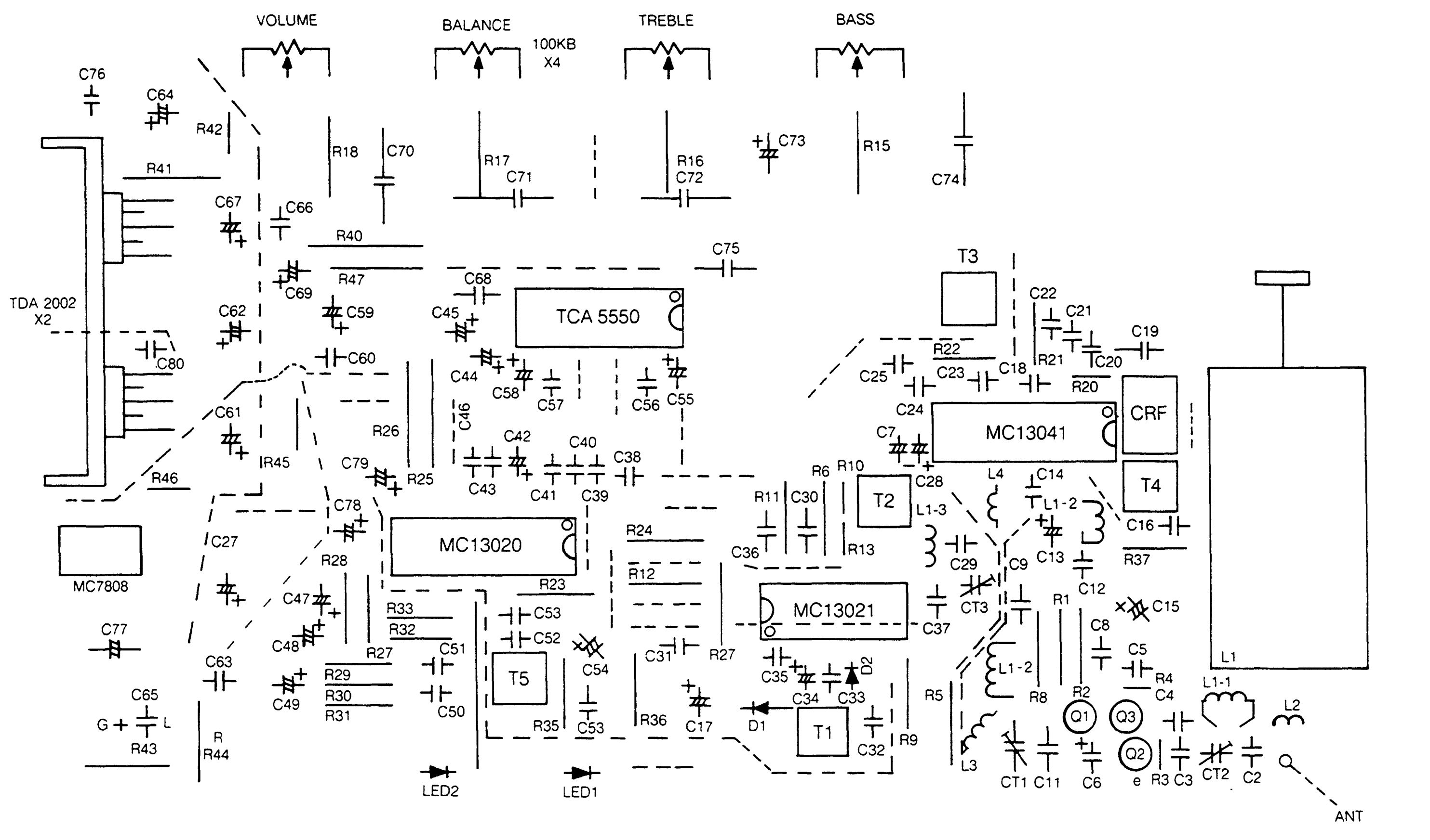


FIGURE 7. COMPONENTS LAYOUT

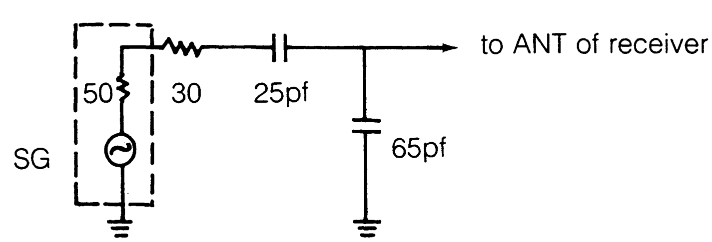
PRINCIPLE OF MICROPHONICS ELIMINATION. MC13021 is very effective in reducing phase modulation due to microphonics in the receiver. However, it can not completely remove all effects, and care must be taken in the mechanical design to reduce microphonics as much as possible. In electrical design, the window width is a determinant factor, a wider window gives a better microphonics elimination effect. It is normally designed at ±10K or more. When the VCO2 circuit has been selected, the window width is determined by the Q of the L-C resonant circuit at pin 11 of MC13021. To add two resistors in series and parallel with L1-3/T2 can lower the Q and obtain uniform and wider tuning window in whole receiving frequency range. VCO2 must use a coil with excellent anti-vibration performance and the TOKO coil TOKO0291CN-T1101Y is recommended for this application. The window width of the MC13021 affects the anti-vibration requirements for all relative components such as the tuner, VCO components and the mechanical parts. The overall frequency drift caused by vibration of components is required to be within the window or else the receiver will switch from stereo to mono mode. So, special attention must be given to the mechanical design, with rigid assembly technic, anti-vibration mounting, gluing and shielding technics. The circuit of figure-5 gives approximate 60-80db of microphonics attenuation. If there is a more stringent requirement on anti-microphonics, a separate PCB for T1 and relative VCO components should be mounted on an anti-vibration fixture.

PERFORMANCES OF THE APPLICATION DEMO SET (FIGURE-5) is shown as follows and the figure-8,9.

Test conditions: Vsupply= 12V, fc = 1MHz, fm = 1khz, m = 30%, Vin = 74db u, Vout = 50mw, R=8 ohm.

Frequency Coverage		1630—530 KHz.
No Signal Current		160 mA.
20db S/N Sens		20 uV.
S/N Ratio	mono	52 db.
	stereo (filtered 25Hz pilot)	48 db.
Separation (filtered 25Hz pilot)		30 db.
IF Rejection		38 db.
Image Rejection		40 db.
Audio Frequency Response (+/−10db)		300hz — 6 Khz.
THD	mono	0.6 %.
	stereo	1 %.
10% THD Output Power		3 w.
Tuning "lock" Sens		20 uv.
Stereo "on" Sens		20 uv.
Tweet 2 IF		26 db.
3 IF		30 db.
Overload (80% mod, 10% THD)		⩾100 db.
AGC		⩾100 db.
Microphonics elimination (electrical)		75 db.

Dummy ANT



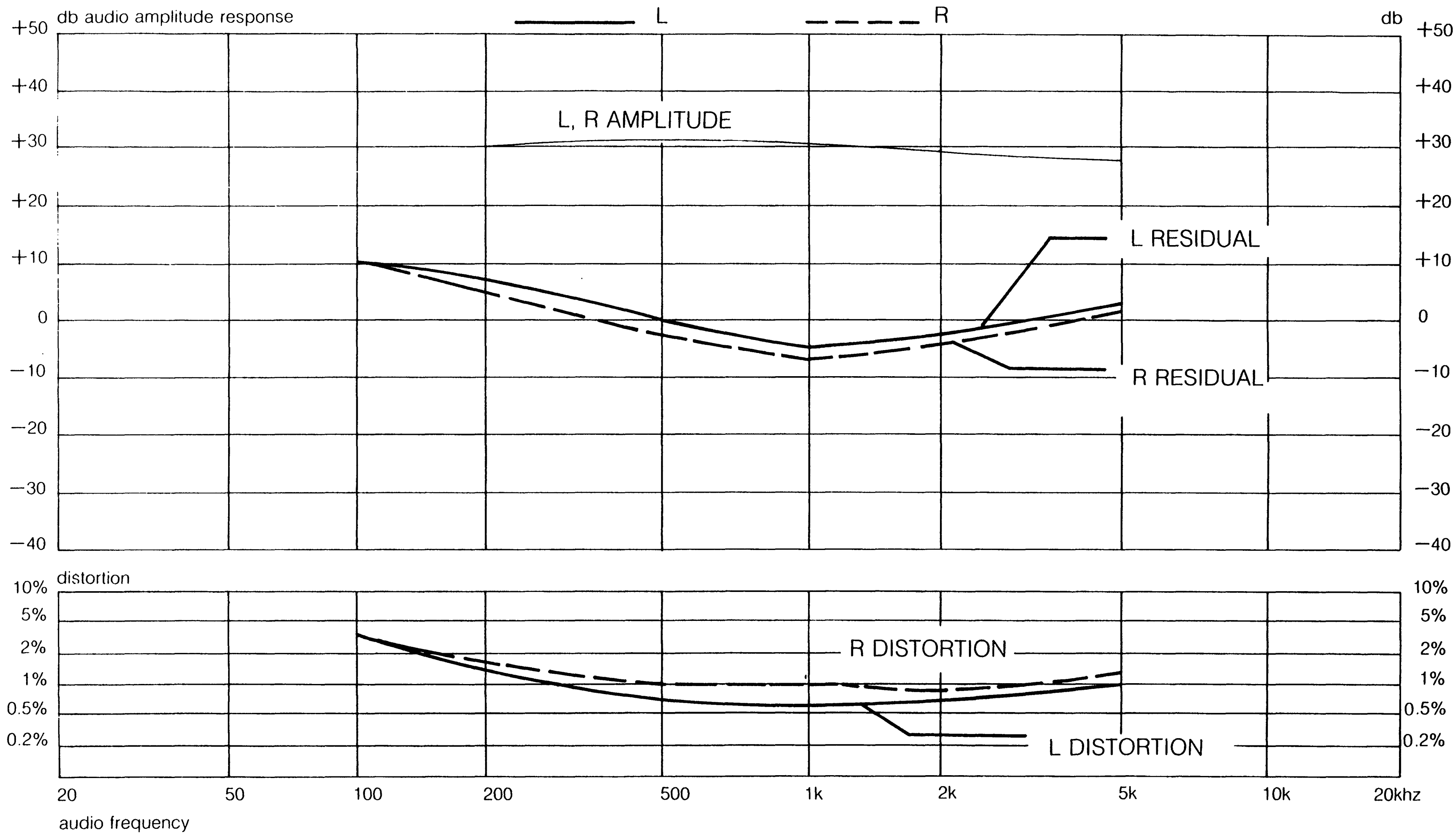


FIGURE 8. PERFORMANCES CHART-1

CHARACTERISTICS OF SENSITIVITY, S/N RATIO, AGC, DISTORTION, OVERLOAD CAPABILITY

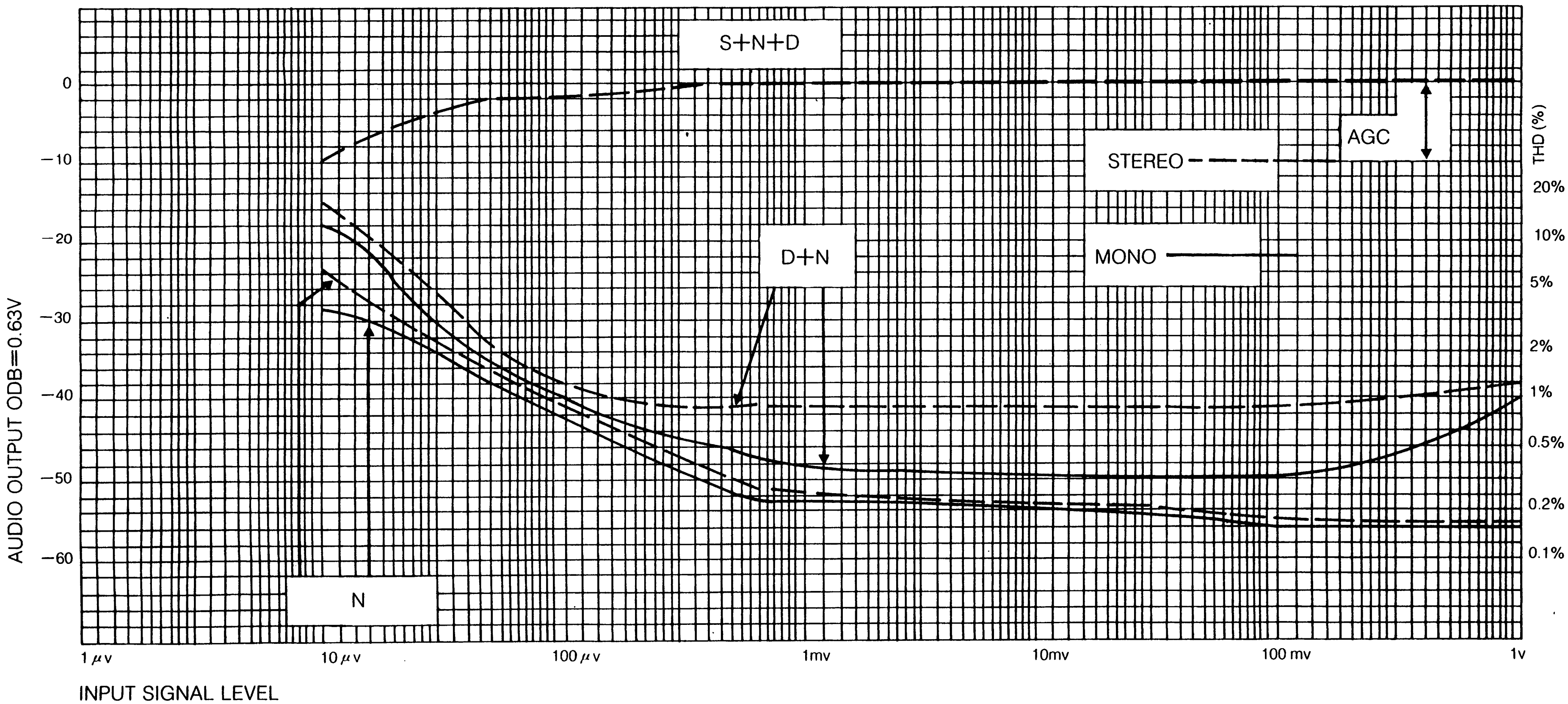


FIGURE 9. PERFORMANCE CHART-2

Literature Distribution Centers:
USA: Motorola Literature Distribution; P.O. Box 20912; Phoenix, Arizona 85036.
EUROPE: Motorola Ltd.; European Literature Centre; 88 Tanners Drive, Blakelands, Milton Keynes, MK14 5BP, England.
JAPAN: Nippon Motorola Ltd.; 4-32-1, Nishi-Gotanda, Shinagawa-ku, Tokyo 141, Japan.
ASIA PACIFIC: Motorola Semiconductors H.K. Ltd.; Silicon Harbour Center, No. 2 Dai King Street, Tai Po Industrial Estate, Tai Po, N.T., Hong Kong.

MOTOROLA

AN–HK–07/H