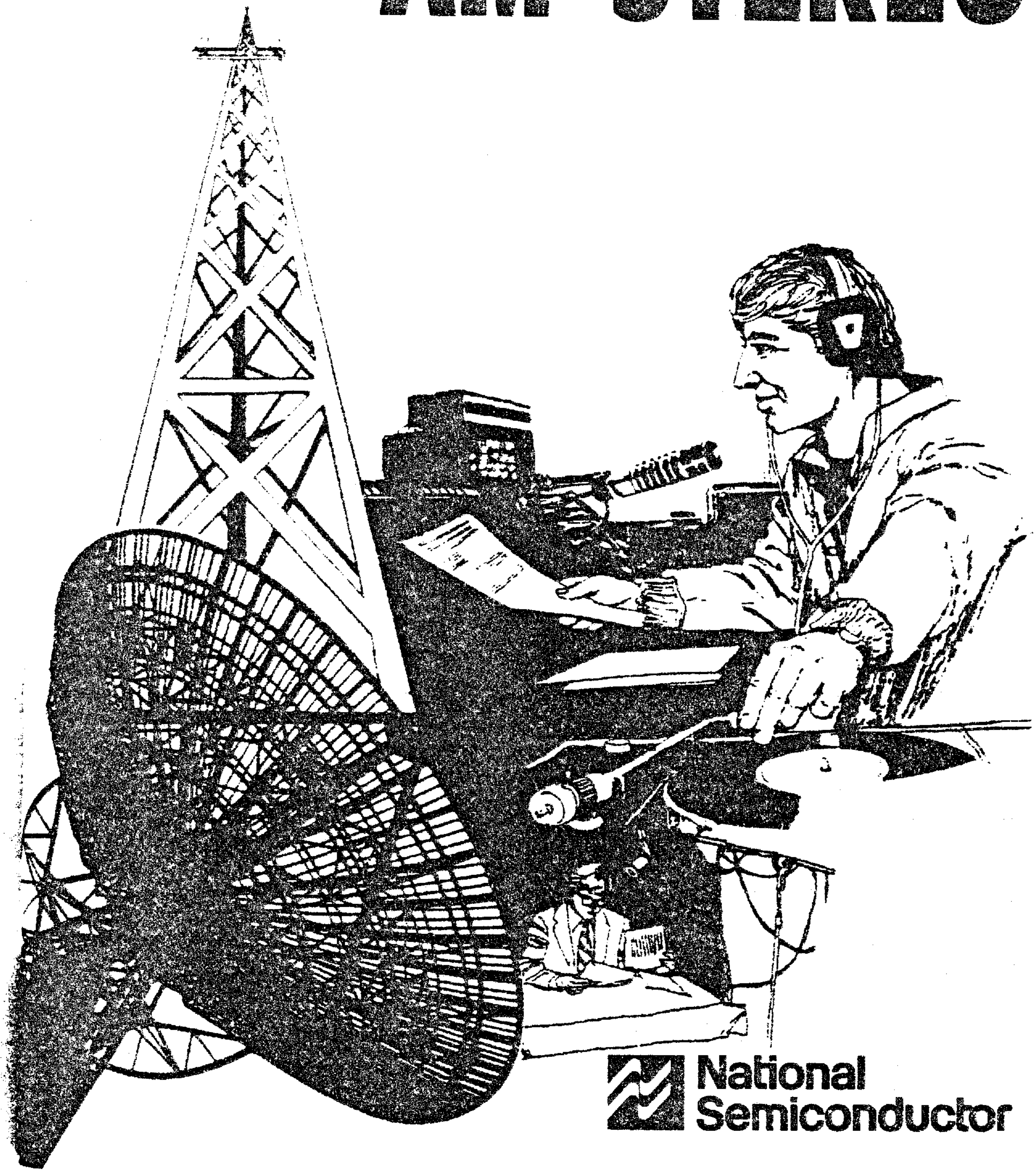
# AM STEREO



National Semiconductor

# AM Stereo NOW with National Semiconductor's LM1981 Stereo Decoder

The industry's first AM stereo decoder, the LM1981, is being made available to designers by National Semiconductor Corporation. This exceptional device, developed using National's proprietary linear circuit technology, decodes, or separates, the AM-IF signal into left and right channels. For the first time designers are able to directly modify existing mono designs for stereo operation.

The FCC is presently re-reviewing its April 1980 selection of the Magnavox system as a standard AM stereo manufacturing approach. The LM1981 is the integral part of at least three of the five proposed systems currently under evaluation. By designing-in the LM1981 now, manufacturers can be in production quickly once the FCC decision is announced.

According to National Semiconductor applications engineers, most AM radio front ends will probably not meet the requirements for AM stereo without substantial improvements in at least two major areas:

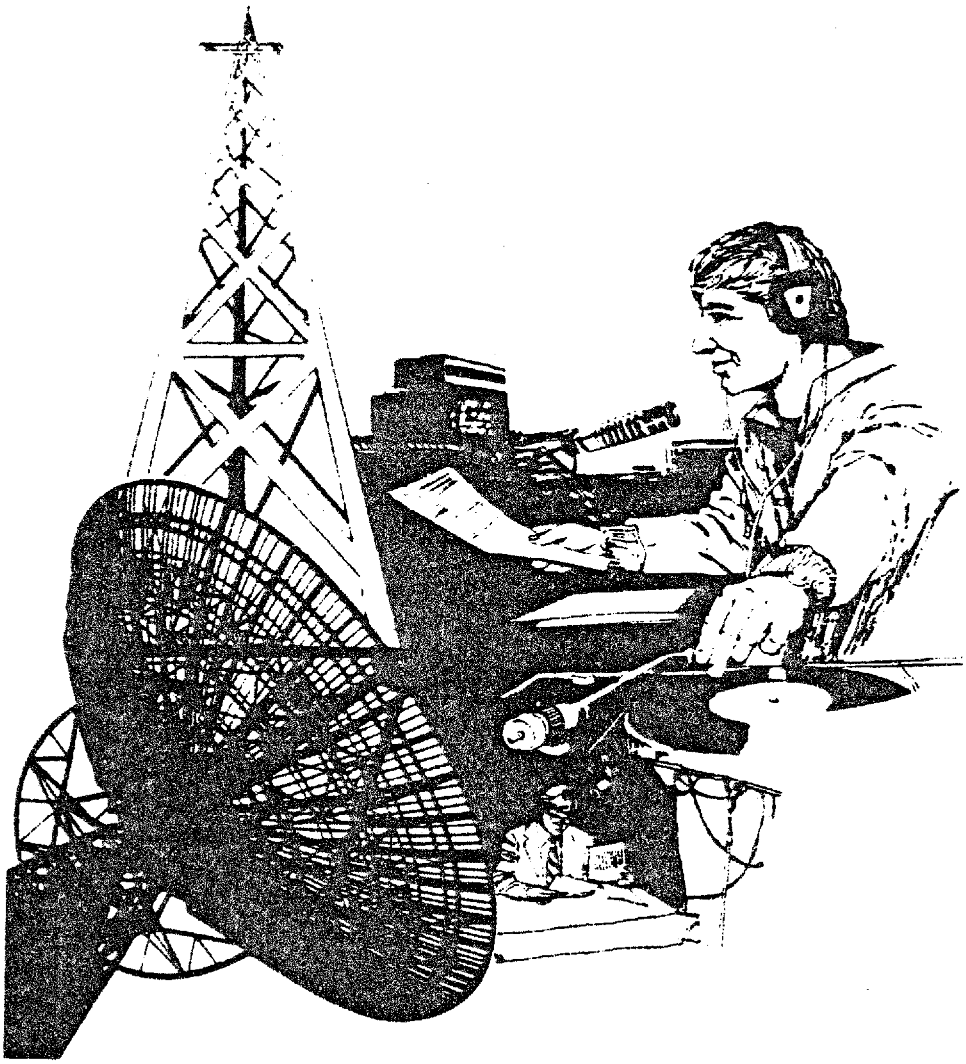
— phase noise of the local oscillator

— IF (intermediate frequency) symmetry

National is nearing introduction of an AM radio chip that will substantially improve performance in these areas. The LM1981 AM stereo decoder is available in a 20-lead, dual-in-line molded package. The device is fully developed and ready to enter volume production. Samples are available now on a restrictive consignment basis.

# The Receiver Manufacturers Speak Out

# AM Stereo



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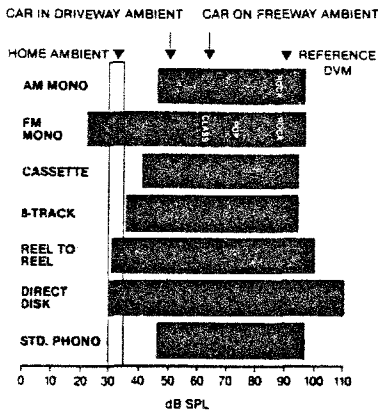
## Broadcast AM Radio: Why Stereo?

As a program source, AM provides sufficient dynamic range—the audio sound level range between the maximum normal listening level and the background noise level—for acceptable listening in all but the quietest audio environments, as shown in Figure 1. Due to narrower frequency bandwidth, heavier scheduling of commercials, and lack of stereo, AM has become a secondary source in recent years. However, the recent FCC decision to allow stereo broadcasting may add new life to the AM market. Since the AM carrier frequencies are relatively low, AM has more geographic range than FM and does not suffer from multipath problems. As a result, many now believe that AM stereo will actually become a favored program source in the automobile and other environments.

**Figure 1. Program Source Summary**




## Market Selection of AM Stereo Systems

After many years of study, testing, and one false start, the FCC announced on March 4, 1982, that AM stereo broadcasting would be allowed but that the market would have to select the system. This was deemed more efficient than the anticipated litigation, as the proponents have proven themselves very capable of frustrating selection by any public or private agency.

Unfortunately, the market has not proven itself either effective or efficient at making this sort of selection, even when fewer industry elements were involved. With two video disk systems on the market, and a third in the wings, overall sales of this playback-only medium are very disappointing in light of measured interest and demand.

While the video disk example involves only the consumer equipment manufacturers, retailers, and the consumer, 4-channel or quad sound added the elements of the broadcasting and recording industries and *four* competing systems. Because of system confusion, not only did quad sound not succeed in any portion of the market, the consumer was left with a bad image of the medium.

AM stereo has the added elements of the broadcasters and the broadcast equipment manufacturers, plus five different systems developed by receiver manufacturers or broadcast equipment manufacturers. The differences between systems are not well defined, with all systems providing adequate performance and all systems having advantages and disadvantages.

When competing, uncompatible systems reach the consumer, his decision process is greatly complicated and has an added factor of doubt. This has proven to have the effect of slowing market acceptance at best.

## Making AM Stereo Happen

When it became a strong possibility early this year that the FCC would allow this market selection, National Semiconductor prepared a plan, the goal of which was to analyze the market forces, determine whether consensus could be reached, and if so, how National could best help the market efficiently arrive at a single system selection. Our analysis was based upon our experience with AM stereo, our communication with the broadcast industry, and our knowledge of the receiver industry and the consumer market. We are forced to continually anticipate the needs of the receiver industry in advance of the receiver manufacturers themselves because of our longer lead times.

National is *not* a system proponent. We will build the integrated circuits for whichever system is chosen. We now have an IC that may be used for signal path decoding of at least three, and possibly all five, of the systems and stand to gain whatever the outcome. We will lose only if AM stereo does not succeed in the market. If our interest was merely selling our existing IC, we would have backed the system where we had the least competition rather than the most.

Throughout any analysis of the AM stereo question, the interests of the consumer—who will determine the success of AM stereo—should be considered above those of the various industry groups. Who *is* the typical audio consumer, and what *are* his needs from AM stereo?

## The "Typical Audio Consumer"

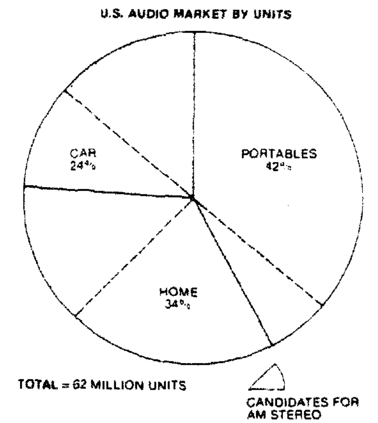
The audio market is diverse, with many segments differing in demographics, in taste, and in ranking of attributes. However, some commonalities form an image of the "typical audio consumer."

a. *Not an Audiophile.* With regard to radio, he is much more concerned with reliable, trouble-free reception than with audio aesthetics.

b. *Influenced by Opinion Leaders.* He is, however, influenced by audio enthusiasts, promotional activities, and status perceptions. He may feel he has to have stereo or Dolby™ or a Blaupunkt, not because he can discern a difference, but because he perceives that these attributes are preferred by others.

c. *Bases Decision on Perceived Value.* His choice of a particular attribute is modulated by the cost of that attribute as well as by his perception of the expected benefit.

**Figure 2. U.S. Audio Market By Units**




SOURCE: DEPARTMENT OF COMMERCE IMPORT STATISTICS
CUSTOM AUTO SOUND ASSOCIATION DATA

d. *Is Easily Scared Off.* He likes to buy new things and is on your side as you try to convince him to replace his existing equipment. However, many buying decisions, particularly of nonessentials, are very easily put off. Any hint of uncertainty introduced in his buying decision process can seriously blunt sales of a particular benefit and even related benefits.

## Consumer Needs: AM Stereo

The consumer is best served by providing him the highest perceived value and by eliminating system confusion. The elements of perceived value relative to AM stereo are the following:

1. Maximum choice of fidelity stations
2. Reliable feedback from the stereo light
3. Full compatibility, mono and stereo
4. Widest price range of stereo receivers
5. Affordable cost.

Meeting the needs of the consumer will have the effect of making AM stereo standard in the receiver whenever FM stereo is provided and greatly narrowing the perceived fidelity difference between AM and FM. The potential market size of AM stereo is shown in Figure 2.

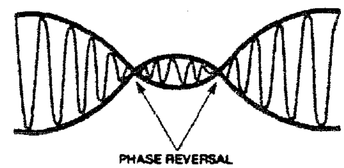
## Perceived Value: Maximum Choice Of Fidelity Stations

Stereo is the first prerequisite to improved *perception* of AM fidelity. Any of the systems can provide adequate stereo performance. In a typical receiver, the average consumer would hear little difference between AM stereo and FM stereo, particularly in a relatively noisy environment such as the automobile. AM stereo will increase the consumer's choice by adding AM stations to the choice range.

Some broadcasters are concerned that AM stereo, some systems more than others, would cost them coverage area, therefore limiting the consumer's choice of stations. They believe that increased levels of modulation have added to their coverage area and, since AM stereo is adversely affected by overmodulation, AM stereo will not be a benefit. Complete independence of phase modulation and amplitude modulation is not possible. Amplitude modulating the signal to the point where the signal disappears (Figure 3) makes it difficult to detect phase information with high quality.

For AM stereo to be compatible with existing receivers, the stereo information can only be impressed on the carrier by means of phase modulation, or its derivative, frequency modulation. Therefore, all systems are basically similar and equally affected by overmodulation. In our LM1981 AM stereo decoder integrated circuit, we prevented most audible effects of overmodulation by quickly recognizing these and other phase-noise conditions and blending the audio into mono, similar to techniques employed for high quality FM reception.

**Figure 3. AM Stereo During Overmodulation**




The FCC has twice rated coverage with the result that the systems tested are roughly equal in coverage, as shown below:

**Coverage (Relative to Mono)**

| Table | Magnavox | Motorola | Harris | Belar | Kahn |
|---|---|---|---|---|---|
| Initial | – | 6 | 6 | 5 | 5 |
| Final* | 5 | 5 | 5 | 5 | 5 |

*Stereo to mono receiver.

## Perceived Value: Reliable Feedback From The Stereo Light

Possibly more important than actual stereo sound for *perceived* fidelity is the visual feedback provided by the stereo pilot light. Recently a major FM station located in Livermore, California, experienced an amplifier failure resulting in mono transmission despite presence of the pilot signal. No consumer complaints were received during this 2-week period.

The stereo pilot light will also provide feedback to the consumer that he has tuned to a good station so that the broadcaster can now consider providing the consumer more dynamic range where appropriate by using less compression.

Unfortunately, the systems vary significantly in pilot tone detectability. For example, while the Motorola pilot tone can be detected, the same technique applied to the Magnavox pilot would have an additional 43 dB noise immunity. More difficult detection will result in either greatly increased cost in the receiver, which will reduce the size of the stereo listening audience, or in unreliable pilot detection leading to lower perceived quality for AM stereo. Delco states that:

> "In these tests, we will evaluate the mobile reception characteristics and considerable emphasis will be placed on the pilot tone and decoder and their efficacy in the mobile environment.... It cannot be susceptible to false triggering. The switchover from mono to stereo or vice versa must be smooth and automatic, preferably."[1]

The ranking for the systems from easiest pilot tone to detect to most difficult is as follows:

1. Magnavox 2. Belar 3. Kahn 4. Motorola 5. Harris[2]

## Perceived Value: Full Compatibility—Mono And Stereo

The consumer is best served by being able to listen to mono or stereo transmissions on mono or stereo receivers without any reduction in reception quality or any other compatibility problem. General Electric Co. states:

> "As a threshhold observation, GE believes that the paramount consideration to this commision must be the ability to any systems design to provide AM stereo broadcasting *without perceptible degradation* of service to existing monophonic receivers."[3] (Italicization by GE.)

The FCC has twice rated the systems on monophonic compability with the following results:

**Monophonic Compatibility**

| Table | Magnavox | Motorola | Harris | Belar | Kahn |
|---|---|---|---|---|---|
| Initial | 12 | 11 | 7 | 12 | 11 |
| Final | 15 | 9 | 6 | 9 | 12 |

It is not clear to us how significant the differences between systems are with regard to compatibility. With regard to the system rated lowest by the FCC, the FCC states,

> "Harris elected to sacrifice full compatibility with monophonic receivers using envelope detectors. Under full stereo separation, harmonic distortion in these receivers would be 4.3%."[4]

This added distortion during the presence of stereo information may not be discernable. While synchronous detectors may see use, the majority of AM receivers will remain asynchronous for many years. Any of the systems can be done synchronously or asynchronously. In the interest of the consumer, AM stereo must be flexible enough to allow the broadest price range f applications.

The pilot signal is the only way we have to ensure we listen to a stereo transmission in stereo and a mono transmission in mono. We are concerned that the pilot signals for the Motorola, Kahn, and Harris systems may be difficult to distinguish from incidental phase modulation. Our concerns are that AM stations would have to replace their transmitters just to maintain present reception quality and that the consumer would be disserved if they did not. Harris states, regarding the Harris system:

> "The mono broadcaster may occasionally need to improve the stereo parameters of his transmitter for the sake of those listening on stereo receivers. This may be necessary to:
>
> 1. Avoid stereo indicator 'falsing'
> 2. ...ensure that his transmitter will not trigger the stereo pilot tone detector circuits of the stereo receivers."[5]

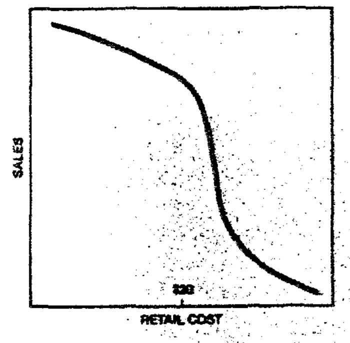
Compatibility problems, if present, will result in consumer dissatisfaction and lower perceived quality for AM transmissions.

## Perceived Value: Widest Price Range Of Stereo Receivers

AM stereo is not an audiophile phenomenon. In our opinion, AM stereo will either be a broad-based consumer success penetrating all receivers that already include FM stereo, or it will fail. We do not believe that AM broadcasters will make the changes necessary to best serve AM stereo reception when only a small segment of their listeners can benefit and when best serving stereo means not serving mono as well. Dolby™ FM is an example of this.

National Semiconductor believes that the Magnavox system best meets the requirements of a satisfactory low priced receiver and a very high quality top-range receiver.

**Figure 4. Effect on Retail Sales Of Incremental Price**




## Perceived Value: Affordable Cost

> "Receiver cost and complexity should be placed in proper perspective and given full consideration.... We believe that the success of AM stereo will be determined by its perceived value to the listener. Therefore, incremental cost is as important a determinate in selling the product as quality of reception. A receiver that may be obtained at the least cost and minimum complexity, will significantly impact buyer acceptance and thus the ultimate success of AM stereophonic broadcasting."
>
> Delco Electronics[6]

Studies by Panasonic have shown that the consumer is willing to pay up to 7–10% in incremental price to obtain the AM stereo benefit.[7] This translates to $8–20 for mid-range mass market audio equipment. If receiver manufacturers can add AM stereo for less than this amount, the listening audience will be able to choose between AM and FM stereo stations. With the costs of doing business in the retail audio market, receiver manufacturers will have to add AM stereo for under $4 in mid-line equipment and well under $3 for the low end. Figure 4 is our estimate of the market size to retail cost relationship for AM stereo.

The systems are not nearly equal in cost of implementation and only the lower complexity systems can meet this criteria. Consider the following:

> "The estimated material cost for the *Motorola*, *Harris*, and *Kahn* systems using custom ICs is again about double that of the Magnavox/Belar system." (Ford)[8]

> "The circuitry to decode the *Magnavox* system is much less complex ...than other systems with which we have experimented." (Delco)[9]

> "However, our analysis...leads to the conclusion that the (*Harris*) proposal is now overly complex without sufficient compensatory attributes to suggest its adoption."

"Component cost, test labor costs, etc., will obviously ultimately be passed on to the consumer, without any apparent concommitant features or benefits by reason of the *Motorola* system."

"Complexity is inherent in the *Kahn/Hazeltine* system design... introducing increased costs."

"This proposal (*Magnavox*) achieves this result at expected reasonable costs to... the manufacturers of receivers, and the consumer." (General Electric)[10]

"Now further, we have tentatively found that there is approximately a 2:1 circuit complexity difference amongst the proponent systems. And obviously the more complex the circuits, the the more the receiver circuit will cost in the receiver. The more expensive of the five would also violate our 7–10% cost rule as we previously mentioned and would not be a wise choice in terms of market reaction." (Panasonic)[11]

## AM Stereo: Additional Concerns

While all AM stereo systems provide adequate stereo performance, we are concerned that the Kahn system may provide high levels of distortion in some conditions. GE states,

"GE believes that the Kahn/Hazeltine proposal, although modified... appears to fall short of desired and available qualities for AM stereo broadcasting. Theoretical mathematical calculations indicate that a severe penalty in noise and/or distortion is encountered in limited bandwidth monophonic receivers that will be further aggravated by unbalanced modulation ratios in left and right channels."[12]

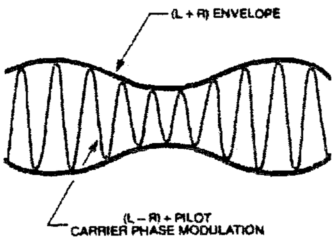
Even though receivers will not be on the market for several months after broadcasting begins, we are very concerned that stations going on the air with differing systems, particularly in the same market, may result in market confusion before AM stereo even gets a chance in the stores. Since receivers able to decode multiple systems are not practical for cost considerations, National believes that this market selection must not extend longer than six months, one year at most.

## System Selection: National Backs Magnavox

National Semiconductor has selected the Magnavox system (Figure 5) as the system which best meets the needs of the consumer based upon our business and technical analysis and the analyses of our customers, the receiver manufacturers. A summary of the specific reasons for this choice are as follows:

1. Momentum in the receiver industry towards Magnavox based upon the original decision.
2. Best system in terms of cost, reliability, stereo pilot signal, compatibility, board space, and overall performance.
3. Twice chosen best overall by the FCC. Ranked best in following categories: monophonic compatibility, coverage, distortion, frequency response, separation, and receiver stereo performance.
4. Expressed preference by major receiver manufacturers.

**Figure 5. Magnavox AM Stereo System**




## System Selection: Major Receiver Manufacturers

The receiver manufacturers have begun to speak on this selection based on their independent technical evaluations. We urge you to carefully evaluate their analyses.

*Delco* "Test results...indicate that the proposed system offered by Magnavox is effective both in cost as well as reception."[13]

*Ford* "Our evaluation of the circuit complexity, economic factors, and applicability to the automotive entertainment environment indicates that the Magnavox or Belar systems present the most desirable alternative."[14]

*GE* "GE has thoroughly studied the various proposals, and, for the reasons stated below, GE believes that the stereophonic transmission standards proposed by Magnavox best meet the Commission's concern for high quality service."[15]

*Pioneer* "According to our research, Magnavox has been shown to be the choice in terms of overall performance and cost."[16]

## AM Stereo: Summary

The advent of AM stereo will upgrade the AM source to at least as important a level as that now enjoyed by FM stereo. However, success of this new source now depends on, besides technical resolutions, the market selection of one system in a relatively short time frame.

National Semiconductor has analyzed the AM stereo system question from the point of view of the consumer and believes the Magnavox system to be the best solution for the long-term success of AM stereo. National believes the business and technical problems are solvable and we look forward to a healthy future for AM stereo broadcasting.

We welcome your comments. Linear Marketing, MailStop D3692.

## Beyond AM Stereo: Improving AM Fidelity

Our first generation AM stereo decoder, the LM1981, already offers performance specifications very similar to our advanced FM stereo decoders. Further improvements in the AM radio circuits will improve stereo performance.

National Semiconductor has continually improved its AM radio circuits but to date we have been constrained to providing improved performance at no increase in cost. We have led the way in this through advanced circuit design and technological improvements.

One example is a new generation AM radio system integrated circuit that we have just begun to sample. This circuit, designed for electronically-tuned portable, car, and home receivers, offers performance and features beyond that available now in most high-end receivers while cutting system cost and board space by 30–40% over present mid-range systems. This asynchronous device will provide 6–10dB lower noise than AM receivers now on the market and will particularly improve audio output on weak stations. AM stereo performance has been improved by a very low-noise local oscillator and a symmetrical IF characteristic.

## Footnotes

1. NAB AM Stereo Panel, Comments by Robert J. McMillin, Delco Electronics, April 6, 1982.
2. NSC Evaluation.
3. Filing to the FCC, Comments of General Electric Co., May 15, 1979, page 2.
4. *Report and Order*, Federal Communications Commission, March 18, 1982, page E2.
5. Filing to the FCC, Comments of Harris Corp., May 15, 1979, page VIII–II.
6. Filing to the FCC, Reply Comments of General Motors Corp., page 3.
7. NAB AM Stereo Panel, Comments by Almon Clegg, Panasonic, April 6, 1982.
8. Filing to the FCC, Comments of Ford Motor Co., December 21, 1978, page 2.
9. Filing to the FCC, Reply Comments of General Motors Corp., page 4.
10. Filing to the FCC, Comments of General Electric Co., pages 6, 8, 9, and 11.
11. NAB AM Stereo Panel, Comments by Almon Clegg, April 6, 1982.
12. Filing to the FCC, Comments of General Electric Co., page 8.
13. Filing to the FCC, Reply Comments of General Motors Corp., page 3.
14. Filing to the FCC, Comments of Ford Motor Co., page 1.
15. Filing to the FCC, Comments of General Electric Co., page 3.
16. Press Release, Pioneer Electronics of America, April 5, 1982.

# AM STE
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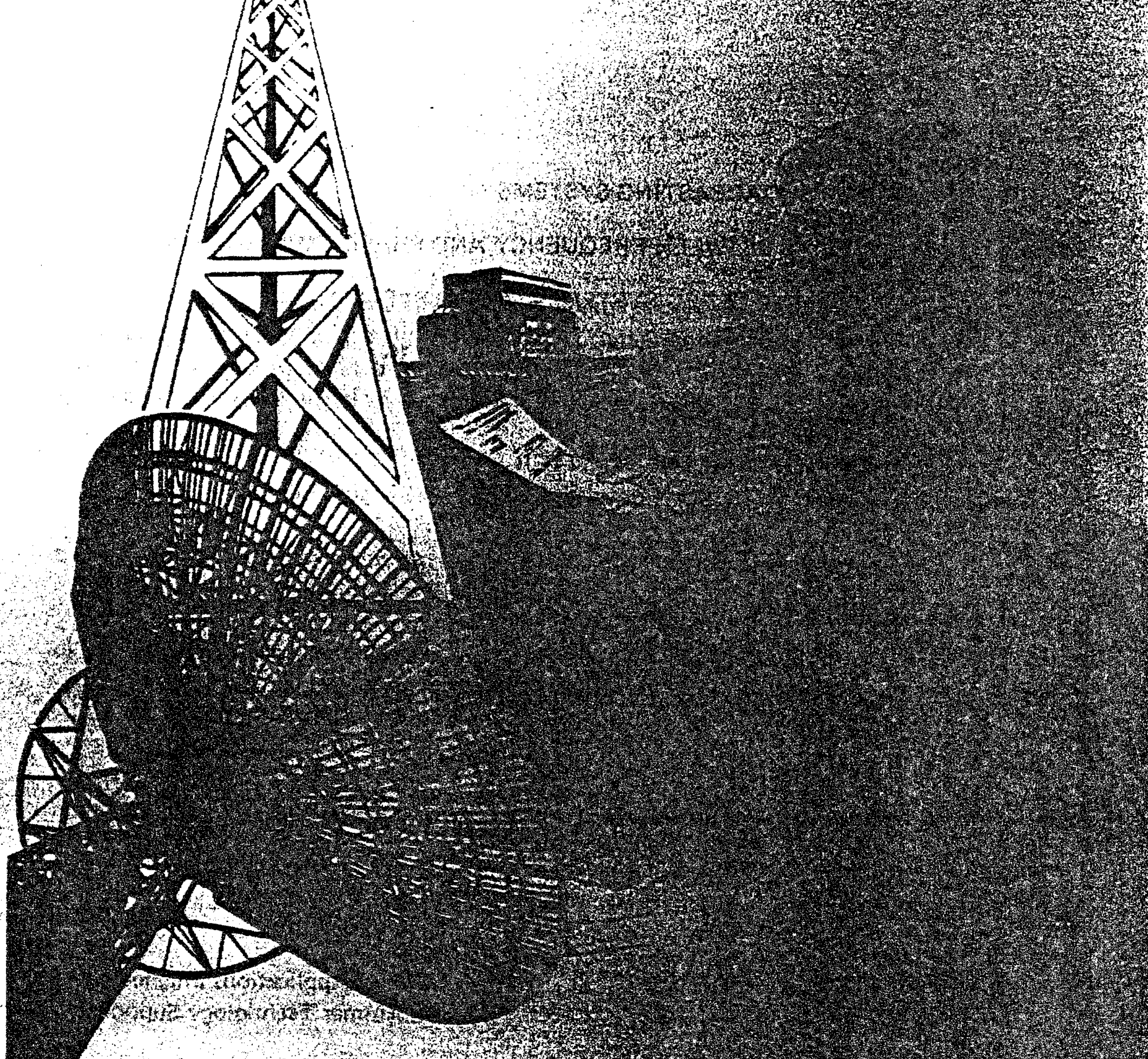

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# AM STEREO BROADCASTING

## INTRODUCTION

### (1) Why Stereo AM Broadcasts?

FM stations have been broadcasting stereo for many years, and it has been proven successful in local broadcasting to provide good quality stereophonic programming; then why are the people so interested in trying to put AM stereo into practice for the last few years and what additional benefits can be obtained by broadcasting stereo AM signal? Main reasons are:

a) Stereo is a preferred program source for most people.

b) AM broadcasters have lost a portion of their listeners not only to record and tape players but to FM stations as well. Since all of these offer stereophonic programming.

c) FM stereo service suffers from limited geographic coverage, line of sight transmission is needed, and multipath – the simultaneous arrival of a second, time delayed signal at the receiving antenna causes serious distortion of the received signal. These factors can severely limit good quality FM stereo reception, as many listeners of automobile radios will attest to it.

d) By introducing AM stereo, it is anticipated that a much wider stereo coverage, free from multipath, will be available to the travelling listeners. Also up-grades the quality of the AM broadcast service.

**Propagation of VHF FM Signal**

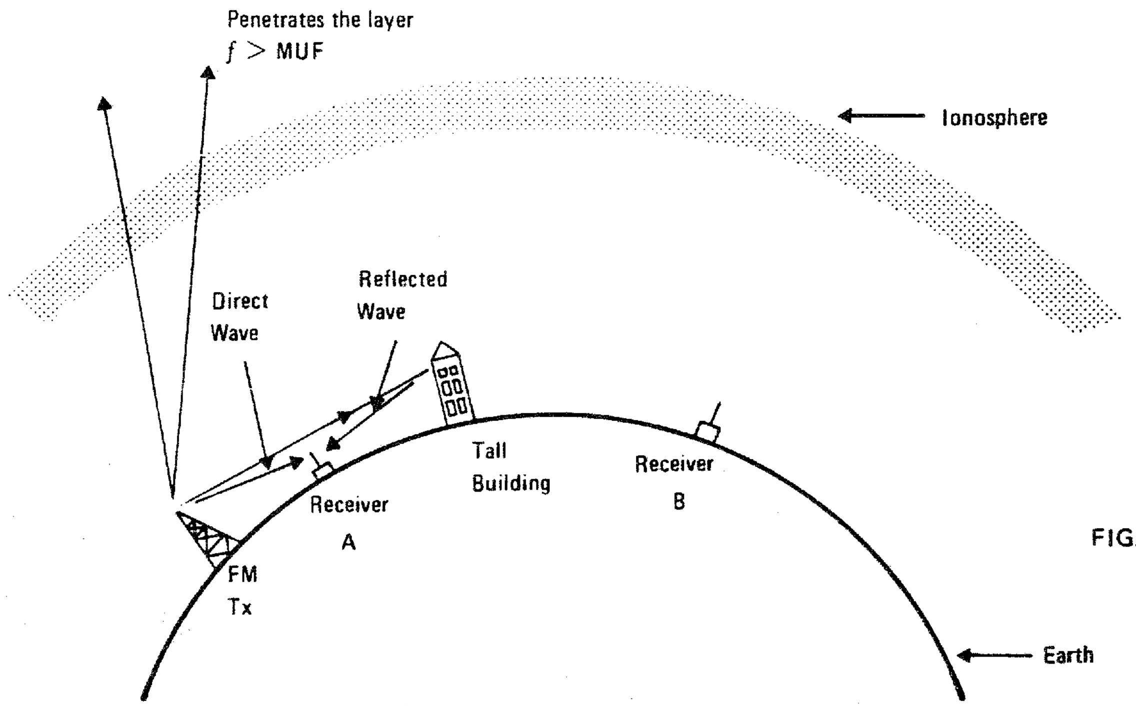



FIG. 1

- FM broadcasting works at the VHF band. The propagation of VHF wave is line of sight transmission, it penetrates the Ionosphere layers, but it can be reflected by mountains or tall buildings.

- The reflected waves are phase distorted. If the reflected wave and the direct wave are received simultaneously, multipath distortion will occur.

- FM is limited to short distance service. In FM stereo broadcasting, the service coverage is even smaller due to noise penalty that caused by much wider frequency spectrum of the composite signal.

**Propagation of MW AM Signal**

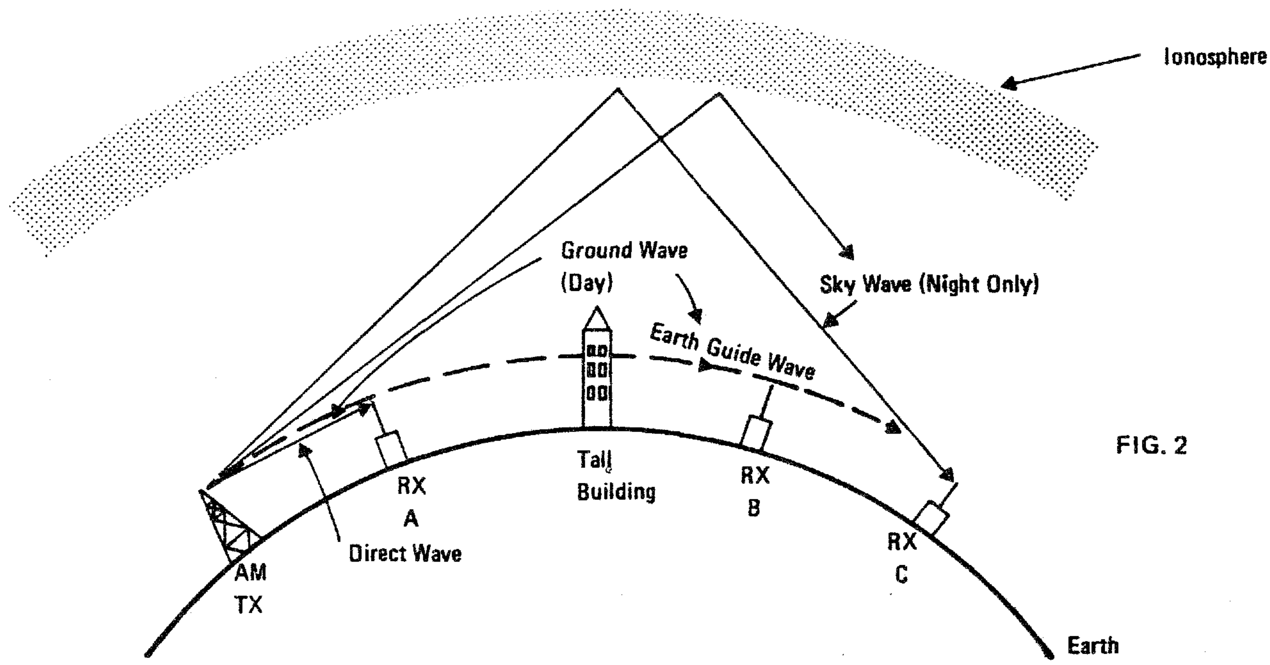



FIG. 2

- AM broadcasting works at the MW frequency band. Its propagation is mainly Ground wave (consisting of direct wave and the earth-guided wave) at day time and plus some sky waves at night time.

- AM broadcasting provides wide service coverage due to earth-guided wave propagation, and the coverage even increased at night due to the increased sky waves.

- Typical data shows that:

  AM – 1 KW : 500$\mu$V/M at 80 miles, depends on Ground Conductivity.
  FM – 1 KW : 50$\mu$V/M at 40 miles, depends on Antenna Height.

  In practice, a 50 KW AM transmitter at daytime will cover 150 – 200 miles radius, a 100 KW FM transmitter will cover 50 miles radius approximately.

(2) **Considerations for Proposed AM Stereo System**

- Simplicity.
- Low distortion.
- Monophonic compatibility.
- Good separation.
- Good frequency response.
- Low noise penalty.
- No additional frequency spectrum required.
- Both channels (L and R) transmitted on the same carrier.

**Monophonic Compatibility**

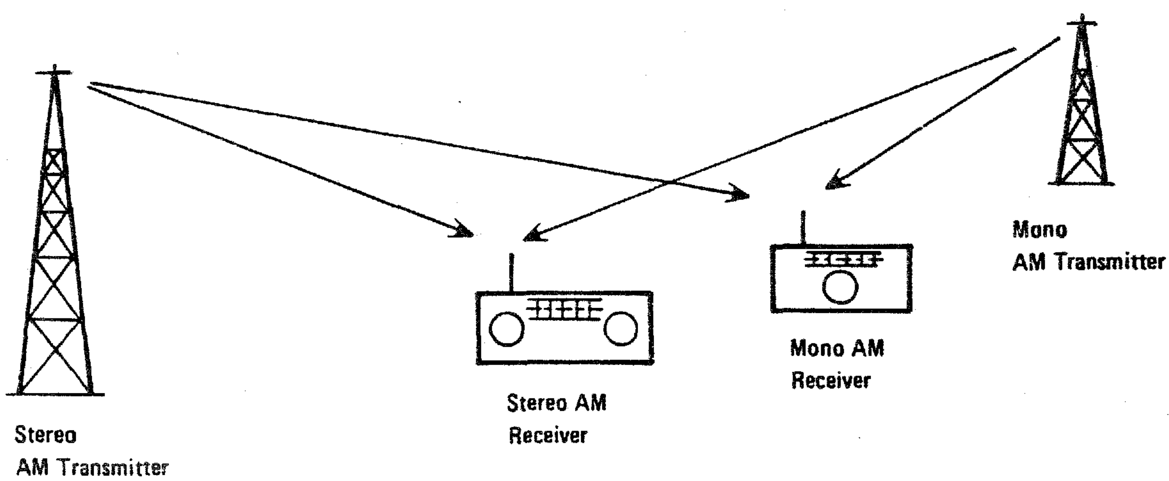



FIG. 3

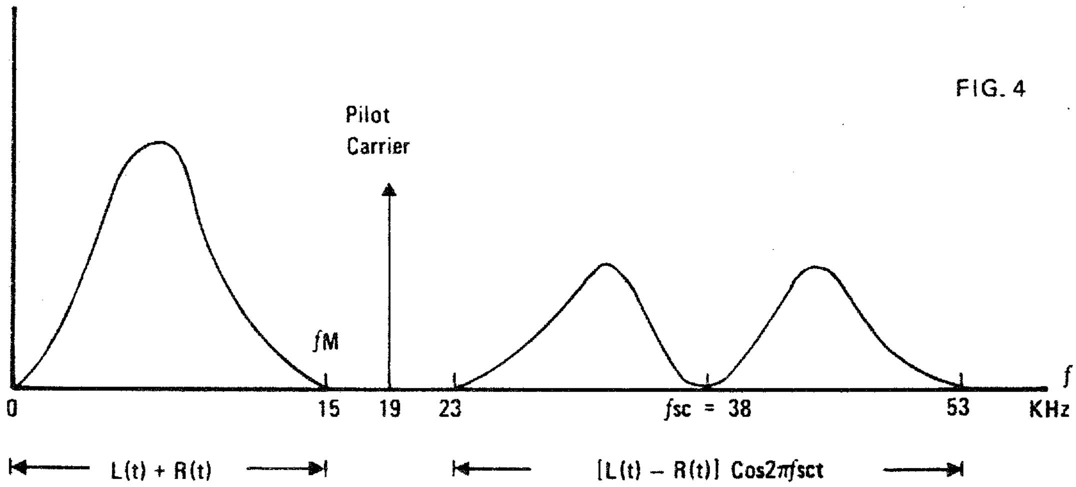



FIG. 4

Spectral density of a typical composite signal in Stereophonic FM Broadcasting.

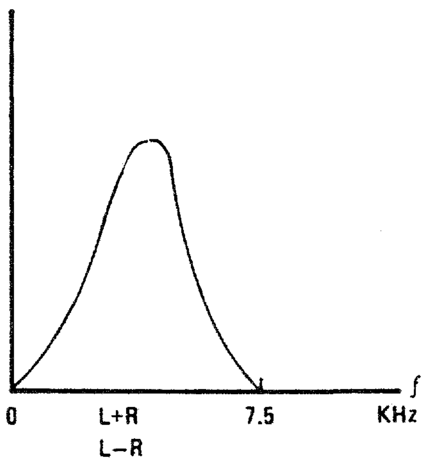



FIG. 5

Spectral density of a typical signal in AM Broadcasting.

# THE AM STEREO BROADCASTING SYSTEMS

A number of systems have been proposed for stereo AM broadcasting. Some of them are found to be unacceptable for various reasons, and the potential candidates are listed below:

1. Independent sidebands.
2. Quadrature sidebands.
3. Amplitude Modulation + Frequency Modulation (AM + FM).
4. Amplitude Modulation + Phase Modulation (AM + PM).

**(1) Independent Sidebands**

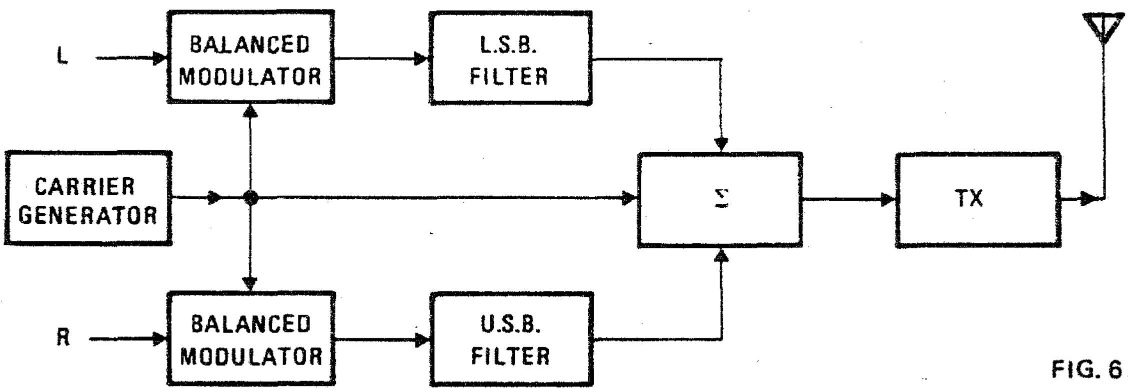



FIG. 6

**Independent Sideband Transmitter**

One of the AM stereo broadcast system proposed is Independent Sidebands. Its basic principle is that on a standard double side band AM carrier with upper side band contains Left information and lower sideband Right information. The carrier is not suppressed and no audio matrix is needed. It is compatible to mono receivers but for stereo reception, it requires two receivers independently tuned to high and low frequencies respectively to produce stereo output.

## (2) Quadrature Sidebands

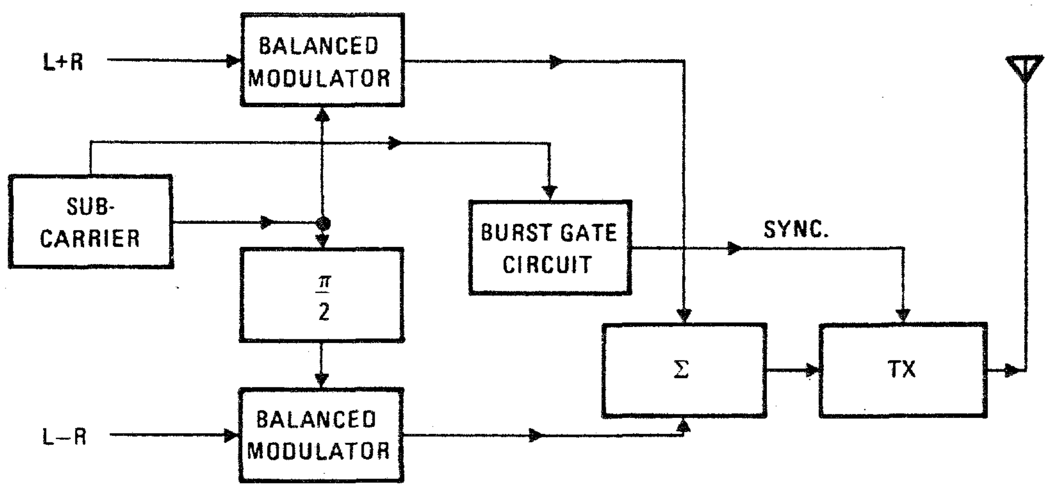


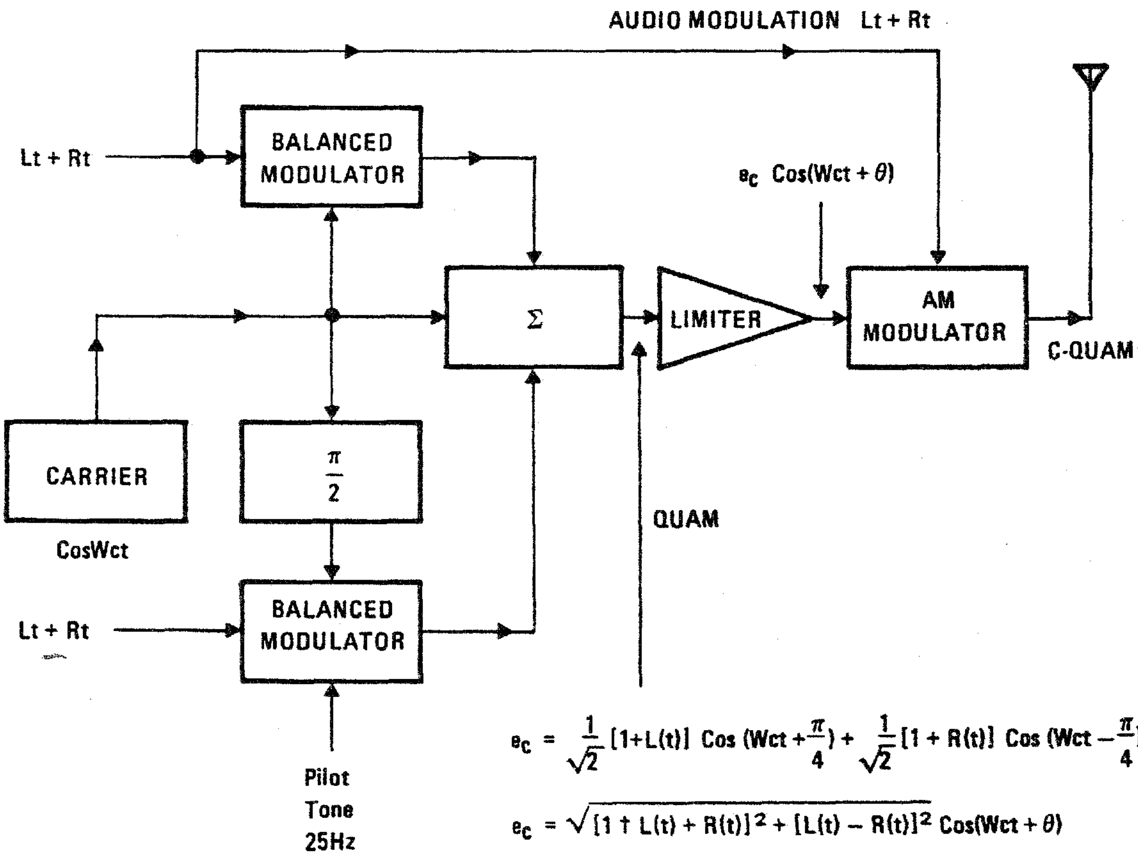

FIG. 7

**Block Diagram Of A Quad-Sideband Transmitter**

This technique is similar to the simultaneous transmission of two chrominance signals in color television. The L+R signal is used to modulate the sub-carrier using a balanced modulator and the L−R signal is used to modulate a sub-carrier of the same frequency but lagging the first by 90°. The output signals from the balanced modulators are summed together for transmission.

The simple quadrature sideband (QUAM) system is not quite compatible with the existing monophonic receivers that employ envelope detector. Besides, employing sub-carrier in MW is not allowed due to severe restriction on broadcasting channel bandwidth. Hence, for AM stereo broadcasting, the QUAM system must be modified to be a stereophonic system with a compatible monophonic signal.

## Compatible Quadrature Amplitude Modulation (C-QUAM)




$$e_c = \frac{1}{\sqrt{2}}[1+L(t)]\ \mathrm{Cos}\ (Wct + \frac{\pi}{4}) + \frac{1}{\sqrt{2}}[1 + R(t)]\ \mathrm{Cos}\ (Wct - \frac{\pi}{4})$$

$$e_c = \sqrt{[1 + L(t) + R(t)]^2 + [L(t) - R(t)]^2}\ \mathrm{Cos}(Wct + \theta)$$

FIG. 8

**Block Diagram Of A C-QUAM Transmitter**

No sub-carrier is required in C-QUAM system, the L(t) + R(t) and L(t) – R(t) components are quadrature modulated onto the R.F. carrier as shown in the block diagram of figure 8. The output signals from the balanced modulators consist the sidebands representing L(t) + R(t) and L(t) – R(t) components; they are generated in quadrature with each other. These signals are combined in a summing device, the output of the summing device is a low level quadrature signal represented by the following equations.

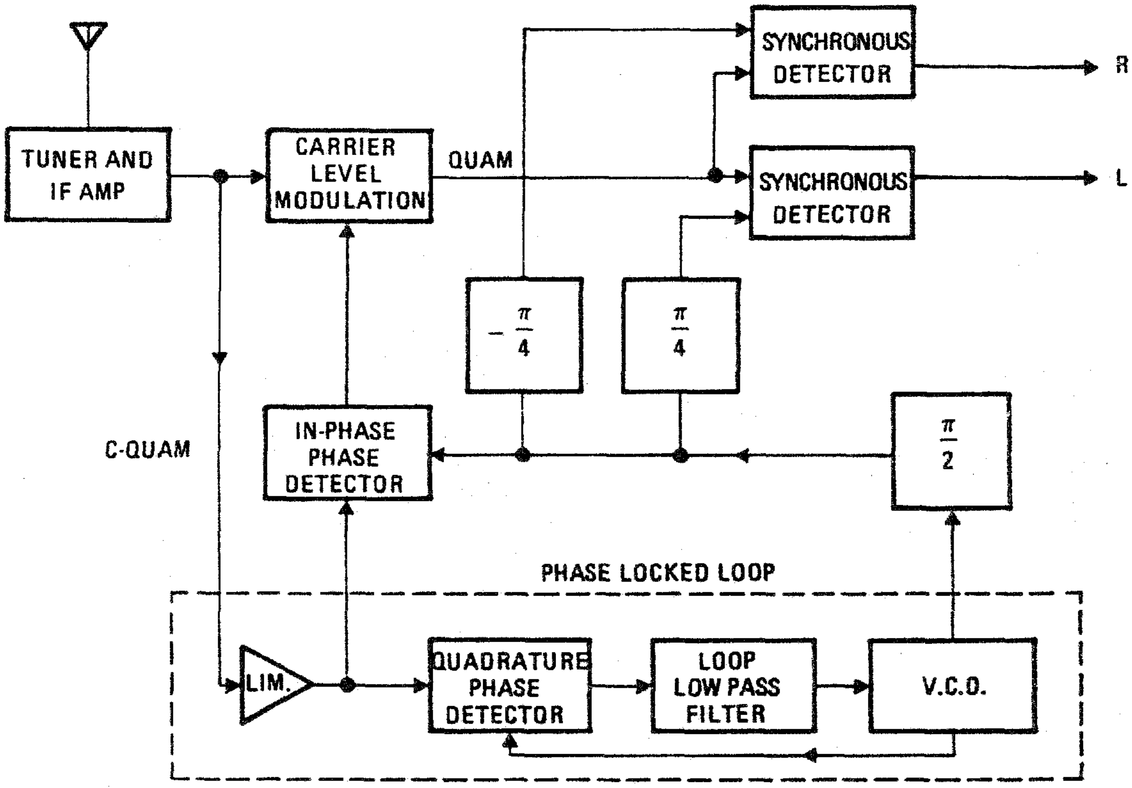
$$e_C = \frac{1}{\sqrt{2}}[1 + L(t)] \ \mathrm{Cos}\ (Wct + \frac{\pi}{4}) + \frac{1}{\sqrt{2}}[1 + R(t)] \ \mathrm{Cos}\ (Wct - \frac{\pi}{4})$$

or $$e_C = \sqrt{[1 + L(t) + R(t)]^2 + [L(t) - R(t)]^2} \ \mathrm{Cos}\ (Wct + \theta)$$

It can be seen from the output signal equations that the signal can be represented by either the sum of two separately modulated signals or a single carrier phase modulated by $\theta$ and an envelope described by the square root of the sum of the squares of the sum and difference signals. By using a limiter the envelope is removed and retains only the phase variation. The phase modulation component can be added to the signal directly at the transmitter exciter input, the transmitter is amplitude modulated with the monophonic compatible sum signal L(t) + R(t). In other words C-QUAM is generated by amplitude modulating a (L + R) carrier which retains the phase information of (L + R) and (L – R) that obtained from the summing device. The output signal from the transmitter is represented by the following equation.

$$e = Ac\ (1 + Lt + Rt)\ (\mathrm{Cos}Wct + \theta)$$

$$\theta = \tan^{-1} \frac{Lt - Rt}{1 + Lt + Rt}$$




**Block Diagram Of A C-QUAM Receiver**

FIG. 9

The basic functional block diagram of a C-QUAM receiver is shown in figure 9. The RF signal (C-QUAM signal) is mixed down to IF signal and amplified. The output of the IF amplifier is split into two ways, one goes to a carrier level modulator and the other goes to a limiter which is one part of the phase locked loop network for synchronous purpose. The PLL network consists of a limiter, a quadrature phase detector, a loop low pass filter and a voltage controlled oscillator. The V.C.O. is locked in phase quadrature with the IF carrier (SinWct). The V.C.O. output is shifted 90° to provide a signal in phase with the IF carrier (CosWct). When the phase shifted V.C.O. signal together with a signal from the limiter is supplied to the phase detector, a signal proportional to Cos$\theta$ is derived. The Cos$\theta$ signal from the In-phase phase detector is applied to the carrier level modulator to restore QUAM signals at its output. The synchronous detectors are worked in phase quadrature with each other. They demodulate the QUAM signals into Left and Right channel signals.

(3) Amplitude Modulation — Frequency Modulation System

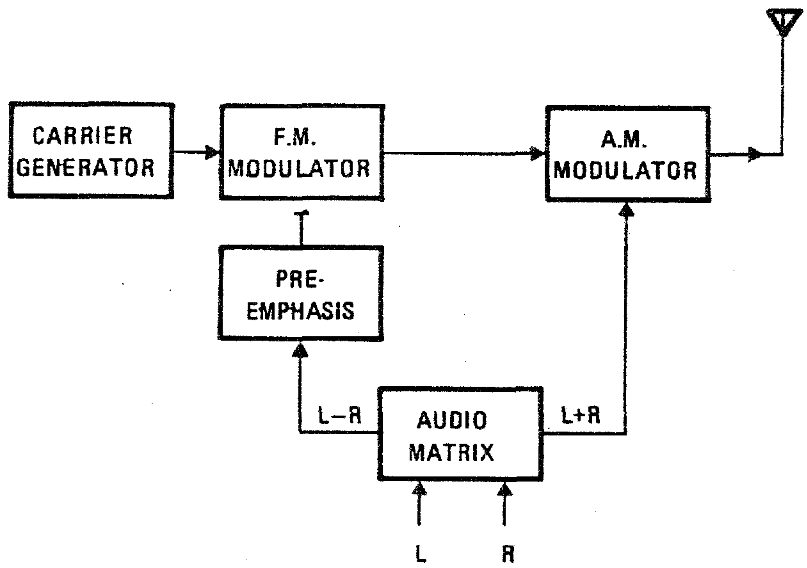



FIG. 10

Block Diagram Of An AM-FM Transmitter For AM Stereo Broadcasting

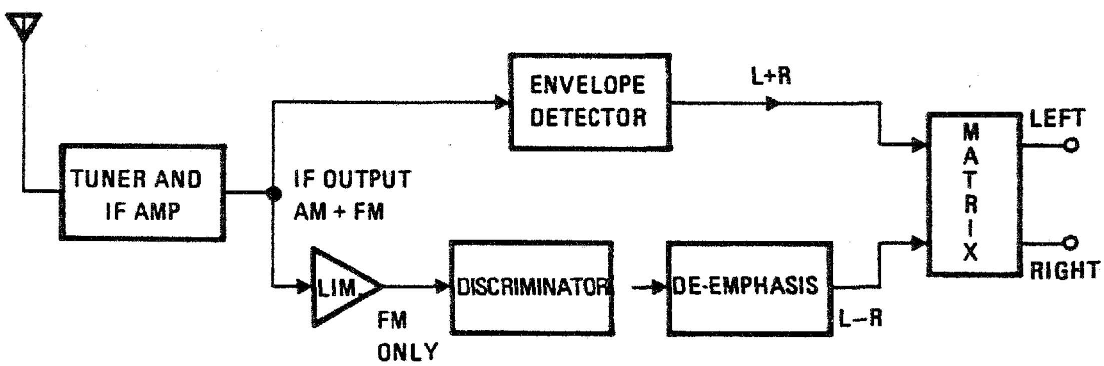



FIG. 11

Block Diagram Of An AM Stereo Receiver For AM + FM Stereo System

An AM stereo transmitter for AM + FM system is shown in figure 10. The Left and Right audio channels are applied to an audio matrix to generate L+R and L–R components. The L–R signal passes through a network with a pre-emphasis time constant of 100$\mu$S, and then goes to an FM modulator. The L–R signal modulates the carrier to a peak low frequency deviation of ±1.25KHz. The FM modulator provides RF drive to the transmitter which is amplitude modulated by the L+R signal in the conventional fashion.

An AM stereo receiver for AM + FM system is shown in figure 11. The tuner and IF amplifier are typical of conventional AM receiver designs. The signal at the output of the IF amplifier is split into two separate paths. One path is applied to a conventional envelope detector where the L+R signal is extracted. The other IF output is applied to a limiting amplifier which removes the AM modulation components, then, it is demodulated in a frequency discreminator. The resulting audio signal is de-emphasised to restore the L–R signal at its original amplitude response. The detected L+R and L–R components are applied to an audio matrix to recover the Left and Right audio information.

# RELATIONSHIP BETWEEN FREQUENCY AND PHASE MODULATION

Frequency and phase modulation are not independent, since the frequency cannot be varied without also varying the phase, and vice versa.

In FM, when a modulating signal is applied, the carrier frequency is increased during one half cycle of the modulating signal and decreased during the half cycle of opposite polarity. The change in the carrier frequency ($\Delta f$) is proportional to the instantaneous amplitude of the modulating signal.

The phase modulation is that, if the phase of the current in a circuit is changed, there is an instantaneous frequency change during the time that the phase is being shifted. In a PM system, the amount of phase shift is proportional to the instantaneous amplitude of the modulating signal. The rapidity of the phase shift is directly proportional to the frequency of the modulating signal. Consequently, the frequency deviation ($\Delta f$) in PM is proportional to both the amplitude and frequency of the modulating signal.

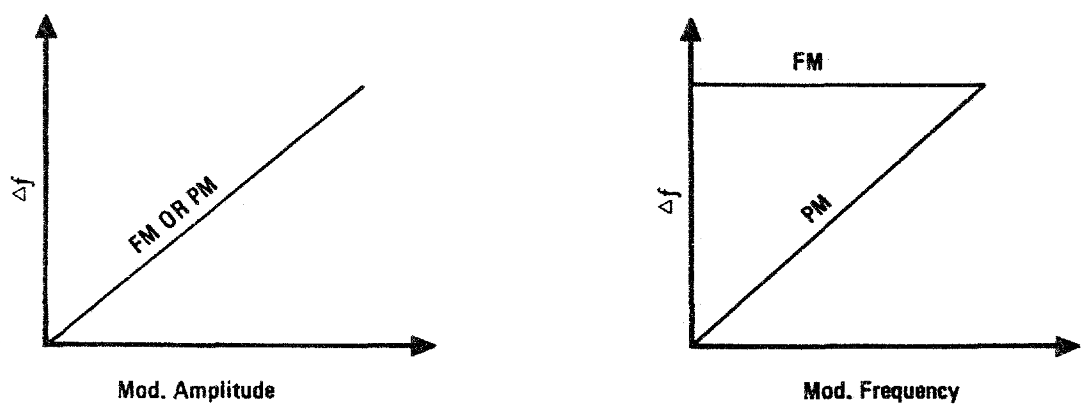



FIG. 12

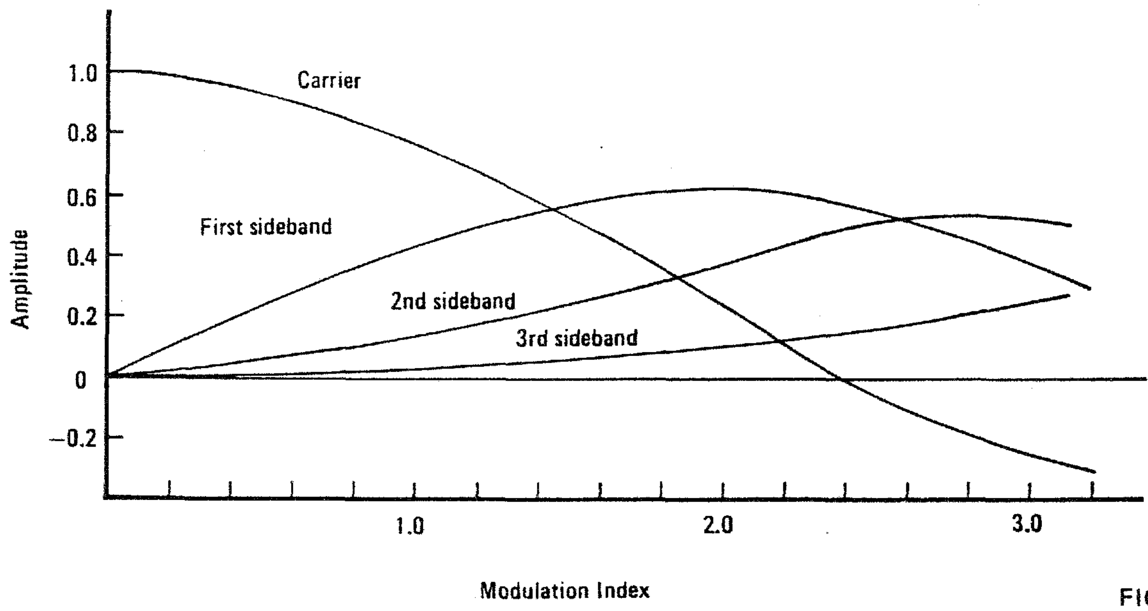



FIG. 13

Amplitude of the pairs of sidebands varies with the modulation index in a FM or PM signal.

$$\text{Modulation Index} = \frac{\text{Carrier Frequency Deviation}}{\text{Modulating Frequency}}$$

FM $\Delta f \propto$ Amplitude of the modulating signal
Modulation Index – varies with modulating frequency

PM $\Delta f \propto$ Amplitude and frequency of the modulating signal
Modulation Index – constant

From the Bessel curves shown in figure 13, the carrier strength varies with the modulation index. (In amplitude modulation the carrier strength is constant; only the sideband amplitude varies.) At a modulation index of approximately 2.4 the carrier disappears entirely. It then becomes "negative" at a higher index, meaning that its phase is reversed as compared to the phase without modulation.

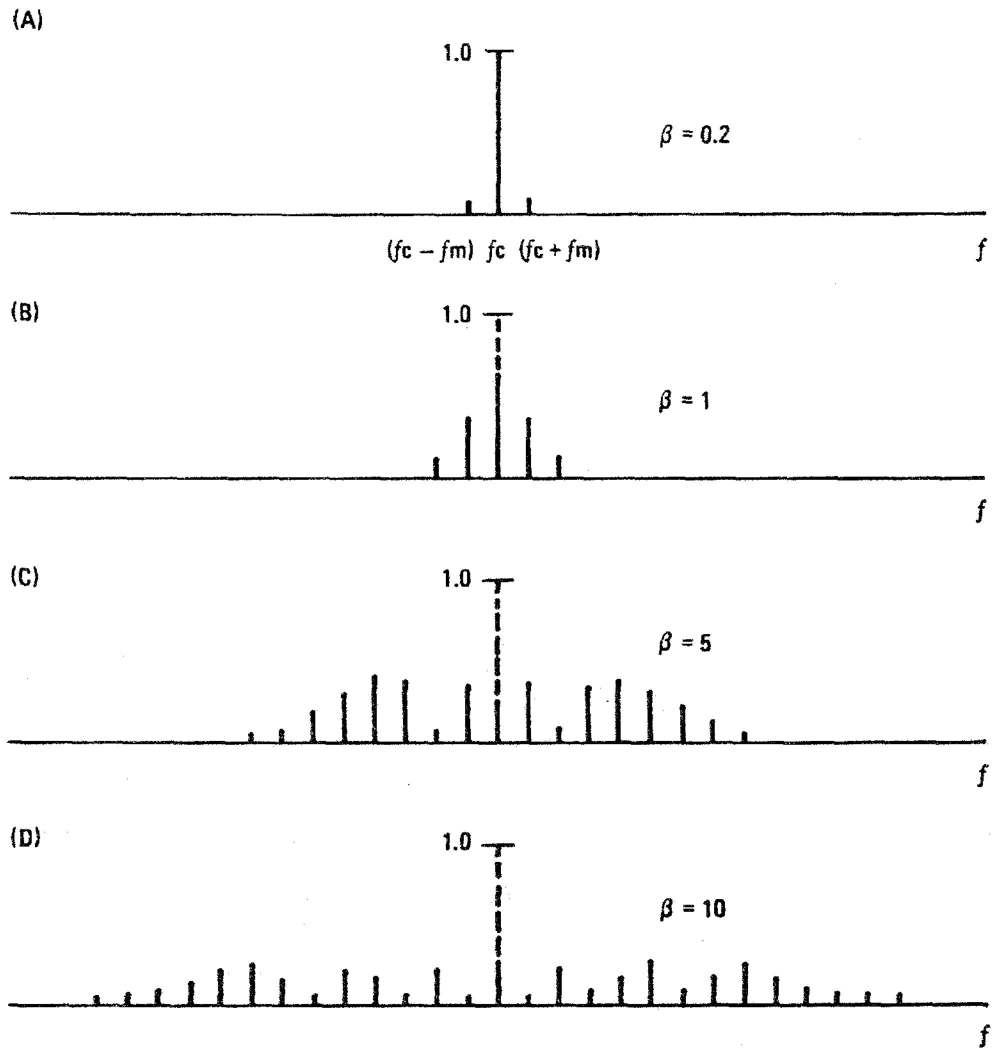



FIG. 14

Sideband Components of sinusoidally modulated FM or PM signal for various Modulation Index.

In FM and PM the energy that goes into the sidebands is taken from the carrier, the total power remaining the same regardless of the modulation index.

# THE MAGNAVOX AM STEREO SYSTEM
# AM/PM SYSTEM

## (1) The Transmitter

The AM stereo system that uses amplitude and phase modulation is proposed by Magnavox. The Left and Right stereophonic program material is matrixed into L+R and L–R signals for transmission. The L+R signal is used to amplitude modulate the carrier in the conventional way, which forms the signal for the envelope detector of the monophonic receivers. The L–R signal is used in phase modulating the carrier to a maximum phase deviation of ±1 radian. Such deviation is large enough to provide detection by several means and to reduce restrictions encountered in the receiver, but not so large as to generate an unwieldly sideband spectrum. A stereo identification signal is also included to facilitate automatic switching into the stereo mode and to provide visual indication of stereo broadcasts. This identification signal is a low frequency tone (5Hz) which modulates the carrier phase by 4 radians. The total signal equation for the Magnavox system can be expressed by the following equation.

$$e_c = E_0 \underbrace{[1 + mSinWmt]}_{\substack{(L+R)\\ \text{mono}}} Cos\,[Wct + \underbrace{mpSinWct}_{\substack{(L-R)\\ \text{stereo}\\ \text{difference}}} + \underbrace{4Sin10\pi t}_{\substack{\text{pilot}\\ \text{signal}}}]$$

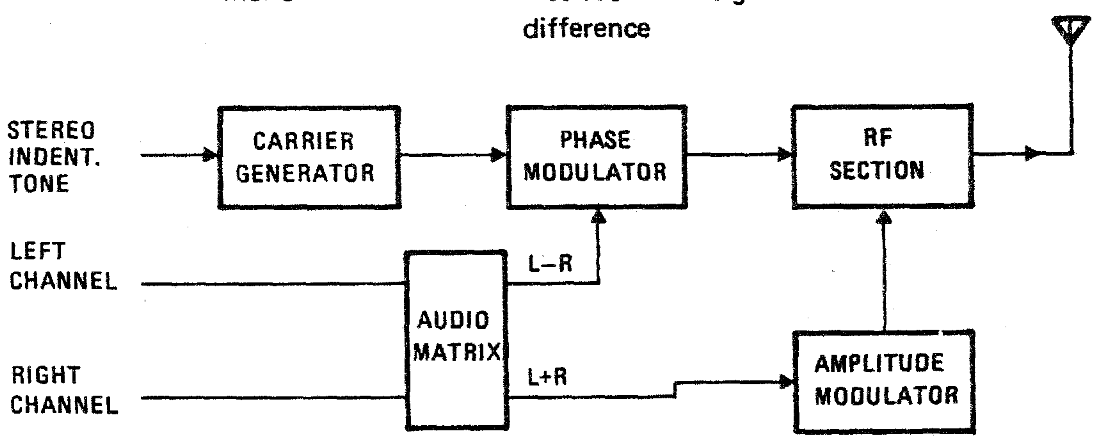



FIG. 15

**Block Diagram Of A Magnavox AM Stereo Transmitter**

In the Magnavox AM stereo broadcasting system, two signals are modulating the carrier in different ways. The L+R is used to amplitude modulate the carrier in the normal way and at the same time the carrier is being phase modulated with the L−R signal. Therefore the instantaneous carrier amplitude cannot be allowed to diminish to zero by large negative modulation indices ($M- \geqslant 1$), and the L+R signal is limited to give the carrier a 95% negative modulation maximum.

$$M+ = \frac{E_{MAX} - E_0}{E_0}$$

$$M- = \frac{E_{MAX} - E_{MIN}}{E_0}$$

**(2) The Permitted Spectrum For AM Broadcasting**

The legally permitted spectrum for AM broadcasting utilization is shown in the following diagram.

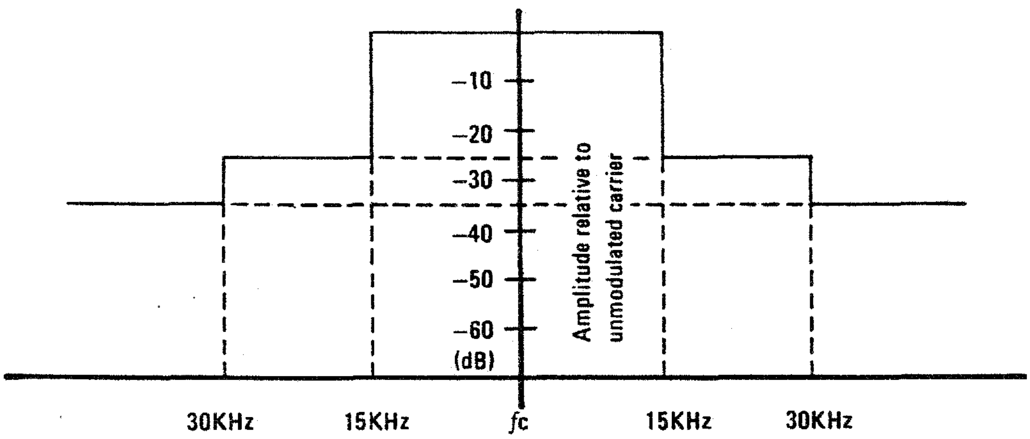



FIG. 16

**The Permitted Spectrum For AM Broadcasting**

The permitted spectrum specified that a single tone mono signal (L+R) is not allowed to produce sideband amplitudes greater than –25dB as compared to the unmodulated carrier amplitude from 15KHz to 30KHz. Above 30KHz the sidebands have to be below –35dB. In practice these sideband amplitudes are unlikely to be encountered. AM transmitters are required to have a frequency response that is ±2dB from 200Hz to 5KHz, and to be proved out to 7.5KHz.

Introduction of AM stereo is not likely to encourage an increase in the broadcasting frequency response, particularly when the spectrum of the (L–R) phase modulating signal is considered.

Phase modulation unlike the amplitude modulation that only produces a pair of sidebands when the carrier is modulated by a single tone signal. The sideband components of a single tone modulated FM or PM signal consists a string of sidebands which varies for various modulation index. Therefore tight control of the modulation index in a PM signal is necessary, otherwise the sidebands will be spread beyond the permitted spectrum.

The following table shows the PM sideband amplitudes produced by any audio frequency, which was calculated by reference to the appropriate Bessel function.

| MODULATION INDEX | SIDEBAND ORDER | LEVEL REFERRED TO UNMODULATED CARRIER | LEVEL (dB) |
|---|---|---|---|
| 0.30 | 0 | 0.977626 | – 0.20 |
| | 1 | 0.148319 | – 16.60 |
| | 2 | 0.011166 | – 39.00 |
| | 3 | 0.000559 | – 65.00 |
| | 4 | 0.000021 | – 93.60 |
| | 5 | 0.000001 | –124.00 |
| | 6 | 0.000000 | –156.00 |
| 0.68 | 0 | 0.887698 | – 1.00 |
| | 1 | 0.320723 | – 9.90 |
| | 2 | 0.055605 | – 25.10 |
| | 3 | 0.006364 | – 43.90 |
| | 4 | 0.000544 | – 65.30 |
| | 5 | 0.000037 | – 88.60 |
| | 6 | 0.000002 | –113.50 |
| 1.00 | 0 | 0.765198 | – 2.33 |
| | 1 | 0.440051 | – 7.10 |
| | 2 | 0.114903 | – 18.80 |
| | 3 | 0.019563 | – 34.20 |
| | 4 | 0.002477 | – 52.10 |
| | 5 | 0.000250 | – 72.10 |
| | 6 | 0.000021 | – 93.60 |

TABLE 1

**Phase Modulation Sideband Amplitudes**

By comparing the sideband amplitude with the permitted spectrum, we can see that 100% modulation is practical up to about 7.5KHz. Above this frequency the maximum modulation with a single tone is limited to 68%. The **sideband spectrum** can be determined easily in PM by controlling the maximum modulating frequency, as the modulation index in PM is constant. This is one of the advantages of using phase modulation for L—R in the AM stereo system.

For a PM signal, its sideband components are much richer than a pure AM signal. Therefore interference from a PM signal to the adjacent channels is increased. Current standard for AM stations specifying that the maximum ratio of overlapping field strength contours with a threshold level of interference taken to be at least −26dB below the desired groundwave signal.

Measurement taken by the National AM Stereo Radio Committee on receivers show that the stereo signal tends to raise the interference level by about 3dB on co-channel, 1dB to 4dB on the 1st adjacent channel and by 14dB on the 2nd adjacent channel, compared to the interference produced by a monophonic signal.

Interference can be substantially reduced by limiting the phase modulated (L−R) signal with an 8KHz filter. If further limiting the (L−R) and (L+R) signals to 5KHz the system produces comparable interference levels to the monophonic conditions.

**(3) The Receiver**

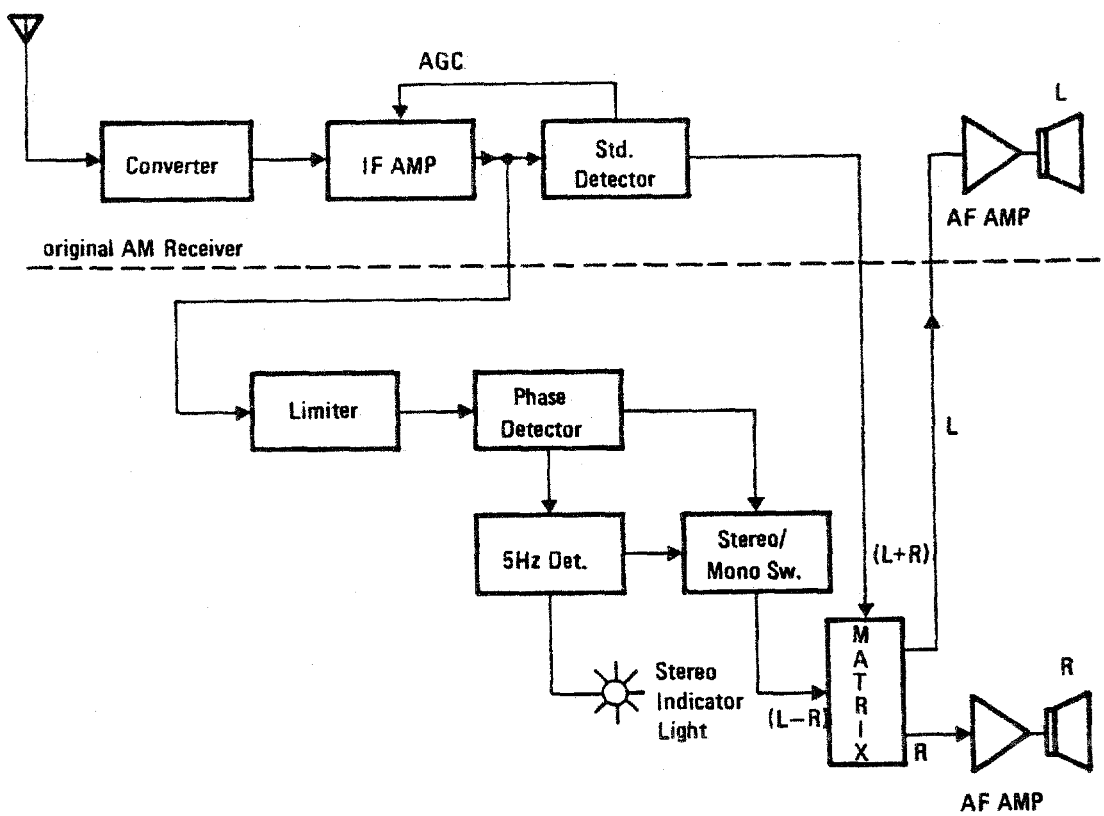



FIG. 17

**Block Diagram Of A Magnavox System AM Stereo Receiver**

A block diagram of a receiver suitable for decoding the Magnavox AM stereo signal is shown in figure 17. It is a conventional AM receiver combining with the additonal blocks for PM detection and L+R / L−R signal conditioning.

The entire AM/PM modulated carrier is mixed down in a superhet front end to intermediate frequency. At the I.F. amplifier output the signal splits in two directions. One of them goes to a conventional envelope detector where the L+R amplitude modulated intelligence is extracted and a R.F. carrier level is detected for an AGC function. At the same time other I.F. amplifier output is applied to a limiter where the AM information (L+R) is removed, then it is demodulated in a PM detector which supplies the (L−R) audio signal and the 5Hz stereo identification tone. Both AM (L+R) and PM (L−R) channel outputs are applied to the matrix which drives the Left and Right channel audio signals. The presence of the 5Hz tone enables the stereo/mono switch in the stereo mode. Absence of the tone, or unsuitable reception condition, will result in the switching to mono mode.

# AN INTEGRATED AM STEREO DECODER — LM 1981N

## (1) The Functional Blocks

The LM1981 is an integrated circuit developed by National Semiconductor to decode the stereo information which is amplitude and phase modulated on a carrier wave. It is capable of accepting the 455KHz (or 262KHz) IF amplifier output and amplitude detecting the (L+R) mono signal; limiting, detecting and conditioning the (L—R) stereo difference signal; and combining these signals in a suitable matrix to form the left and right channel audio outputs. Apart from the forementioned functions, the chip also incorporates other features that are essential for building a practical AM stereo receiver. They are an excess phase detector, a stereo pilot tone output, a stereo/mono blend function, 2 output sample and hold circuits and an internally regulated reference voltage.

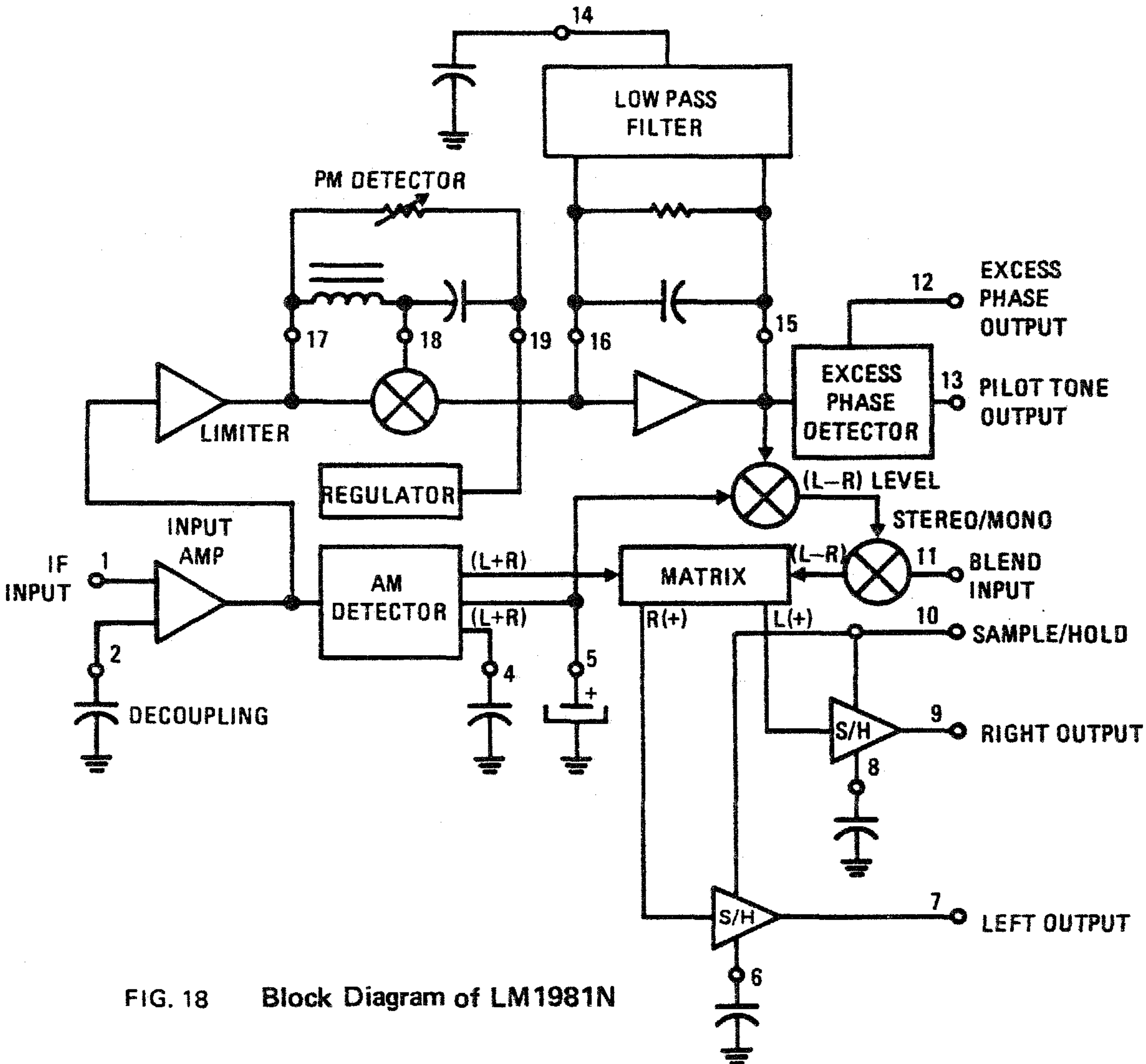



FIG. 18 **Block Diagram of LM1981N**

(2) **The Amplitude Modulation Detector**

The output signal from the IF amplifier is applied to pin 1 which is the input of the buffer stage of LM1981N. The signal at the output of the buffer stage is split into 2 separate detection paths. One of the paths is applied to the AM detection circuit where the (L+R) signal is extracted. The AM detector in LM1981N is differed from the conventional diode detector. It is a high quality full wave AM detector. Besides being a low distortion circuits, the average output of the AM detector is proportional to the input signal amplitude and can be used to adjust the gain of detected PM signal. It is very important to have such an AM detector in the design of an AM stereo decoder. Since the AM stereo signal composes of AM and PM; the detected AM signal level changes when the AGC is not perfectly tracking the RF signal strength; but in PM, the detector output is relatively independent of the input signal amplitude. For a maximum separation it is necessary that the amplitude of the detected PM signal be related to the amplitude of the received signal. This is accomplished by a full wave AM detector which provides the L+R signal for the matrix network. It also provides a D.C. voltage proportional to the average value of the IF carrier to the PM audio level control circuit by heavily filtering the detected AM output signal.

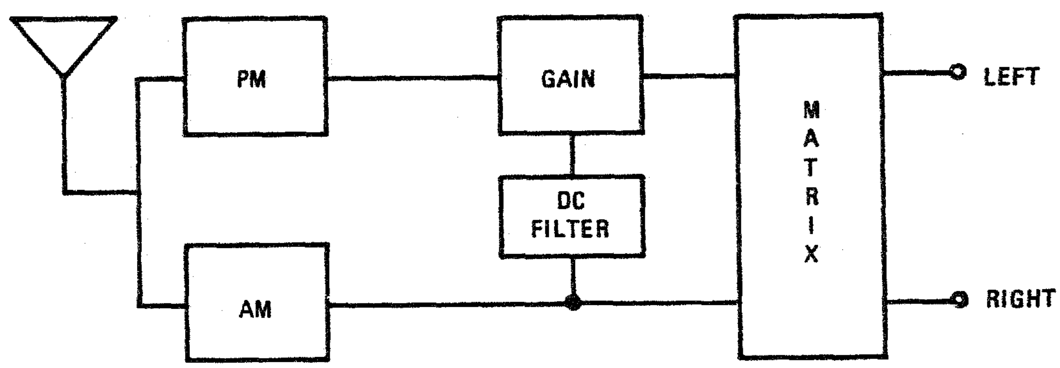



FIG. 19

**Gain Compensation of The Detected PM Signal**

A full wave AM detection circuit is shown in Fig. 20. Current $I_1$, and $I_2$ will be equal as will the voltage of the two nodes fed by the currents. Both currents will be shunted to ground through the two grounded emitter NPN transistors. The bias voltage applied to the base of the double emitter transistor is chosen so that the transistor is barely on. An AC signal applied to the input causes a decrease in one input current relative to the other and the corresponding node will drop in voltage. This turns on one emitter of the dual emitter transistor until the difference current flows through the emitter to the collector. The circuit is completely symmetric if the two grounded emitter transistors are well matched.

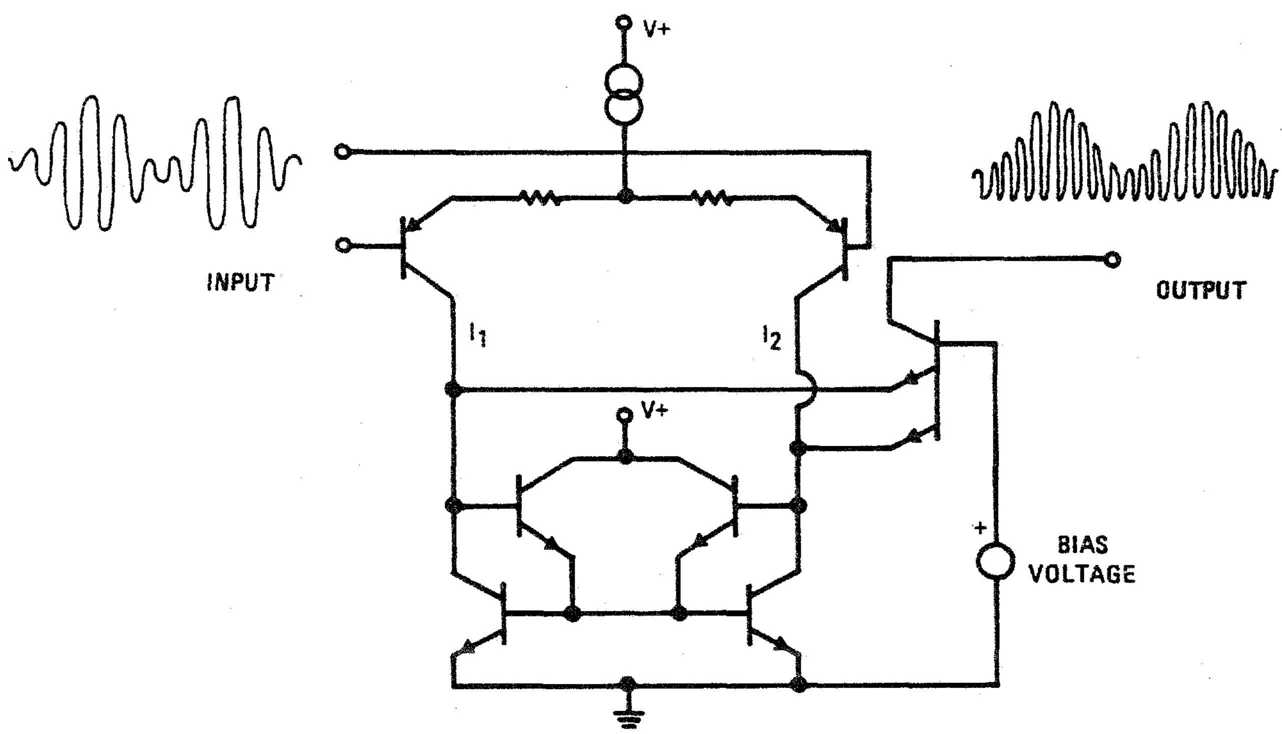



FIG. 20

**Full Wave AM Detector**

### (3) The Phase Modulation Detector

As described previously, the deviation frequency ($\Delta f$) in PM is proportional to both amplitude and frequency of the modulation signal. Thus, the deviation frequency ($\Delta f$) in FM is proportional to the amplitude of the modulating signal only. Therefore, an PM detector can be accomplished by combining an FM detector and an integrator.

The signal from the other output path of the input buffer stage is led to a limiter where the AM information is stripped. The stripped signal which contains the L—R information is FM detected in a quadrature demodulator and then integrated to restore the L—R signal.

The most popular FM detector implemented by using IC technology is the quadrature detector. Fig. 21 is its equivalent circuit.

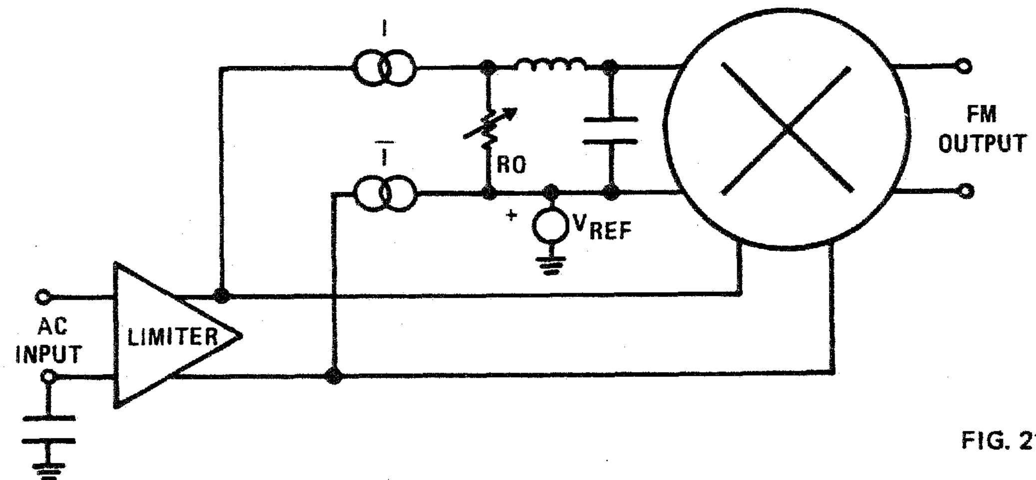



FIG. 21

**Equivalent Circuit of A Quadrature Detector**

The AM information is stripped with a limiter which has two outputs. A current from one of the outputs of the limiter drives the frequency-sensitive filter. Ultimately this current makes its way to an internal voltage source ($V_{REF}$). So an equal and opposite current comes from the other output of the limiter directly to the voltage source. Since, the filter's output phase is sensitive to input frequency. The FM signal is detected by comparing the output phase of the filter with the phase of the original limited signal and the comparision is done with a four quadrant mulitplier. The FM detector has two output currents. Resistor RQ shown in the circuit determines how sensitive the filter is to frequency. It also defines the maximum linear frequency range of FM detector. The usefulness of RQ in an AM stereo decoder is that it can be used to fine-adjust the gain of the overall PM detector for maximum separation.

The PM detector requires an integrator that immediately follows the FM detector. Naturally, a capacitor across the output terminals of the FM detector will do the job, but one thing that this simple integrator lacks is the ability to handle common mode and differential DC current. The outputs of the FM detector have common mode bias current and will have differential current proportional to the mistunning of the radio. So that, the integrator has to be modified as follow.

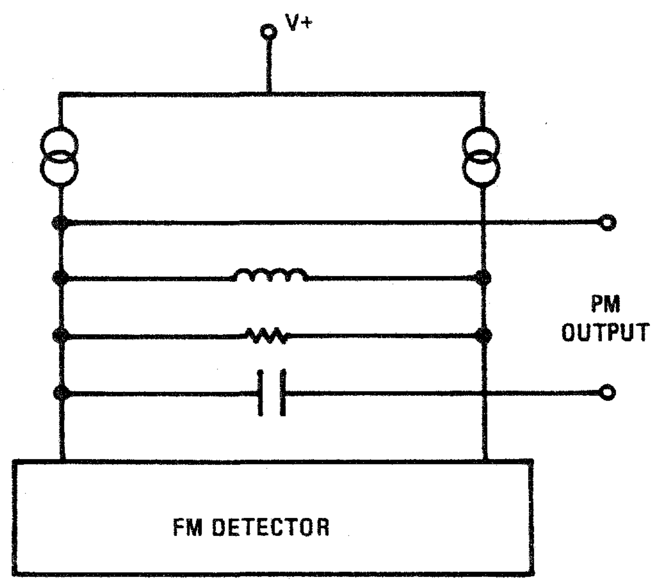



FIG. 22

**Phase Modulation Detector**

The modified circuit shows some additional circuitry that is added to the integrator. Two equal current sources controlled by a common mode feedback loop cancel out the common mode bias current. An inductor is connected across the outputs of the FM detector to handle mistunning and prevent offset voltage exceeding the dynamic range of the next stage. An external resistor is also connected across the outputs of the FM detector as a damper and it has the function to make the PM detector to settle in a minimum amount of time. Now, it seems a perfect PM detector has been designed; but, actually it is not. Because the value of the integrating capacitor that is selected to give nominal (L—R) detected level for maximum separation is 0.047μF which is tuned with the inductor to produce a low frequency pole in the detector output, so a 30Hz pole requires that the inductor be almost 600 Henries. It is not practical!

The problem can be solved without difficulty using IC technology and a practical circuit is shown in Fig. 23.

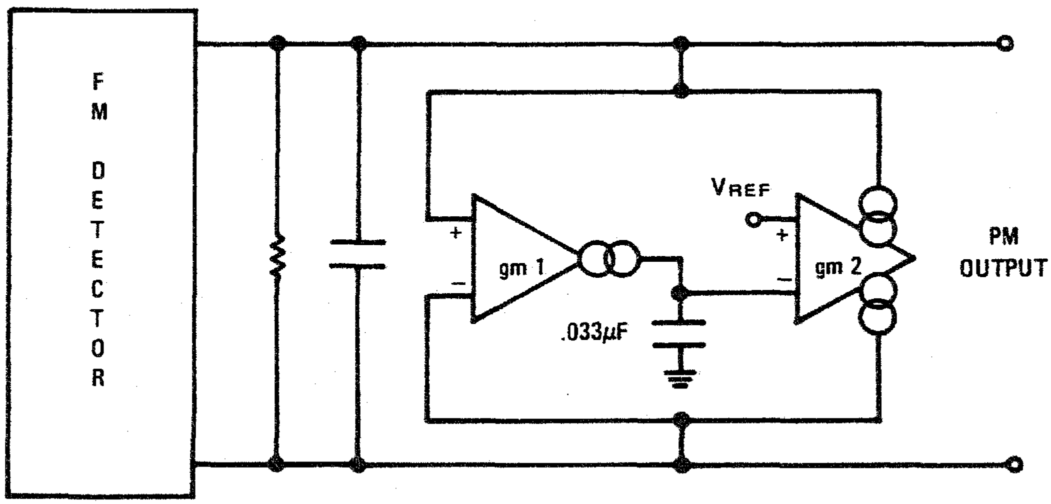



FIG. 23

**A Practical PM Detector Using Simulated Inductor**

The practical PM detector is using simulated inductor instead of the large value inductor. The simulated inductor consists of two operational transconductance amplifiers gm 1 and gm 2. Given an input voltage to transconductance amplifier gm 1, an output current will flow into the 0.033μF capacitor (at pin 14 of LM1981). For DC conditions the 0.033μF capacitor has little effect, and as the input voltage to the second transconductance amplifier increases, an output current will result to oppose the input voltage. At high frequencies the 0.033μF capacitor created phase shift and reduces the amount of output current that opposes the input signal, such that the whole circuit resembles an inductor. In this specific circuit, the simulated inductance value is proportional to the size of the capacitor and it can be calculated by the following equation.

$$L = C \times k$$
$$= C \times 1.8 \times 10^{10} \text{ H}$$

For 600 Henries, 0.033μF is a suitable value.

## (4) The L—R Signal Level Control Amplifiers

The L—R signal is detected and is connected internally to the matrix through a varible gain block controlled by the average level of the IF carrier. By this means, the L+R and L—R signals are matched in level even the AGC characteristic of the receiver is not perfectly tracking the RF signal strength; that will assure maximum channel separation over a wide range of signal strength. A second gain control is placed between the (L—R) signal and the matrix. This gain block is controlled by the mute/blend input at pin 11 and enables stereo/mono switching or a gradual blend from stereo to mono as the RF signal detereorates. The control amplifier is equivalent to a differential pair biased at $V_{REF}$ with 5KΩ between the bases and a series 50KΩ to pin 11. For a 100mV differential across the pair.

$$V\ \text{pin}\ 11 \geqslant V_{REF} \pm 100 \times 10^{-3} \times \frac{50+5}{5} = V_{REF} \pm 1.1V$$

The $V_{REF}$ has been designed to be 4.26V, such that the voltage needed for stereo/mono switching is between 3.16V and 5.36V. The voltage within this range will drive the decoder gradually blending from stereo to mono or vice versa. Fig. 24 shows the typical performance of it.

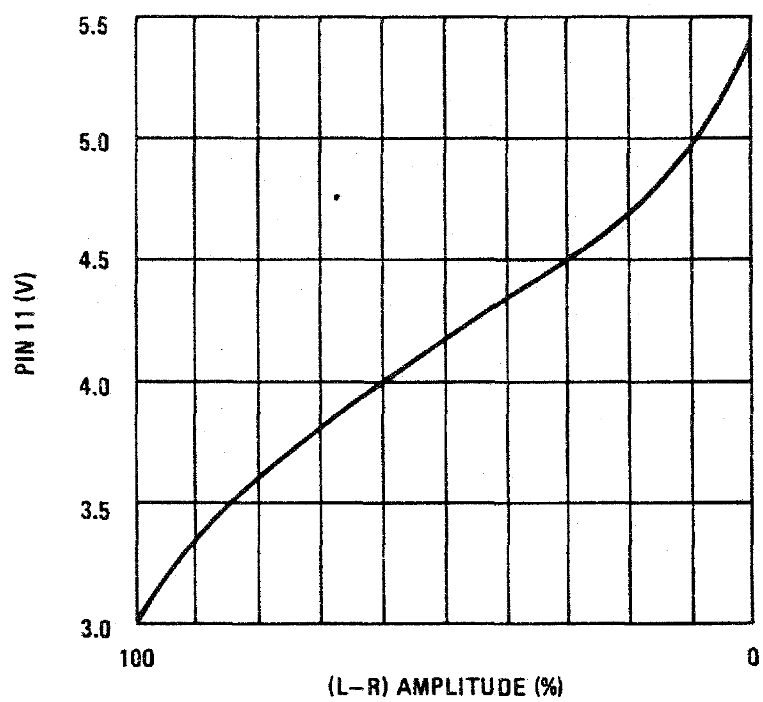



FIG. 24

**Stereo Separation Vs Blend Control**

## (5) The Excess Phase Detector

The (L−R) signal that is obtained through the level control amplifiers is led to the audio matrix and it is always monitored by an excess phase detector. The purpose of the detector is to switch the decodes into mono mode when an excessive phase deviation signal is received, as it is a highly distorted and noisy signal.

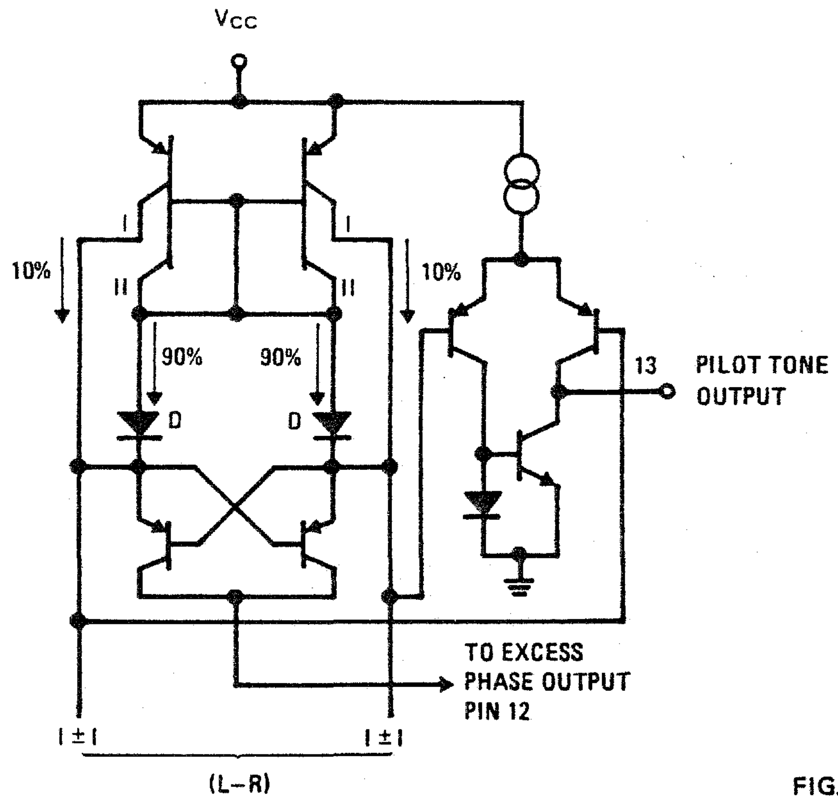



FIG. 25

**Excess Phase Detector**

The excess phase detector is a 90% differential current detector which has a DC to AC ratio such that each degree of detected phase deviation causes a 1.2% change in the current draw from each side of the detector. Unless the differential current applied to the inputs exceed 90%, there will be no output current. A differential current excess of 90% means that one of the input currents is less than 10% of the average. For this condition the diode that is connected to that node will turn off and current will flow through the PNP transistor whose emitter is connected to that node. The output is coupled over to pin 12 which then provides an excess phase indication.

### (6) The Audio Matrix

The detected (L−R) and (L+R) signals are combined in an audio matrix, which is a circuit providing linear addition and subtraction of these components to recover the original Left and Right channel audio signals. Fig. 26 is an audio matrix equivalent circuit.

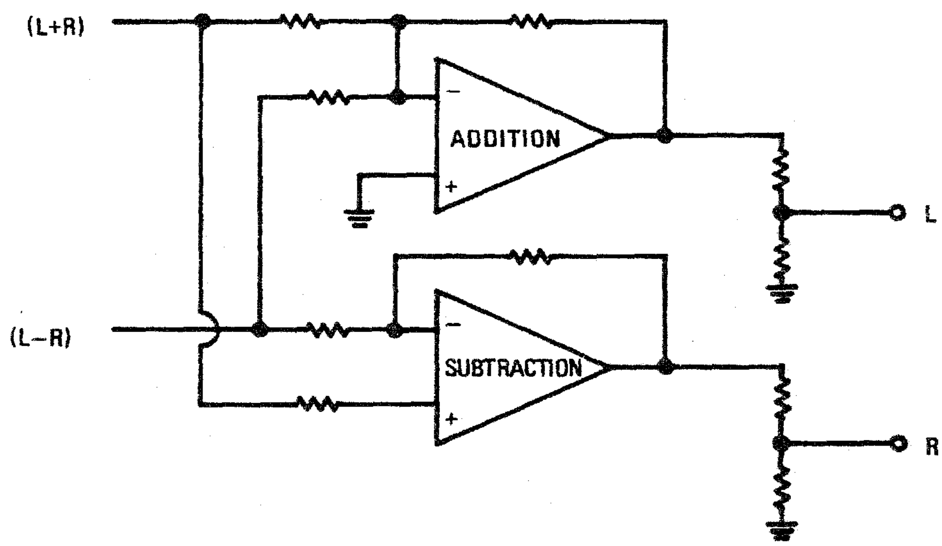



FIG. 26

**Audio Matrix**

### (7) The Sample And Hold Circuit

Both Left and Right channel outputs (pin 9 and 7 respectively) are buffered with Sample/Hold circuits, which can be used to hold the signal level in the presence of a detected noise burst. If pin 10 is left floating, the S/H circuits will pass the signal. Pulling pin 10 to a $V_{BE}$ above ground holds the pins 7 and 9 output levels. The capacitors for the S/H circuits are at pin 6 and 8, and these capacitors will slew limit the audio signal.

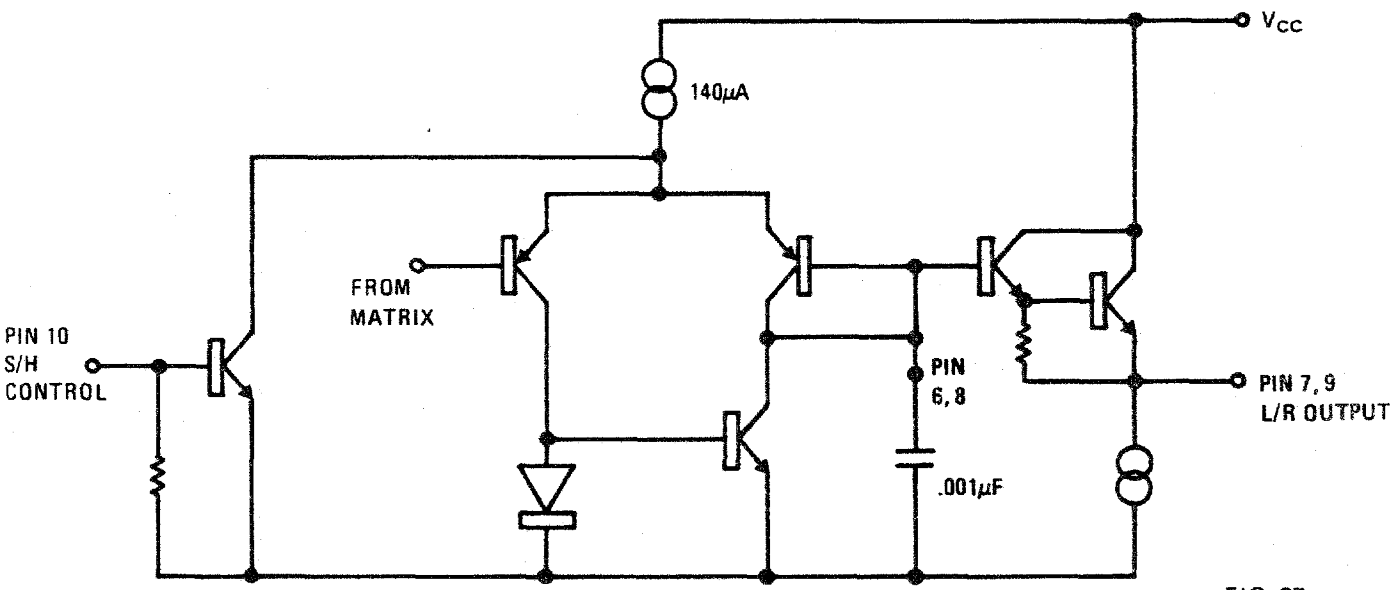



FIG. 27

**Output Sample and Hold Circuit**

# BUILDING AN AM STEREO RECEIVER

## (1) Requirements for AM Stereo Receiver

Basically the receiver front end for AM stereo is similar to that of an AM mono receiver, except care must be taken in certain areas to obtain optimum performance. These requirements are examined in the following text.

### a) RF Antenna

A high Q-factor helps increase the radio sensitivity but it limits the input signal bandwidth. Taking a typical Q-factor of 100 as an example, the input signal bandwidth is about ±5KHz at 1MHz. At lower frequencies near 600KHz, the bandwidth is even less a little over ±2KHz for −3dB point. In order for the human ear to recognize stereo effect, data has shown separation is best perceived in the frequency range from 200Hz to 5KHz. Therefore, a high Q-factor antenna is not recommended for stereo AM receiver for accurate reproduction of the broadcast stereo signal.

### b) Local Oscillator Stability

Phase noise from the local oscillator can limit the signal-to-noise ratio. Because the phase detector inside the decoder cannot discriminate the phase deviation that is from the local oscillator or the incoming signal, the local oscillator must exhibits high stability and low phase jittering. Also "pulling" is not allowed.

### c) IF Amplifier Bandwidth and Symmetry

IF amplifier bandwidth plays an important role to the overall selectivity performance. Narrow band IF filter limits the overall frequency response, wide band IF filter tends to receive interference from the adjacent channel. During the night, radio wave propagation at medium frequencies by skywave becomes a significant factor, multiplying the number of potentially interfering transmitters. Because of this, satisfactory daytime reception with a relatively wide receiver bandwidth may be totally unsatisfactory at night.

For designing a high quality AM stereo receiver, it is advised to have a "Fidelity" position giving a bandwidth of ±6KHz to ±8KHz at daytime, and decreasing to something less than ±3KHz in the "Normal" position at nighttime or when there is a strong station at the adjaction channel. The actual IF amplifier bandwith is not the only factor should be considered. Asymmetry in the IF filter generates phase modulation which degrades separation and increases distortion.

### d) AGC Characteristic

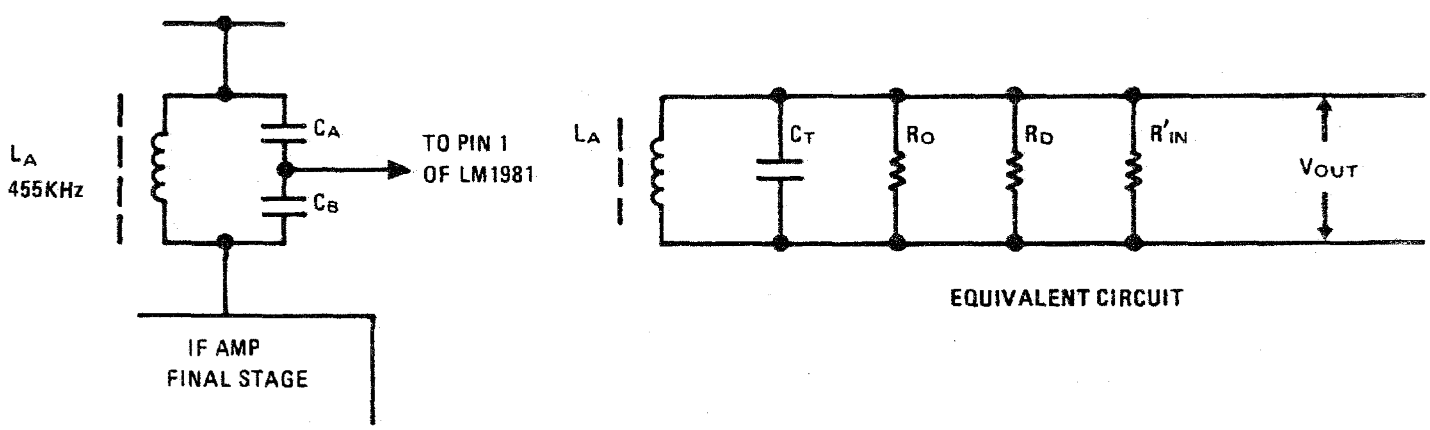
To maintain the channel separation better than 20dB (30dB typ from 2 mV/M – 50 mV/M) from an RF signal strength of 1 mV/M to 1 V/M the (L+R) level must change less than 4dB. This implies an AGC figure of merit better than 60dB. Using high AGC figure of merit is not always possible or desireable. An alternative is to control the output amplitude of the PM channel with a control voltage derived from the (L+R) detected output. Such a circuit was built inside the LM1981N, so that the AGC figure of merit can be at the range of 40–50dB.

## (2) Determining The Values of The Key Components of The AM Stereo Decoder

Although the external component selection for the decoder are not critical, the values of the external components can be determined by a straight forward simple calculation.

### a) The Input Matching Network

Usually the signal input to LM1981 is extracted from the final AM IF amplifier tuned circuit. From the data sheet, we obtains 15KΩ for the LM1981 input resistance ($R_{IN}$) and the input signal level for proper stereo operation is from 20mV to 400mV. It implies that the tank circuit impedance is required to be 15KΩ and the 455KHz carrier level is approximately 400mV when the RF signal strength is above the AGC threshold. Fig. 28 shows the input matching network and its equivalent circuit.




**The Input Matching Network for LM1981** FIG. 28

- $L_A$ : The inductance of the tuned circuit.
- $C_T$ : The tuning capacitance of the tuned circuit. The value of $C_T$ is equivalent to the capacitance of $C_A$ and $C_B$ in series.
- $R_O$ : IF amplifier output resistance, 100KΩ approximately.
- $R_D$ : The dynamic resistance of the tuned circuit. It is determined by the L and C values.
- $R'_{IN}$ : The reflected input resistance of LM1981. It is determined by the tapping ratio of the total tuning capacitance to the capacitance of $C_B$.

As mentioned previously, the output level from the final IF amplifier is 400mV, and the input signal level for LM1981 is 20—400mV. Therefore a tuned circuit having a tapping ratio (n) of 2:1 will provide 200mV type signal level to LM1981. This is a proper level for optimum stereo performance. The reflected resistance $R'_{IN}$ is given by.

$$R'_{IN} = n^2 R'_{IN}$$
$$= 2^2 \times 15 \times 10^3$$
$$= 60K\Omega$$

and $R_t = R'_{IN} \parallel R_O$
$$= 37.5K$$

If we set the tuned circuit bandwidth at 20KHz, the loaded circuit Q is

$$Q_L = \frac{fo}{\Delta f} = \frac{455 \times 10^3}{20 \times 10^3} = 23$$

The dynamic resistance ($R_D$) of the tuned circuit in parallel with $R_t$ must present a 15KΩ load to the IF amplifier output.

$$R_D \parallel R_t = 15K\Omega \qquad \therefore \quad R_D = 25K\Omega$$

Since $R_D$ also determines the unloaded Q of the tuned circuit

$$\frac{Q_L}{Q_U} = \frac{R_t}{R_t + R_D}$$

$$Q_U = \frac{Q_L\,(R_t + R_D)}{R_t} = 38.3$$

For a parallel resonant circuit we have

$$L = \frac{R_D}{\omega Q_U}$$

$$= \frac{25 \times 10^3}{2\pi 455 \times 10^3 \times 38.3} = 228\mu H$$

The total capacitance necessary to tune this inductance to 455KHz is 536pF. So each capacitor is put at 1000pF.

b) **Sample and Hold Capacitors**

The purpose of the sample and hold capacitors is to slew limit the audio signal in order to hold the signal level in the presence of a detected noise burst. The charge/discharge current designed is 140$\mu$A max so that for a 1V swing at 20KHz the capacitor value can be calculated as follows:

$$XC = \frac{0.5}{140 \times 10^{-6}} \qquad 1\ \text{Vp-p} = 0.5\ \text{V Max}$$

$$XC = \frac{1}{2\pi f C}$$

$$\therefore C \leqslant \frac{1}{2\pi f\ Xc}$$

$$= \frac{140 \times 10^{-6}}{2\pi \times 20 \times 10^{3} \times 0.5} \qquad \leqslant 0.0022\mu F$$

In the application circuit, the S/H capacitors $C_4$ and $C_5$ are chosen to be 0.001$\mu$F.

c) **The Resonant Circuit for Quadrature Detector**

The series resonant circuit for the quadrature detector is driven from a current source in order to minimize radiation at the carrier frequency. It is designed to be 130$\mu$A max. To ensure the switching amplitude of 400mVp-p at the multiplier inputs, the capacitor can be chosen as follow:

$$XC = \frac{200 \times 10^{-3}}{130 \times 10^{-6}} \qquad 400\ \text{mVp-p} = 200\text{mV Max}$$

$$\therefore C \leqslant \frac{1}{2\pi f\ Xc}$$

$$= \frac{130 \times 10^{-6}}{2\pi \times 455 \times 10^{3} \times 200 \times 10^{-3}} \qquad \leqslant 227\text{pF}$$

Choosing C to be 220pF gives the inductor nominal value as

$$L = \frac{1}{(2\pi \times 455 \times 10^{3})^{2}\ 220 \times 10^{-12}} \qquad = 556\mu H$$

**d) Conversion Gain Adjustment Potentiometer for Quadrature Detector**

Correct level of L–R signal will ensure maximum channel separation and optimum distortion performance. Therefore, providing external means of adjust the detector conversion gain is necessary. This is most conveniently done by a potentiometer connected aross the tuned circuit which will dominate the circuit Q if the inductor series resistance ($R_O$) is low.

With a coil $Q_U$ = 110, $R_O$ = 14.5Ω at 455 KHz. If we choose a tuned circuit bandwidth of ±30KHz, then the loaded Q will be 7.5. The shunt resistance R will be

$$\frac{Q_L}{Q_U} = \frac{R_O}{R + R_O}$$

$$\therefore \quad R = \frac{R_O Q_U}{Q_L} - R_O = \frac{14.5 \times 110}{7.5} - 14.5$$

$$\hat{=} \quad 200\Omega$$

A potentiometer of 300–500Ω is chosen.

**e) The Integrating Capacitor**

The integrating capacitor is connected immediately following the quadrature detector. It determines the (L–R) detected level. This value and the shunt resistor determine degree of separation and the high frequency roll-off point of the detected signal. With a high roll-off point at 15KHz, the capacitance will be

$$C = \frac{1}{2\pi f\ R}$$

$$= \frac{1}{2\pi 15 \times 10^3 \times 200}$$

$$= 0.053\mu F$$

The value of the integrating capacitor is chosen to be 0.047$\mu$F in the application circuit.

**f) The Integrating Capacitor for Simulated Inductor**

As mentioned in the descriptions of LM1981 previously. The actual inductance value is proportional to the size of the capacitor at pin 14.

$$L = C \cdot K$$

For a simulated inductance of 600H

$$C = \frac{600}{1.8 \times 10^{10}} = 0.033\mu F$$

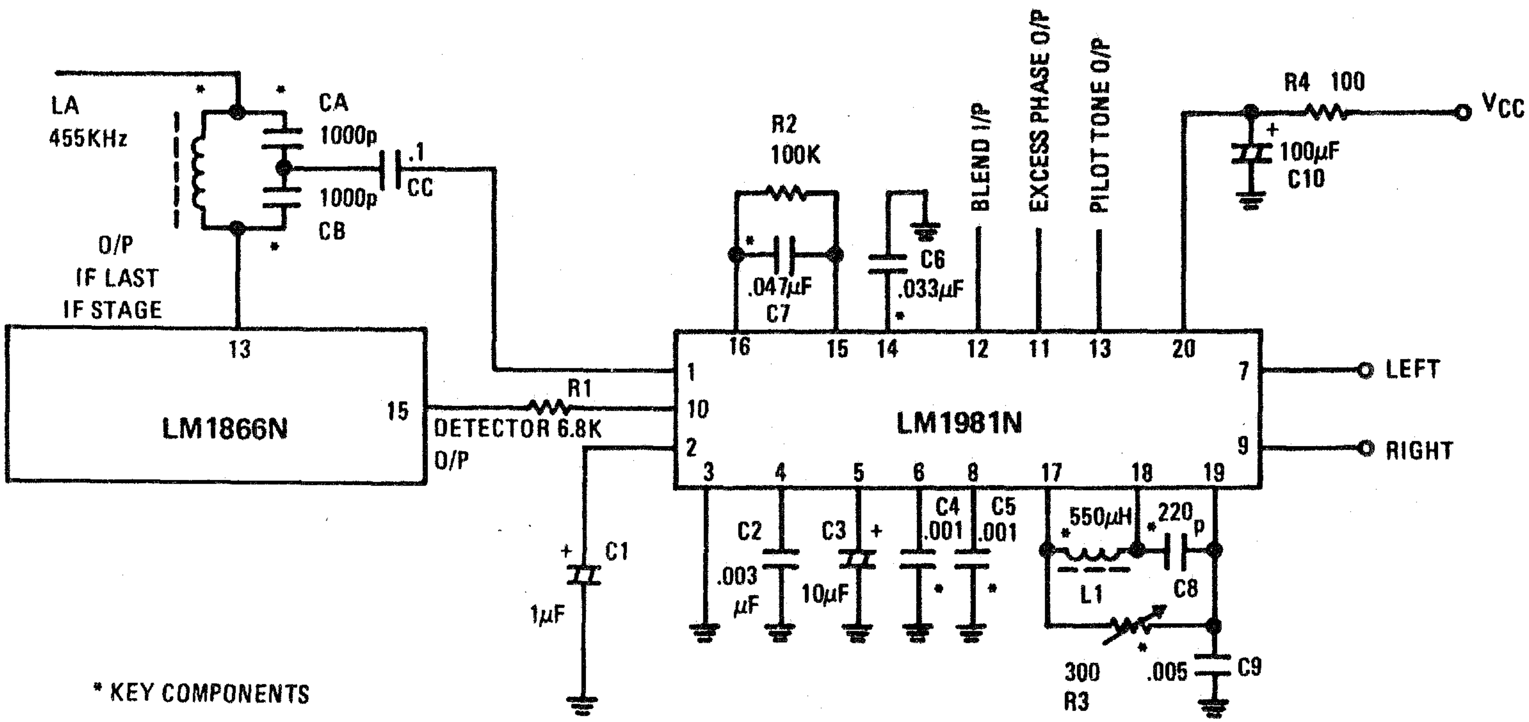



FIG. 29

**LM1981 With External Components**

### (3) Alignment and The Considerations for PCB Layout

Alignment procedures for AM stereo receiver front-end is the same as the procedures required for a mono AM receiver. The only thing that required special attention is the adjustment of the IF filters for good symmetry.

The alignment of the decoder is straight forward. The blend input is shorted to ground and the quadrature coil is tuned for resonance at 455KHz by adjustment until the voltage on the capacitor at pin 14 matches the reference voltage at pin 19. To prevent loading effect, the voltmeter for measuring voltage at pin 14 must be a high impedance DVM and the best way to connect it is between pin 14 and pin 19 rather than from pin 14 to ground.

After frequency adjustment, the next step is channel separation adjustment. With left or right only information modulating the carrier, the potentiometer between pins 17 and 19 is adjusted for maximum separation.

Now the receiver is ready for stereo reception. AM stereo receiver also gives a pilot lamp and auto stereo switching when a stereo station is received, in the same manner as FM stereo receiver. AM stereo does not have the bandwidth to broadcast a 19KHz pilot tone like the FM stereo stations. To indicate a AM stereo station, broadcasting a 5Hz low frequency pilot tone is the only option. But this means detection time will be slow. Slow detection of a stereo station is definitely going to distinguish AM stereo from FM stereo.

The AM stereo decoder consists of an envelope detector, a quadrature detector and a high gain limiter. They may have radiation to the receiver front end. Considerations have been taken seriously to minimize the radio frequency radiation when the chip was designed. It is to confine most of the high frequency processing of signals inside the chip but external circuitry is always necessary. Therefore, the important external components (such as the quadrature tuned circuit, RF filtering capacitors etc.) must be placed as close as possible to the IC. For the copper traces that are carrying signal currents must be designed to minimize magnetic radiation to the receiver front-end. It is recommended to put the decoder chip as far away as possible from the antenna bar.

# BUILDING AN AM STEREO TRANSMITTER

(1) The AM Stereo Transmitter

AM stereo is a new broadcasting system and AM stereo station is not available in most places at the moment. In order to evaluate and test receiver decoder circuits, a source of program material is necessary. Fig. 30 shows a block diagram of a simple AM stereo transmitter which is designed for demonstration of AM stereo receivers. The transmitter consists of a crystal controlled oscillator, an Armstrong phase modulator, an audio matrix and an amplitude modulator. Its transmitting frequency is 750KHz.

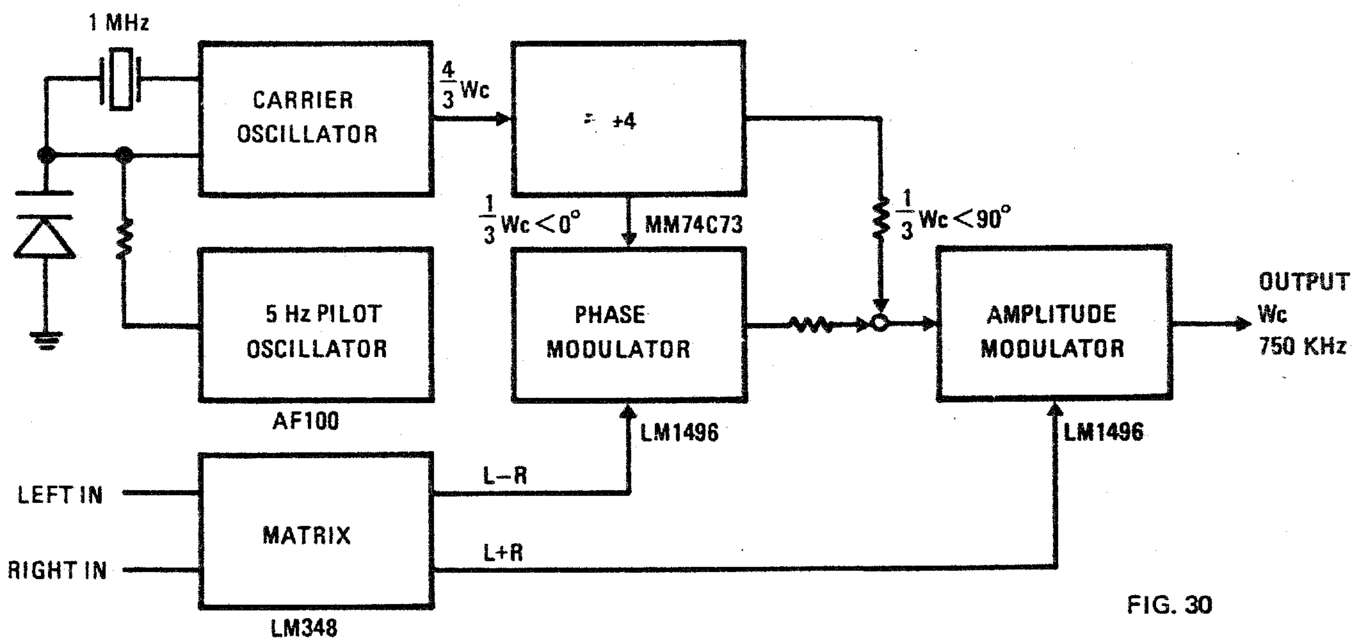



FIG. 30

AM Stereo Transmitter

(2) **Transmitter Alignment**

Adjustment of the transmitter may be made by applying sufficient audio signal to either the left or right inputs to obtain 1 radian of (L–R) modulation (the (L+R) channel switched off). The level can be verified by spectrum analyzer data – the carrier will decrease by 2.33 dB below no modulation, and the 1st and 2nd sidebands will be 4.77dB and 16.47dB below the carrier with 1 radian (100%). The L+R level may be set for 100% amplitude modulation.

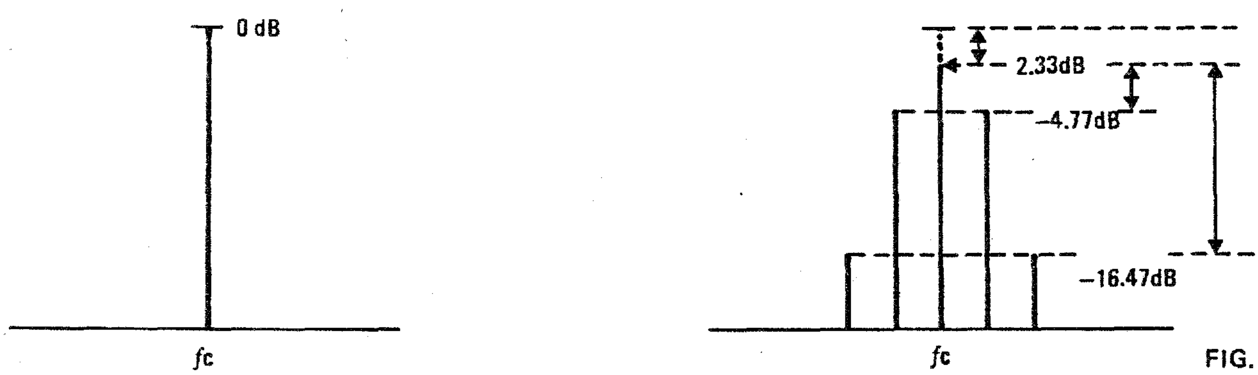



FIG. 31

(a) $\beta = 0$ (b) $\beta = 1$

**Carrier and Sidebands Amplitude**

Remark:

Detailed AM stereo receiver and transmitter circuits are shown in the preliminary application report – GL2701.

## REFERENCE

(1) Principle of Communication Systems, by Taub & Schilling, McGraw-Hill.

(2) Radio Handbook, by William I. Orr, "Radio".

(3) "A Proposed AM-PM Compatible AM Stereo System", by E.F. Close, A.L. Kelsch and R.D. Streeter, IEEE transactions on Consumer Electronics Volume CE-23, 1977.

(4) "An Integrated AM Stereo Decoder", by Don Sauer, IEEE transactions on Consumer Electronics Volume CE-27, 1981.

(5) Application Note – CLAU 124, "AM Stereo", by Don Sauer and Martin Giles, National Semiconductor.

**CLAU—** 124 (Edition B)

**Product:** LM1981

**Topic:** Compatible AM Stereo

**Date Issued:** October 1980

**By:** Martin Giles
Don Sauer

National Semiconductor

# LINEAR APPLICATION UPDATE

This CLAU 124 introduces the industry's first AM Stereo Decoder IC: the LM1981. The basic operation is described while decoding the Magnavox system. Also, included is a description of how to decode the Motorola and Belar systems with this same chip. We believe that the LM1981 may also be usable with the Harris and perhaps even the Kahn systems, although at this time we'll have to leave the implementation as a project for the very interested reader (who also has an encoder).

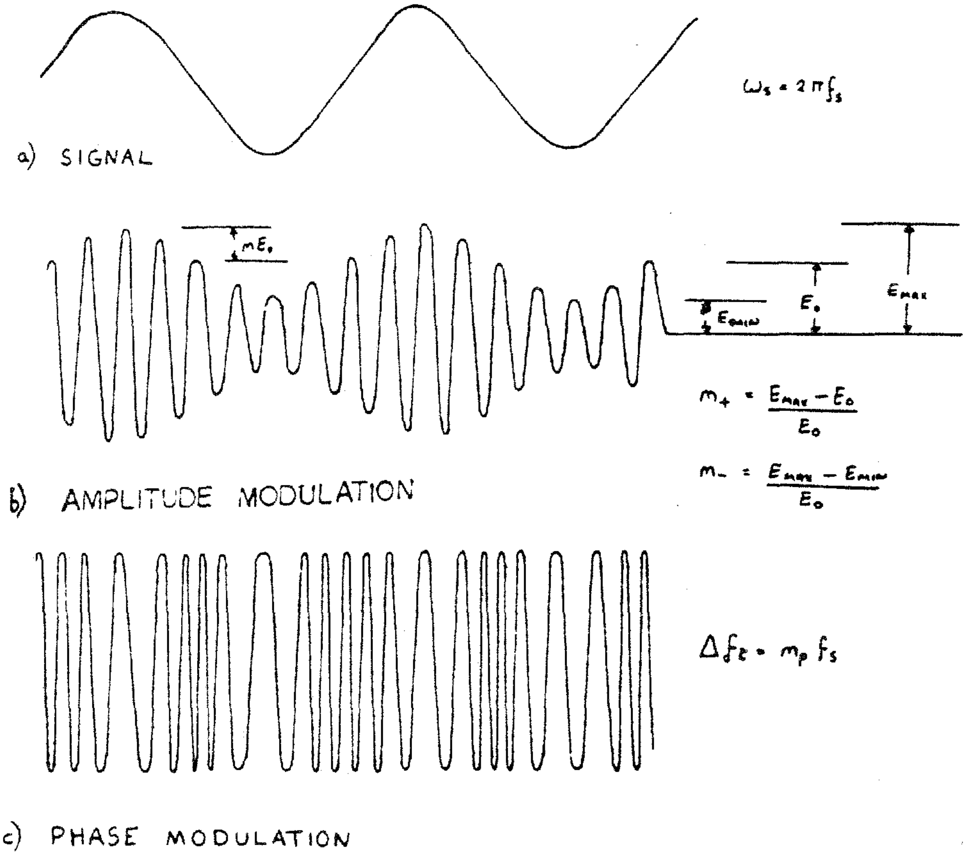



FIGURE-1. CARRIER AMPLITUDE AND ANGLE MODULATION

## Introduction

Why stereo AM broadcasts? After all, FM stations have been broadcasting stereo for many years now, so what additional benefit is obtainable by putting AM signals into stereo?

For the AM broadcaster, upgrading the quality of the AM service by introducing stereo clearly has an economic impact, since stereo is already a preferred listening source for many people. Also, since the FM stereo service suffers from a limited geographic coverage line of sight transmission is needed, and multipath - the simultaneous arrival of a second, time delayed signal at the receiving antenna caused by reflection from tall buildings etc. - can cause serious distortion of the received signal. These factors can severely limit good quality FM stereo reception, as many listeners to automobile radios in particular will attest to. By introducing AM stereo, it is anticipated that much wider stereo coverage, free from multipath, will be available to the travelling listener.

## The AM Stereo Signal

In the U.S. a conventional AM broadcast signal consists of a carrier frequency between 535kHz and 1605kHz that is amplitude modulated with the intelligence(!) being transmitted. The extent to which the carrier envelope varies is expressed by the degree of modulation M+ or M- as shown in Figure 1. If the modulation is symmetrical, then $M+ = M- = M$ where M is known as the modulation index. Full modulation occurs when $M = 1.0$. Therefore for $M \leq 1$, the monophonic AM signal can be written as

$$e_c = E_o\left[1 + m(\sin\omega_m t)\right]\sin\omega_c t \qquad (1)$$

where $\omega_c$ is the carrier angular velocity and $\omega_m$ represents the audio signal angular velocity. For a stereo audio source, a compatible mono signal is composed of the sum of Left and Right components and can be written $(L + R) = \sin\omega_m t$

To transmit the stereo signal for the benefit of receivers equipped to decode it, in the Magnavox system the radio frequency carrier is deviated in phase (PM) by the instantaneous amplitude of the stereo component (L - R) of the signal. If $\phi(t)$ is the angular displacement of the carrier at time t then

$$\frac{d\,\phi(t)}{dt} = \omega_c \qquad (2) \qquad \therefore \phi(t) = \omega_c t + \theta \qquad (3)$$

(where $\theta$ = displacement at $t=0$)

For phase modulation the reference phase $\theta$ is varied with the instantaneous amplitude of the modulating signal

$$\theta = \theta_o + m_p \sin\omega_s t$$

$\theta_o$ = phase with no modulation
$\omega_s$ = signal angular velocity
$m_p$ = phase modulation index
$(\sin\omega_s t = (L-R))$

Substituting this is Eq. (3) and assuming for convenience that $\theta_o = 0$

$$\phi(t) = \omega_c t + m_p \sin\omega_s t \qquad (3)$$

$$e_c = E_o \sin(\omega_c t + m_p \sin\omega_s t) \qquad (4)$$

This is the equation for a phase modulated carrier waveform. Therefore, combining Eq. (1) and Eq. (5) we obtain the AM/PM stereo signal

$$e_c = E_o\left[1 + m\sin\omega_m t\right]\sin\left[\omega_c t + m_p \sin\omega_s t\right] \qquad (5)$$

To limit the spectrum utilization, the Magnavox system limits the peak deviation produced by the (L - R) modulating waveform to 1 radian (57.3°). This means that for 100% modulation in both the AM and PM channels, $M = M_p = 1$.

Unlike FM stereo, where the (L - R) or stereo information is modulated on a suppressed subcarrier requiring the simulataneous transmission of a harmonically related pilot carrier, the AM stereo signal does not require a pilot for decoding. Nevertheless, a stereo identification signal is also included, to facilitate automatic switching into the stereo mode and to provide visual identification of stereo broadcasts. This identification signal is a low frequency tone (5Hz) which modulates the carrier phase by 4 radians. Therefore the total signal equation, for the Magnavox system, becomes

$$e_c = E_o\Big[1 + \underbrace{m \sin \omega_m t}_{\substack{(L+R)\\ \text{MONO}}}\Big]\cos\Big[\omega_c t + \underbrace{m_p \sin \omega_s t}_{\substack{(L-R)\\ \text{STEREO}\\ \text{DIFFERENCE}}} + \underbrace{4 \sin 10\pi t}_{\substack{\text{PILOT}\\ \text{TONE}}}\Big] \quad (6)$$

## The Transmitter

The conversion of a conventional monophonic AM transmitter to AM/PM is relatively straightforward, as shown by the block diagram of Figure 2. Instead of a fixed frequency r.f. carrier, the carrier is phase modulated by a 5Hz stereo identification signal with a peak deviation of 4 radians.

It can be shown that the peak frequency deviation of a phase modulated carrier waveform is given by Equation (7)

$$\Delta f_c = m_p \times f_s \qquad (7)$$

$f_s$ = modulating frequency
$m_p$ = modulation index
$\Delta f_c$ = carrier deviation

The 5Hz tone produces a 20Hz peak frequency deviation of the carrier.

Left and Right audio components are matrixed to form (L + R) and (L – R) signals. The (L + R) signal is the normal monophonic signal and is used to amplitude modulate the carrier in the normal way. Because the carrier is simultaneously being phase modulated with the (L – R) signal, the carrier instantaneous amplitude cannot be allowed to diminish to zero by large negative modulation indices ($M- \geq 1$). Therefore the AM section of the transmitter is restricted to 95% negative modulation. Positive modulation peaks are no problem, allowing up to 125% carrier level increase as in current practice.

Regarding the permitted spectrum utilization, Figure 3, an (L + R) single tone cannot produce sideband amplitudes greater than –25dB compared to the unmodulated carrier amplitude from 15kHz to 30kHz. Above 30kHz the sidebands have to be below –35dB. Clearly the occupied spectrum standards allow the broadcast of a "HiFi" signal. In practice these sideband amplitudes are unlikely to be encountered. AM transmitters are required to have a frequency response that is ± 2dB from 200Hz to 5kHz, and to be "proofed" out to 7.5kHz. Where the studio and transmitter are physically separated, an 8kHz telephone line link is common. Even when broadcasting occurs at frequencies out to 15kHz (30kHz bandwidth at r.f.)

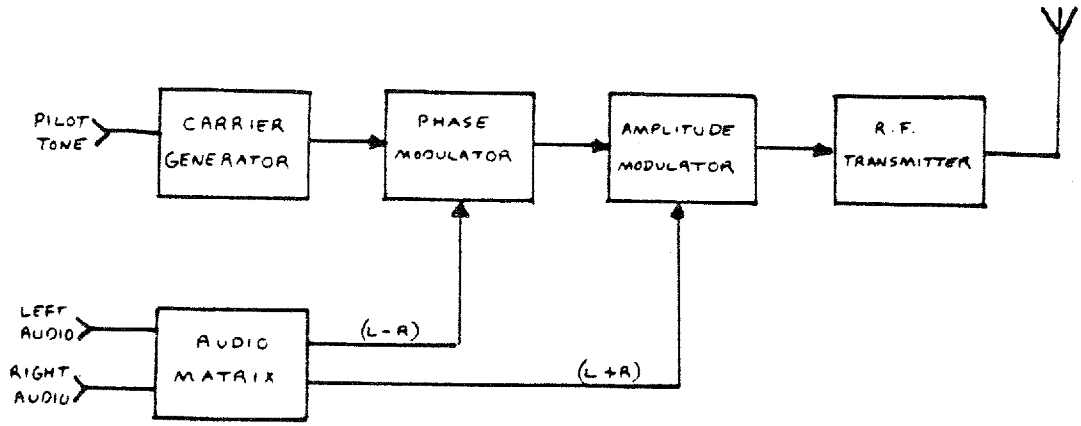



FIGURE 2. AM STEREO TRANSMITTER

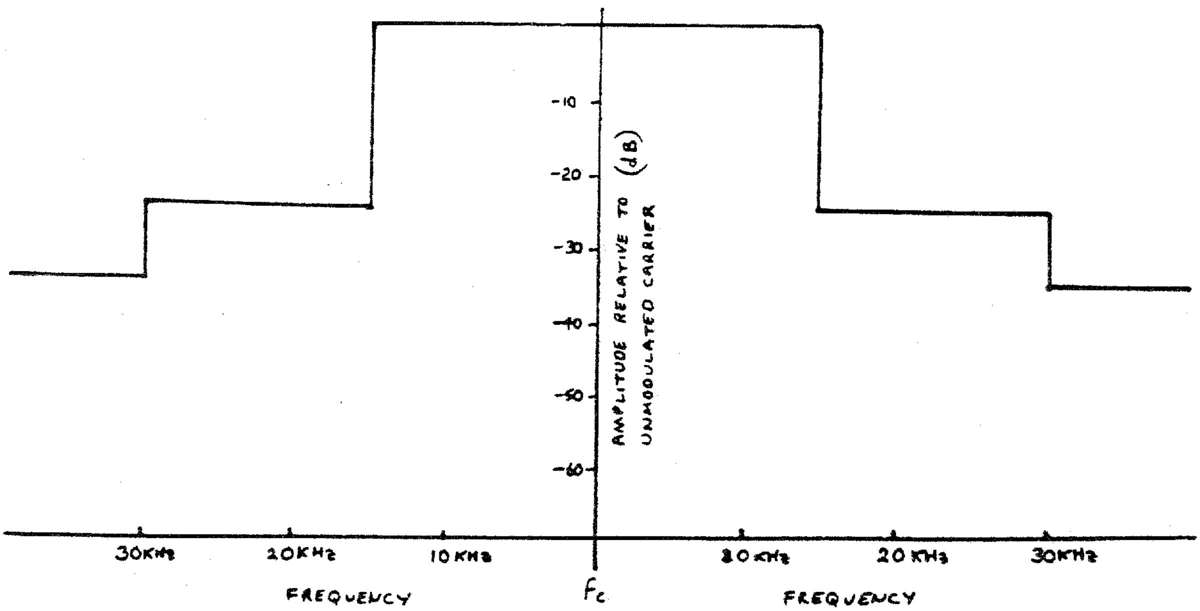



FIGURE 3. AM BROADCAST SPECTRUM LIMITS

# TABLE I

| MODULATION INDEX | SIDEBAND ORDER | LEVEL REFERRED TO UNMODULATED CARRIER | LEVEL (dB) |
|---|---|---|---|
| 0.30 | 0 | 0.977626 | -0.2 |
| | 1 | 0.148319 | -16.6 |
| | 2 | 0.011166 | -39.0 |
| | 3 | 0.000559 | -65.0 |
| | 4 | 0.000021 | -93.6 |
| | 5 | 0.000001 | -129.0 |
| | 6 | 0.000000 | -156.0 |
| 0.68 | 0 | 0.887698 | -1.0 |
| | 1 | 0.320723 | -9.9 |
| | 2 | 0.055605 | -25.1 |
| | 3 | 0.006364 | -43.9 |
| | 4 | 0.000544 | -65.3 |
| | 5 | 0.000037 | -88.6 |
| | 6 | 0.000002 | -113.5 |
| 1.00 | 0 | 0.765198 | -2.33 |
| | 1 | 0.440051 | -7.1 |
| | 2 | 0.114903 | -19.8 |
| | 3 | 0.019563 | -34.2 |
| | 4 | 0.002477 | -52.1 |
| | 5 | 0.000250 | -72.1 |
| | 6 | 0.000021 | -93.6 |

PHASE MODULATION SIDEBAND AMPLITUDES

most of the energy in the broadcast signal is at frequencies well below 10kHz - fortunately so for receivers tuned to adjacent channels (10kHz away). Introduction of AM stereo is not likely to encourage an increase in the broadcast frequency response, particularly when the spectrum of the (L - R) phase modulating signal is considered.

Neglecting for the moment the 5Hz stereo identification tone, the (L - R) signal can cause a carrier phase peak deviation of 1 radian. Because the PM modulation index is constant for all modulating frequencies, the sideband amplitudes produced by any audio frequency can be calculated by reference to the appropriate Bessel functions. Table 1 shows the sideband amplitudes for 30%, 68% and 100% PM. By comparing these amplitudes with the permitted spectrum of Figure 3 we can see that 100% modulation is practical up to about 7.5kHz. Above this frequency the maximum modulation with a single tone is limited to 68%.

Another factor to be considered with the increased spectrum utilization is the impact on protection ratios. Current standards for AM stations place limitations on the day/night co-channel radiation, and on groundwave signal (day) radiation to the 1st, 2nd and 3rd adjacent channels. These standards specify the maximum ratio of overlapping field strength contours with a threshold level of interference taken to be at least -26dB below the desired groundwave signal. Measurements taken by the NAMRSC on receivers shows that the stereo signal tends to raise the interference level by about 3dB on co-channel, 1dB to 4dB on the 1st adjacent channel, and by 14dB on the second adjacent channel, compared to the interference produced by a monophonic signal. The second adjacent channel interference for stereo is actually at the -26dB threshold level. Further work by Magnavox shows tnat limiting the (L - R) signal with an 8kHz filter substantially reduces the 2nd adjacent channel interference. Limiting the (L - R) and (L + R) signals to 5kHz produces comparable interference levels to the monophonic condition.

It might be wondered how much stereo information is available if the audio signals are going to be restricted to something less than 8kHz?

Fortunately (for the recognition of stereo) there is data that shows separation is best perceived in the frequency range from 200Hz to 5kHz. As a result the transmitted separation is proposed to be $\geq$ 26dB over the frequency range 600Hz to 5kHz.

A further aspect of transmitter performance is that of incidental PM. If the carrier frequency varies with the level of amplitude modulation, then stereo separation will suffer and the distortion in the (L - R) channel will be increased. An example of this type of problem can be provided by a typical laboratory AM/FM signal generator used to simulate AM stereo signals. This particular generator is specified to have no greater than 60Hz carrier deviation when amplitude modulated by 30%. An accuracy of 0.006% is more than adequate for standard AM but if this deviation actually occurs when modulating the carrier with a 1kHz (L + R) signal, a simultaneous 1kHz PM signal is generated. Since, from Equation (7), a 30% modulated 1kHz (L - R) signal produces a carrier peak deviation of $1 \times 10^3 \times 0.3 = 300$Hz our unwanted carrier deviation of 60Hz is only 14dB down. Quite obviously, this generator is totally unsuitable for making measurements on an AM stereo receiver. The trasmitters are expected to produce less than 2% phase modulation with a 400Hz tone at 85% amplitude modulation. This implies a carrier accuracy of 8Hz at 1MHz.

One final aspect of the AM/PM stereo signal to be considered is that of the S/N ratio - will the stereo signal suffer as much degradation in S/N compared to the mono signal as does an FM stereo signal (≃ -23dB)? This is not the case. In FM stereo the additional noise comes from the (L - R) subchannel which occupies a different part of the spectrum to the (L + R) signal. For the AM/PM stereo signal, the (L - R) signal occupies the same frequency spectrum as does the (L + R) signal. It can be shown that the AM stereo quiescent noise level is from 1.8dB to to 3dB higher than the conventional monophonic quiescent noise level.

## The Receiver

A block diagram of a receiver suitable for decoding the AM stereo signal is shown in Figure 4. This resembles a conventional AM receiver in several respects and it would be possible to convert a standard AM/FM/FM Stereo receiver to one capable of AM stereo reception by the addition of a limiter, PM detector, stereo identification tone detector and audio matrix. However, as we shall see, it is more likely in practice that complete re-design or modification of the entire AM section will occur.

Briefly, the entire AM/PM modulated carrier is mixed down in a superhet front end, either to a 455kHz or to a 262kHz intermediate frequency. At the I.F. amplifier output the signal splits in two directions. A typical envelope detector may be used to extract the amplitude modulated intelligence and to detect the r.f. carrier level for

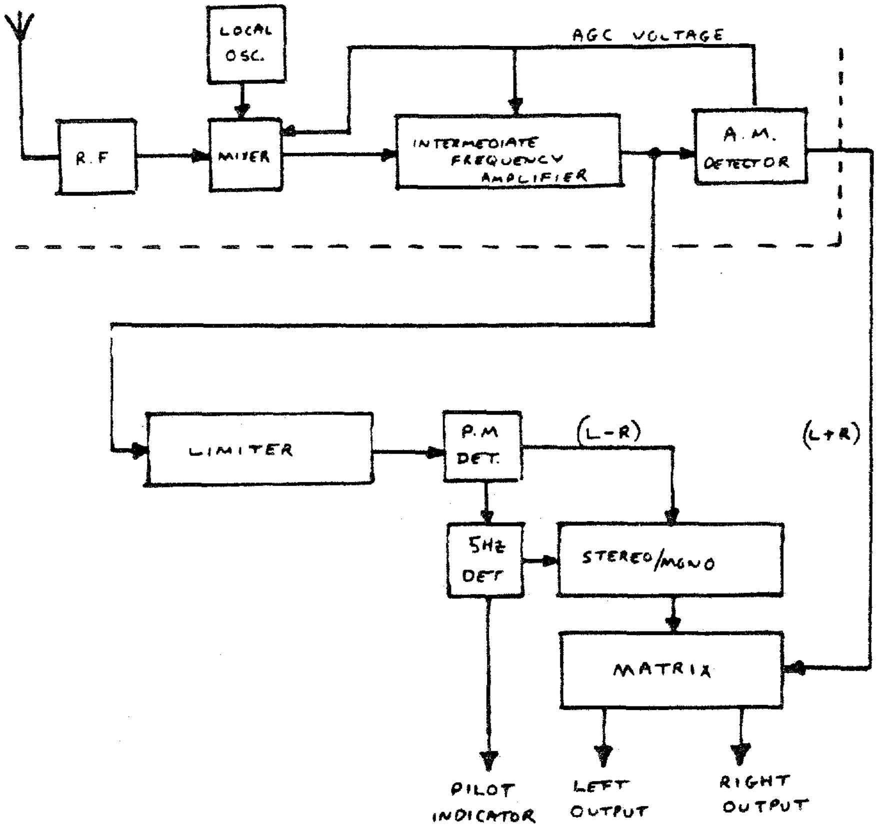



FIGURE 4. AM STEREO RECEIVER

an a.g.c. function. At the same time the I.F. amplifier output is limited to remove amplitude modulation, and a PM detector supplies the (L - R) audio signal and the 5Hz stereo identification tone. Both AM and PM channel outputs are applied to the matrix which will drive the Left channel and Right channel audio signals. If indeed an (L - R) signal is present, indicated by the 5Hz tone detection, the stereo/mono switch is enabled in the stereo mode. Absence of the tone, or unsuitable reception conditions, will result in the switch being in the mono mode, and (L + R) is applied to both Left and Right channel outputs. In the stereo mode

$$\text{LEFT} = \frac{(L+R)+(L-R)}{2} \qquad \text{RIGHT} = \frac{(L+R)-(L-R)}{2}$$

Practical circuits rarely operate as smoothly as block diagrams would suggest, and decoding the AM/PM signal is no exception. To begin with, we can examine more closely the requirements of the AM receiver front end, up to the 455kHz I.F. output and including

a) the r.f. antenna,

b) Local oscillator stability,

c) I.F. Amplifier Bandwidth and Symmetry,

and d) Agc characteristics.

a) The Antenna Circuit.

Two types of AM antenna are most common. In automotive radios a whip antenna is used, whereas for portable and table radios a built-in ferrite rod antenna is most popular. Both types of antenna are coupled to the input stage of the radio through a tuned circuit and there may or may not be any active gain stage at radio frequencies before the mixer stage (see Section 3 of National's AUDIO/RADIO HANDBOOK). For most present day designs the front end bandwidth is not wide - an input tuned circuit loaded Q of 100 being typical. Because of the short effective height of the ferrite rod antenna, this high Q helps increase the radio sensitivity but also means that the input bandwidth is about ±5kHz at 1MHz. At lower radio frequencies near 600kHz the bandwidth is even less a little over ±2kHz for -3dB response. If we have any intention of accurately reproducing the broadcast stereo signal it will be necessary to redesign the receiver front end for less selectivity.

b) Local Oscillator (L.O.) Stability.

A similar situation exists for the (L.O.) in a superhet front end receiver as does for the transmitter carrier frequency generator. Incidental phase modulation will cause loss of separation and/or raise the "noise floor" in the PM channel. For example, in synthesized AM frequency tuners, the noise floor caused by phase variations in the V.C.O. frequency (either intrinsically in the V.C.O. or in the phase detector control voltage of the P.L.L.) seems to be typically at about -60dB. Conventional discrete or I/C mixer/oscillator combinations can easily produce higher incidental PM since this has not been a design consideration for mono AM receivers. Isolation between the mixer and the L.O. is important, to prevent "pulling" of the L.O. by the mixer signal. Even the tuning capacitor can cause audible problems (i.e. microphonics). Typical solid dielectric tuning capacitors are unsuitable from this viewpoint - any slight vibration of the p.c.b. will produce an output in the PM detector. For table radios that use air dielectric tuning capacitors ganged for AM/FM operation the problem will be less severe, but compact portable designs are likely to pose difficulties.

c) I.F. Amplifier Bandwidth and Bandpass Symmetry.

In their evaluation of the proposed systems for AM stereo, the National AM Stereophonic Radio Committee (NAMSRC) stated

"The choice of I.F. bandwidth is probably one of the largest variables affecting the NAMSRC tests of AM stereo receivers".

This can be true for either stereo or monophonic broadcasts but the addition of the phase modulated (L - R) channel does create some new performance differences.

As mentioned earlier in the description of the transmitter signal, current AM transmitters are able legally (although unlikely) to broadcast over a full 15kHz audio bandwidth, occupying a 30kHz r.f. bandwidth. If a receiver were designed to take full advantage of this and had a 30kHz received bandwidth, only transmitters much stronger than the adjacent channel transmitters (which are separated by only 10kHz) would provide a satisfactory signal. This is because the AGC developed by the strong transmitter r.f. signal strength reduces the receiver sensitivity to the adjacent and potentially interfering transmitters. However when the receiver is tuned to a weaker transmitter, or for an automobile receiver moving away from the transmitter, this situation will not necessarily exist and objectionable adjacent channel interference could occur. The use of protection ratios defining the permitted level of fieldstrength overlap between adjacent channels helps minimize interference problems and the fact that most of the radiated energy is within 10kHz of the carrier frequency enables receivers with severely limited bandwidths to be used. Even so, protection ratios apply only to groundwave signals or normal daytime broadcasting. At night, radio propagation at medium frequencies by skywave becomes a significant factor, multiplying the number of potentially interfering transmitters. Because of this, satisfactory daytime reception with a relatively wide receiver bandwidth may be totally unsatisfactory at night. Current AM receiver designs are dominated by restricted bandwidth I.F. amplifiers and antenna circuits (which also results in fewer components and more economic designs) but consideration of the ability to recieve a stereo broadcast should change this. Because of the day/night difference, it is likely that there will be a return to dual bandwidth receivers with a "Wide/Sharp" (or Fidelity-Normal!) front panel switch.

The actual bandwidths that are used will depend on the quality (and price) of the radio as well as what will be considered an acceptable level of performance. Referring back to the transmitter signal description, the need to provide comparable adjacent channel performance and keeping the spectrum within permitted limits means that the stereo signal will already be limited in terms of the audio bandwidth. A "Fidelity" position giving a bandwidth of ±6kHz to ±8kHz, decreasing to something less than ±3kHz in the "Normal" position is likely.

Before leaving the subject of the I.F. amplifier bandwidth, it is worth noting that limiting the bandwidth to something less than the transmitted signal bandwidth has a different effect on the (L−R) channel than on the (L + R) channel. When a single 5kHz tone is amplitude modulated on the carrier, this will produce two equal amplitude sidebands at 5kHz on either side of the carrier frequency. A ±6Hz bandwidth receiver will detect this with no problem and produce an undistorted 5kHz output. If this same tone is now considered to be an L = - R stereo signal which is phase modulating the carrier, the transmitted spectrum will include sidebands at 5kHz, 10kHz, 15kHz and 20kHz (See Table 1) if high modulation indices are being used. Now the ±6kHz bandwidth in the receiver will cause attenuation and complete loss of the higher frequency sidebands which will result in distortion of the detected 5kHz tone. This will occur only for large modulation indices - for low carrier phase deviations the transmitter spectrum will more closely resemble the AM case with a single set of significant sidebands. Since in an actual broadcast the total carrier modulation is a function of the prescence of a number of tones, any individual frequency is unlikely to have large amplitude higher sidebands. Even so, the receiver designer will have to be aware of the sources or potential for high distortion numbers and not necessarily attribute them to faults in transmission or decoding.

The actual I.F. amplifier bandwidth is not the only factor to be considered. Assymetry of the passband about the center frequency can also cause distortion and loss of separation. For example, separation loss because of mismatched (L + R) sidebands is shown in the curve of Figure 5. This mismatch can be caused by passband assymetry through a.g.c. action or mistuning.

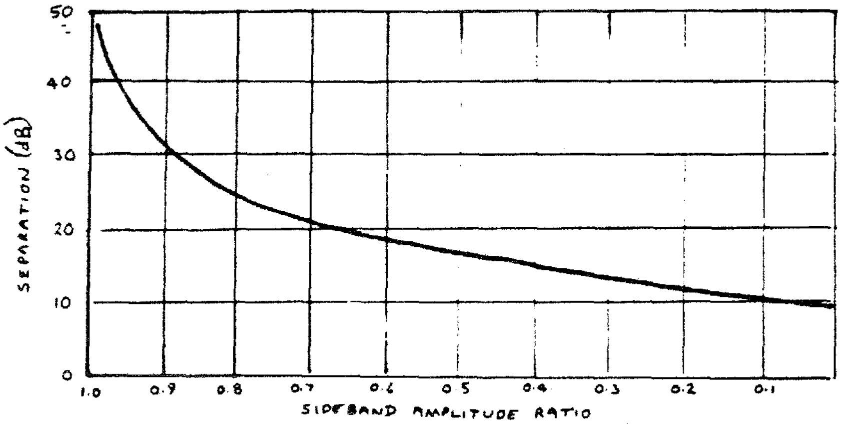



FIGURE 5. CALCULATED SEPARATION LOSS VS SIDEBAND AMPLITUDE IMBALANCE (L+R ONLY)

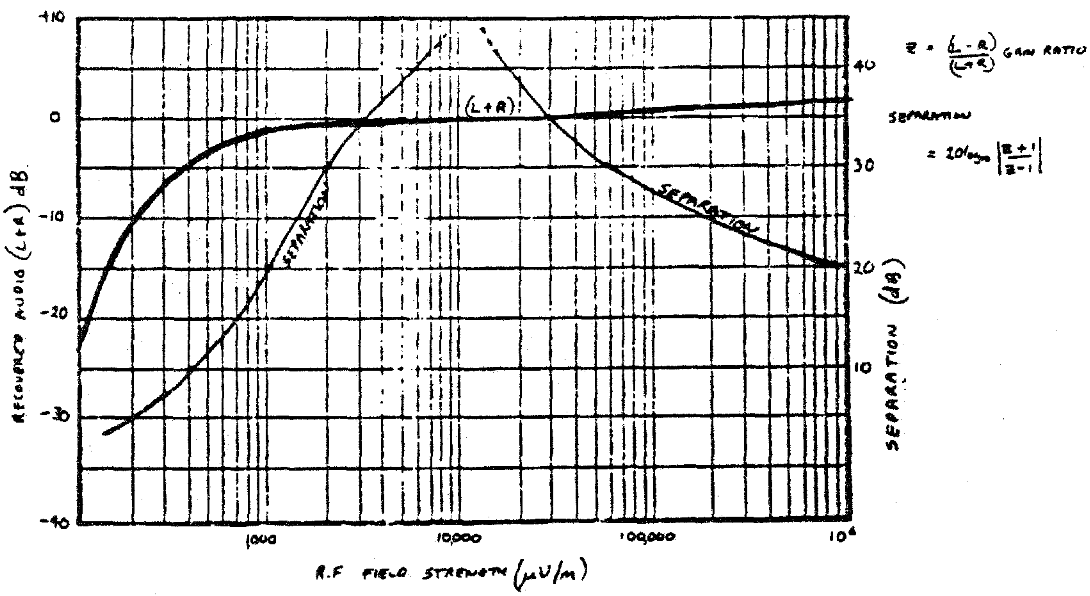



FIGURE 6. CALCULATED SEPARATION LOSS WITH (L+R) AMPLITUDE CHANGE (AGC CHARACTERISTIC) VS RF FIELD STRENGTH

d) A.G.C. Characteristics.

When the receiver is properly tuned the phase modulated (L - R) signal is detected after passing through a limiter stage to remove amplitude variations. The (L + R) signal is detected and the average detector level is used as an indication of the r.f. signal strength for A.G.C. purposes. Therefore the actual detected (L + R) level can be expected to vary depending on the mixer/i.f. amplifier a.g.c. characteristics. Comparable variations in detected level will not be occuring in the PM channel so that the signals (L - R) and (L + R) that are applied to the matrix will not have the correct amplitude ratios. The loss in separation is shown graphically in Figure 6. For example, if we wish to maintain the separation better than 20dB from an r.f. signal strength of 1000μV/m to 1V/m the (L + R) level must change less than 4dB. This implies an A.G.C. figure of merit better than 60dB. Using high a.g.c. F.O.M. is not always possible or desireable. An alternative is to control the output amplitude of the PM channel with a control voltage derived from the (L + R) detected output.

## The Decoder

Assuming that any deficiencies or distortions in the RF/IF stages are either eliminated or accounted for, we can move on the the new section of the receiver, the AM stereo decoder.

The I.F. amplifier output is first passed through a limiting amplifier to remove the amplitude modulation. Obviously this limiter needs sufficient gain to provide limiting in the presence of a 95% negative modulated I.F. carrier frequency and some method for handling the times when over modulation of the carrier will occur. If the limiter is capable of limiting on this and lower input signal levels, the limiter will also switch on noise inputs. If the r.f. carrier S/N ratio is less than 26dB then the phase channel input will be simply noise on large negative modulation swings. Normally, of course, the carrier/noise ratio will be better than 26dB for acceptable listening. For example a 20dB S/N with 30% AM is actually a carrier/noise ratio of 30dB. Nevertheless temporary carrier fading can mean that the PM channel is producing bursts of noise (maximum detected amplitude because of the random noise phase). Therefore the decision to remain in the stereo mode can depend in part on the average modulation depth and field strength of the received signal.

There are two basic ways to detect the signal on an angle modulated carrier. The first, possibly most direct way, is to use a phase locked loop as shown in Figure 7. For an FM signal the error voltage detected at the phase detector filter output is that necessary to keep the V.C.O. in precise phase lock with the incoming signal - i.e. the modulating signal. Hence the L.P.F. determines the detected audio signal bandwidth or the range of frequencies over which the V.C.O. can stay in exact phase with the incoming carrier. For a PM signal, if the V.C.O. is locked to the carrier frequency but stable (non-varying) in phase, then the output of the phase detector is proportional to the phase difference between the V.C.O. and the carrier - or the modulating signal. The L.P.F. must not pass any desired modulating frequency through to the V.C.O. While this technique is direct, it does present several problems of a practical nature.

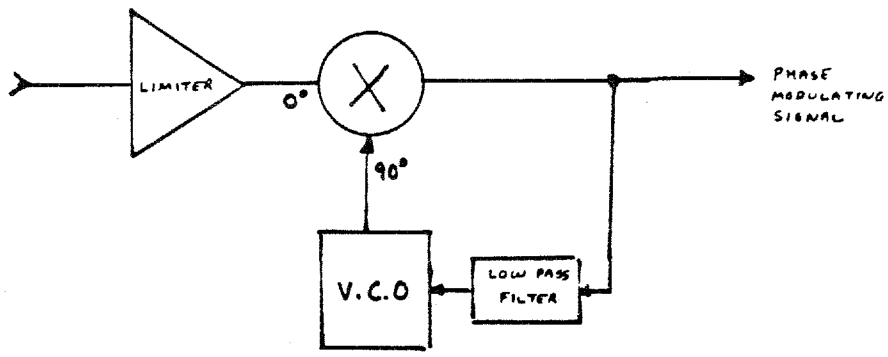



FIGURE 7 P.L.L DECODER

1) V.C.O. Radiation.

Since the V.C.O. must be operating at the intermediate frequency (455kHz or 262kHz), the radio front end must have good I.F. rejection and the V.C.O. itself have low radiation and coupling to the mixer or I.F. input.

2) Muting.

As the V.C.O. comes into lock during tuning to the transmitter frequency, the instantaneous frequency difference between the V.C.O. and the I.F. amplifier output can produce beat notes or a whistling tone that decreases in frequency as the V.C.O. approaches lock. This means that muting circuits are needed to prevent this tuning effect from being heard.

3) Stereo Identification Tone Detection.

The Magnavox AM stereo signal presents a particular problem in that the stereo identification tone is low frequency and has a much higher deviation than does the audio, 229° compared to 57° maximum. If the V.C.O. is stable in phase, then output signal inversion will occur at each 90° change in phase of the stereo identification tone. To avoid this the L.P.F. must pass some proportion of the 5Hz tone through to the V.C.O. in order to keep the multiplier detected phase difference less than 90°. As the detected 5Hz tone level is reduced by this technique, the low frequency pole in the main signal path goes higher, which will tend to reduce the low frequency stereo separation. However the acquisition time of the loop will be enhanced since the V.C.O. control voltage frequency response is improved. This latter point is probably more significant than loss of separation at low frequencies, particularly since long acquisition times are not very acceptable in consumer products. Thus a trade-off will occur between locking time, low frequency stereo separation and the 5Hz detected level unless more complex circuitry is resorted to.

The other, and more general method for detecting angle modulation is to apply the amplitude limited carrier to a differentiating network which will produce an envelope modulation proportional to the carrier instantaneous frequency. This envelope modulation can be amplitude detected (for FM) and then integrated to recover the original modulating information (for PM).

There are several possible ways to differentiate and detect the angle modulated carrier and the most popular (at the consumer level) have been either frequency domain or time domain types. Frequency domain differentiation is obtained by a linear network with a sloping magnitude response over the relevant band of frequencies. Resonant circuits tuned above or below the carrier frequency can be used, particularly when the frequency deviation is small compared to the carrier frequency, but these simple circuits are sensitive to incidental amplitude variations. (Actually the standard AM/IF amplifier tuned circuits are capable of slope detecting the angle modulation of the carrier if the carrier is tuned over to the passband skirts). In the time domain, the differentiation function is obtained by the time delay of a tuned circuit resonant at the carrier frequency. If the limited signal is applied to one input of a multiplier, then the tuned circuit will present a second delayed signal with amplitude

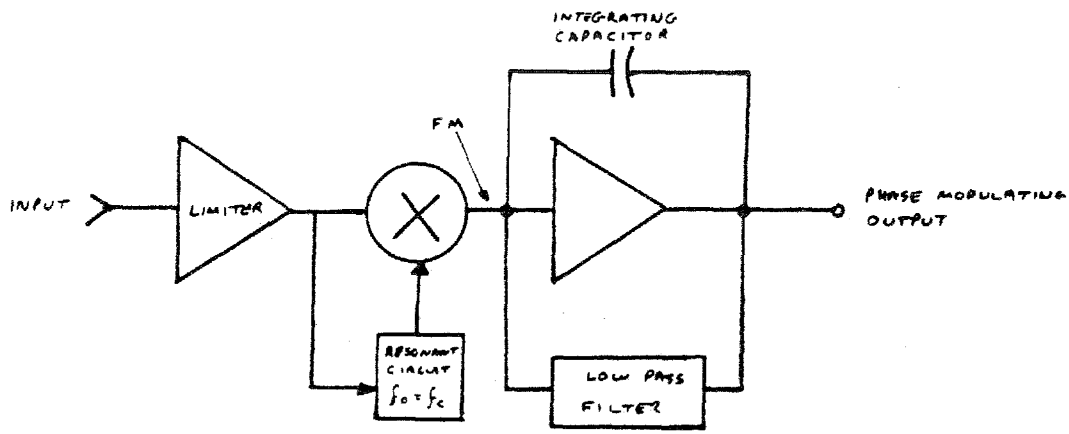



FIGURE 8 F.M DETECTOR AND INTEGRATOR FOR PM

and phase variations proportional to the carrier instantaneous frequency to the other input. This is the basis of the most popular I/C FM detectors such as the LM2111 and LM3089. Since this is a frequency modulation detection scheme, for recovering the PM stereo signal we simply integrate the detected output. Expressed mathematically we have

$$e(t) = E_o \sin(\omega_c t + m_p \sin\omega_m t) \quad (4)$$

Differentiating,
$$\frac{d}{dt}e(t) = K_1 \underbrace{(\omega_c + \omega_m m_p \cos\omega_m t)}_{\text{Envelope proportional to carrier instantaneous frequency}} \cos(\omega_c t + m_p \sin\omega_m t) \quad (8)$$

The detector recovers the envelope in Eq. (8) and the carrier frequency and higher harmonics are filtered or balanced out. Therefore, integrating the detected output yields the modulating signal.

$$e_m = \int K_1 K_2 \omega_m m_p \cos\omega_m t$$

$$= -K_1 K_2 m_p \sin\omega_m t \quad (9)$$

where $K_1 K_2$ are differentiation and detector conversion constants

Using conventional FM techniques to detect the PM signal offers several advantages. The detector technology is widely available, low cost and simple to adjust. Absence of a V.C.O. means that radiation problems are eliminated and there are no audible tuning transients. While the quad coil needs to be precisely tuned to the carrier frequency (IF), millions of FM receivers show that this is not difficult or unreliable.

In the case of the AM/PM stereo signal, the integrated output includes the 5Hz pilot identification tone which has four times the amplitude of the maximum audio signal - in essence the audio will be riding up and down at a 5Hz rate. This can simply be decoupled from the matrix or, as shown in Figure 8, a low pass filter back around the integrator reduces the amplitude to limit the dynamic swing requirement. After detection the PM signal path goes in two directions. First a 5Hz tone detector identifies the stereo signal and provides an input to the stereo/mono mode switch and a front panel stereo indicator light. Secondly the (L - R) signal is applied to the matrix along with the amplitude detected (L + R) signal. At this point several practical considerations need to be taken into account.

While the identification tone will indicate the presence of a stereo broadcast, its detection may not be a sufficient reason to switch to the stereo mode or to maintain this mode. For example a badly noise contaminated signal may be preferable in mono (when the PM channel is experiencing modulation depths producing outputs that are totally random noise). Since noise produces phase deviations greater than 57°, detection of excess phase may also be used to help determine the stereo/mono switching function. On the other hand, since detection of the low frequency pilot can take a significant time period, if temporary loss of pilot detection occurs it may not be desirable to promptly switch out of the stereo mode. Provision of a blend function will help, in that stereo to mono switching can be done gradually (and less perceptibly) as the r.f. input signal deteriorates.

As mentioned earlier, I.F. amplitude variations caused by the signal strength/a.g.c. performance of the receiver will mean that the matrix inputs will be incorrect since the (L - R) signal is unaffected by carrier signal amplitude changes. To compensate for this, rather than improve the a.g.c. characteristics, the decoder can include a variable gain amplifier controlled by the detected average level of the (L + R) signal. Now the level of the (L - R) signal can track the amplitude changes of the (L + R) ensuring proper decoding with no shift in stereo image. In passing, it is worth noting that having the ability to modulate the (L - R) detected level also means that correction signals can be applied - in order to properly decode a quadrature modulated signal as used in the Motorola system for example. A block diagram of the LM1981 incorporating these features is shown in Figure 9.

## Conclusion

AM stereo broadcasting, with the stereo information conveyed on an angle modulated carrier looks practical from a Transmitter and Receiver design viewpoint. However, to obtain full benefit of the stereo information being transmitted, redesign or modification of the AM receiver tront end is necessary - simply tracking on a decoder to a conventional AM/IF output is not likely to be satisfactory.

Some emphasis has been placed on describing the ability of the decoder to detect angle modulation. While the Magnavox system uses PM, other methods of encoding the stereo information, such as FM or quadrature, will require the same general building blocks. It seems reasonable, therefore, that the LM1981 I/C can be configured to decode most of the proposed AM stereo systems.

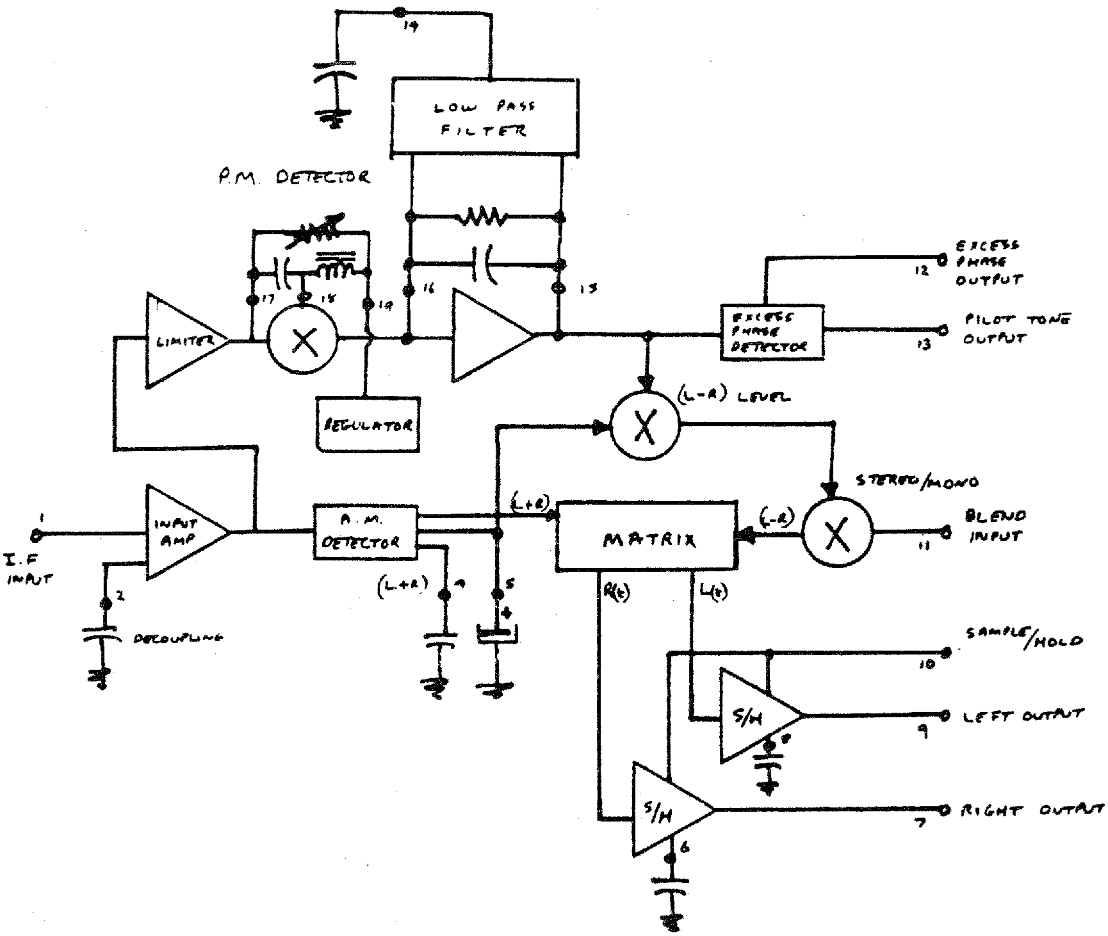



FIGURE 9. AM STEREO DECODER

# LM1981 AM STEREO DECODER

## Introduction

The LM1981 is an I/C designed to decode the stereo information that is amplitude and angle modulated on an AM Stereo broadcast carrier. It is capable of accepting the 455kHz (or 262kHz) I.F. amplifier output and amplitude detecting the (L + R) mono signal; limiting, detecting and conditioning the (L - R) stereo difference signal; and combining these signals in a suitable matrix to form the Left and Right channel audio outputs. Other features include an excess phase detector, stereo pilot tone output, stereo/mono blend function, output sample and hold circuits and an internal regulated reference voltage. This note describes the various functions of the LM1981, typical operating parameters, and details external component selection for a working AM stereo decoder. Preliminary ac/dc characteristics of the LM1981 are given in Table 3.

## LM1981 Circuit Description

The basic features of the LM1981 are shown in the block diagram of Figure 9, which includes typical external component values used when the signal format is the Magnavox AM/PM system.

Usually the signal input to the LM1981 will be extracted from the final AM/IF Amplifier tuned circuit. In this particular design example, the tank circuit impedance is required to be 15kΩ and the 455kHz carrier level is approximately 400mVrms when the r.f. signal strength is above the a.g.c. threshold. From Table 3 we see that the

# TABLE III

$V_{cc}$ = 8V, $V_{in}$ = 200mVrms, MODULATION DEPTH 45%

| PARAMETER | NOTES | | UNITS |
|---|---|---|---|
| SUPPLY CURRENT | $V_{cc}$ = 8V | 19 | mA |
| REFERENCE VOLTAGE | PIN 19 | 4.26 | Volts |
| REFERENCE CURRENT CAPABILITY | PIN 19 | ±1 | mA |
| MONAURAL GAIN | PIN 11 SHORTED TO Vcc<br>I/P 200mV @ 45% MOD | 200 | mV rms |
| MONAURAL DISTORTION | 45% MOD | 1 | % |
| STEREO SEPARATION LEFT | LEFT ONLY 45% MOD | 30 | dB |
| RIGHT | | 30 | dB |
| STEREO DISTORTION | 45% MOD | 1 | % |
| S/N RATIO | | 50 | dB |
| OUTPUT CURRENT CAPABILITY | PINS 7 AND 9 | ±1 | mA |
| INPUT IMPEDANCE | PIN 2 | 15 | kΩ |
| PILOT AMPLITUDE | PIN 13 | 28 | μA(p-p) |
| INPUT DYNAMIC RANGE | PIN 2 | +6, -20 | dB |
| EXCESS PHASE OUTPUT | PIN 12 | 100 | μA(p-p) |
| OPERATING SUPPLY VOLTAGE | | | |
| MAXIMUM | | 18 | Volts |
| MINIMUM | | 7.5 | Volts |

LM1981 input resistance is 15kΩ and the nominal input level is 200mVrms. The input stage is capable of handling signal levels +6dB greater or -20dB less than 200mVrms which will ensure proper stereo operation until the signal S/N ratio is too low to be satisfactory, as shown by Figure 10.

It is necessary for the I.F. amplifier final stage bandwidth to be relatively wide so that the I.F. bandwidth, which may be selectable, is determined by the previous stages. A suitable circuit with a take-off point for the LM1981 is shown in Figure 11, along with the equivalent circuit. If the I.F. amplifier output resistance ($R_O$) is 100kΩ, the tank will be damped by this and the parallel input resistance ($R'_{IN}$) presented by the input resistance of the LM1981 reflected across the tank. Since the tap ratio will be 2:1 to provide the proper signal level to the LM1981, the reflected resistance $R'_{IN}$ is given by

$$R'_{IN} = n^2 R_{IN} \quad \text{——(10)} \qquad \therefore R'_{IN} = 60K\Omega$$

$$\text{and} \qquad R_t = R'_{IN} \| R_o = \underline{37.5K\Omega}$$

If we set the tuned circuit bandwidth at 20kHz, the unloaded circuit Q is

$$Q_L = \frac{f_o}{\Delta f} = \frac{455 \times 10^3}{20 \times 10^3} = \underline{23}$$

Now the dynamic resistance ($R_D$) of the tuned circuit in parallel with $R_t$ must present a 15kΩ load to the I.F. amplifier output

$$\text{ie} \quad R_D \| R_t = 15K\Omega, \quad \therefore \underline{R_D = 25K\Omega}$$

Since $R_D$ also determines the unloaded Q of the tuned circuit

$$\frac{Q_L}{Q_u} = \frac{R_t}{R_t + R_D} \quad \text{——(11)} \qquad \therefore \underline{Q_u = 38.3}$$

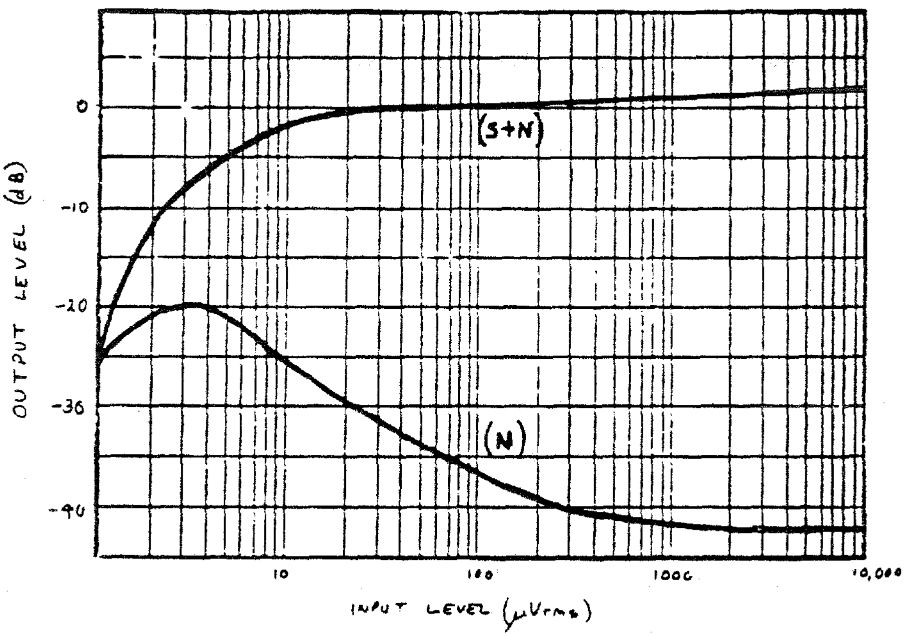



FIGURE 10 AM RADIO SIGNAL/NOISE PERFORMANCE

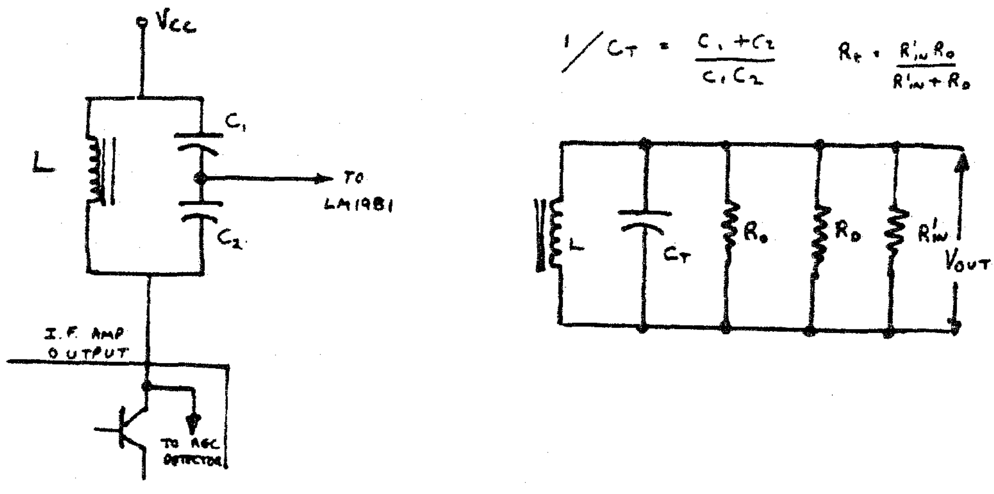



FIGURE 11 LM1981 INPUT CIRCUIT

For a parallel resonant circuit we have

$$L = \frac{R_o}{\omega Q_u} \qquad (12)$$

$$L = \frac{37.5 \times 10^3}{2\pi\, 455 \times 10^3 \times 38.3} = 228\mu H$$

The total capacitance necessary to tune this inductance to 455kHz is 536pF, so each capacitor is put at 1000pF.

Following the input stage, the signal is split up into two paths one to a limiter for the angle modulated information and the other to an envelope detector for the amplitude modulated information. This latter detector is a full wave rectifier shown in more detail in Figure 12. The balanced input will produce differential signal currents at the carrier frequency and the difference between these currents must be supplied by the emitters of $Q_5$. Therefore $Q_5$ collector current is proportional to the absolute magnitude of the carrier frequency. Filtering the carrier component at Pin 4 leaves the amplitude modulating information. Internally the resistance at Pin 4 is 2kΩ so that a 3900pF capacitor sets the -3dB bandwidth at 20kHz. The output level for 30% modulation (200mVrms I.F.) is 200mVrms.

Although the (L + R) monophonic signal is available at Pin 4, normally the signal for the audio amplifiers will be taken from the matrix which follows the detector. Also the detected output is heavily filtered at Pin 5 to provide a dc voltage proportional to the average value of the i.f. carrier. Because the absolute value detector will not peak detect on noise, this voltage is an accurate indication of the i.f. carrier level and is used to compensate the detected level of the (L - R) signal, which is insensitive to changes in the average carrier level caused by the a.g.c. not perfectly tracking the r.f. signal strength.

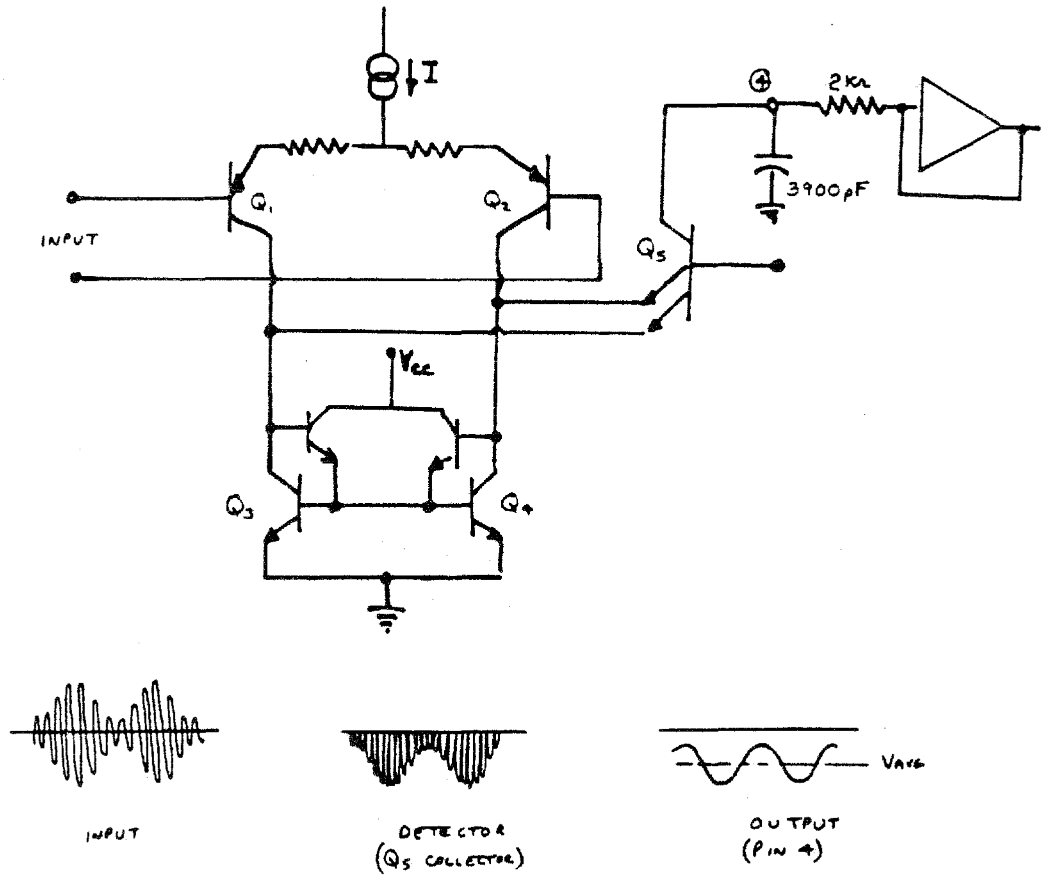



FIGURE 12(a) LM1981 AM DETECTOR

The internal load resistance at Pin 5 is 9kΩ so that a 10μF capacitor gives a 90mSec time constant.

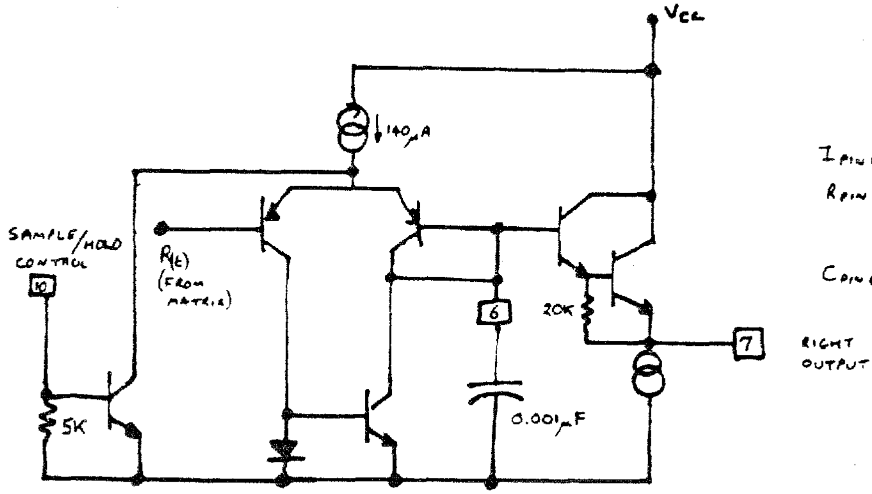
At the matrix the (L - R) signal is added to the (L + R) signal. The actual amplitude of the (L - R) signal will not only depend on the control voltage developed at Pin 5, but also on the voltage at the blend input, Pin 11. If Pin 11 is held above the internal reference voltage (4.26V on Pin 19) the (L - R) signal is completely muted and the Left and Right channel outputs will be (L + R) information only.

Both Left and Right channel outputs (Pins 9 and 7 respectively) are buffered with Sample/Hold circuits, Figure 12(b), which can be used to hold the signal level in the presence of a detected noise burst. If Pin 10 is left floating, the S/H circuits will pass the signal. Pulling Pin 10 to a $V_{BE}$ above ground holds the Pin 7 and 9 output levels. The capacitors for the S/H circuits are at Pins 6 and 8, and these capacitors will slew limit the audio signal. The charge/discharge current is 140μA so that for a 1V swing at 20kHz

$$C_{PIN\,6,8} \leq 0.0022\mu F$$

In the FM channel, the signal passes through 5 stages of limiting before being applied to the detector circuit. The limiter is stabilized with dc feedback decoupled at Pin 2. Although the carrier switching frequency is relatively low, the capacitor at Pin 2 is not large to enable it to track dynamic offset voltages in the limiter caused by the simultaneous large amplitude modulation of the carrier.

The signal is FM detected in a quadrature demodulator and then integrated as shown in Figure 13. The limited amplitude r.f. carrier

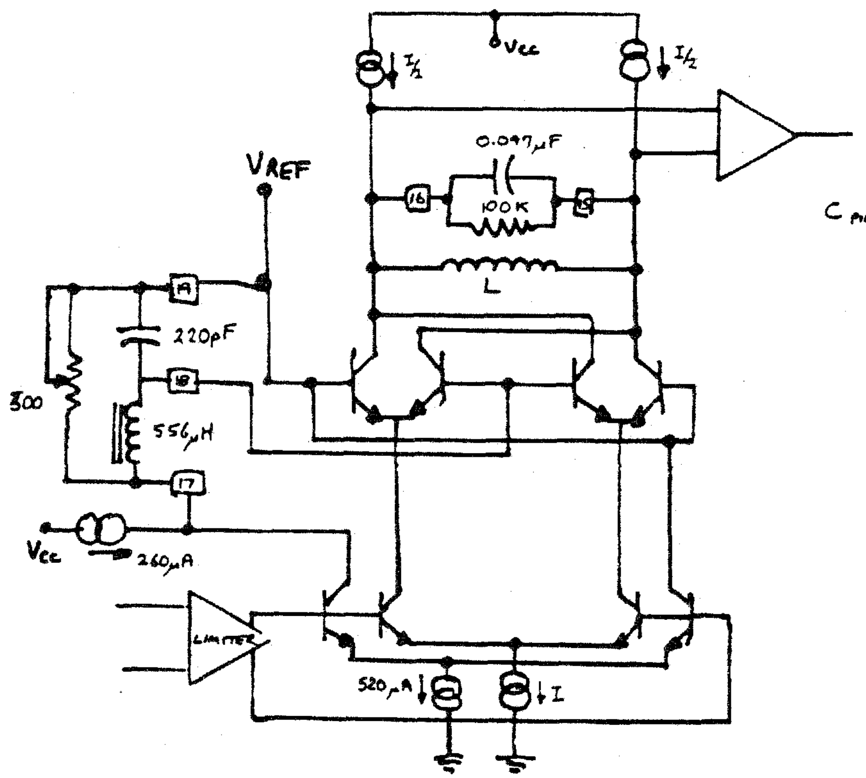



$$I_{PIN\,10} \simeq 1mA \quad (HOLD)$$

$$R_{PIN\,10} = \frac{V_{cc} - 0.7}{1 \times 10^{-3}} \, \Omega$$

$$C_{PIN\,6} \leq 0.002 \mu F$$

FIGURE 12(b) OUTPUT SAMPLE AND HOLD CIRCUIT




$$C_{PIN(15-19)} \leq 227 pF$$

$$L_{(17-18)} = \frac{1}{\omega^2 C_{(15-19)}}$$

$$\frac{Q_L}{Q_u} = \frac{R_0}{R + R_0}$$

FIGURE 13 P.M DETECTOR CIRCUIT

signal switches one set of balanced input ports to the multiplier, while the other ports are receiving the signal after it passes through a resonant circuit tuned to the carrier frequency. A series resonant circuit is used, driven from a current source in order to minimize radiation at the carrier frequency. Since this available signal current is typically 130μA (peak), the capacitor is chosen to ensure switching amplitude (about $400mV_{(p-p)}$) at the multiplier inputs.

$$|\omega C| \geqslant \frac{260 \times 10^{-6}}{400 \times 10^{-3}} \geqslant 0.65 \times 10^{-3}$$

$$\therefore C \leqslant 227\,pF$$

Choosing C to be 220pF gives the inductor nominal value as

$$L = \frac{1}{(2\pi \times 455 \times 10^{3})^{2}\, 220 \times 10^{-12}} = \underline{556\mu H}$$

Although both sets of input ports to the multiplier are switched, the conversion gain can change since the multiplier operating currents are internally set. In order to avoid different levels of (L - R) from part to part we need to provide some external means for adjusting the detector conversion gain. This is most conveniently done by a potentiometer connected across the tuned circuit which will dominate the circuit Q if the inductor series resistance ($R_o$) is low. With a coil $Q_u$ of 110, $R_D$ = 14.5Ω at 455kHz. If we choose a tuned circuit bandwidth of ±30kHz then the loaded Q will be 7.5. For a series tuned circuit with a shunt resistance R we have

$$\frac{Q_L}{Q_u} = \frac{R_D}{R + R_D} \qquad (13)$$

and the potentiometer resistance will be approximately 193Ω. Now that suitable components have been chosen for the resonant circuit that yield a gain adjustment and the proper bandwidth, it becomes possible to select the integrating capacitor that gives the nominal (L - R) detected level necessary for best separation. With a 500Ω pot set to 200Ω the capacitor value is 0.047μF.

Also connected across the multiplier output is an active inductor which serves a two-fold purpose. First, it places a dc short across the multiplier outputs preventing offset voltages exceeding the dynamic range of the next stage. These offsets can occur because of mismatching in the multiplier active devices but, more importantly, as the tank circuit is tuned for resonance (or the input signal is mistuned) dc terms are present in the multiplier output which must be cancelled if the output linear operating range is not to be exceeded. Secondly the inductor is tuned with the integrating capacitor to produce a low frequency pole in the output. Since we would like some means for detecting excess phase signals for noise suppression purposes, the detected stereo identification tone peak voltage must be reduced below the peak audio voltage (remember, in the Magnavox system, the detected audio is riding up and down on a 5Hz waveform that is 4 times the peak audio amplitude). This is done by choosing the pole frequency to be around 30Hz. The capacitor has already been determined as 0.047μF, so a 30Hz pole requires that the inductor be almost 600H!! Hence an active inductor is used.

Two operational transconductance amplifiers (OTA's) are used to realize the simulated inductor, Figure 14. The actual inductance value is proportional to the size of the capacitor at Pin 14 such that

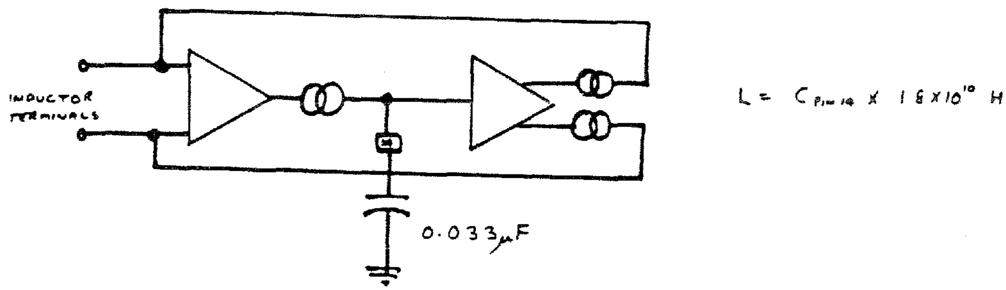



FIGURE 14 SIMULATED INDUCTOR FROM TWO O.T.A's

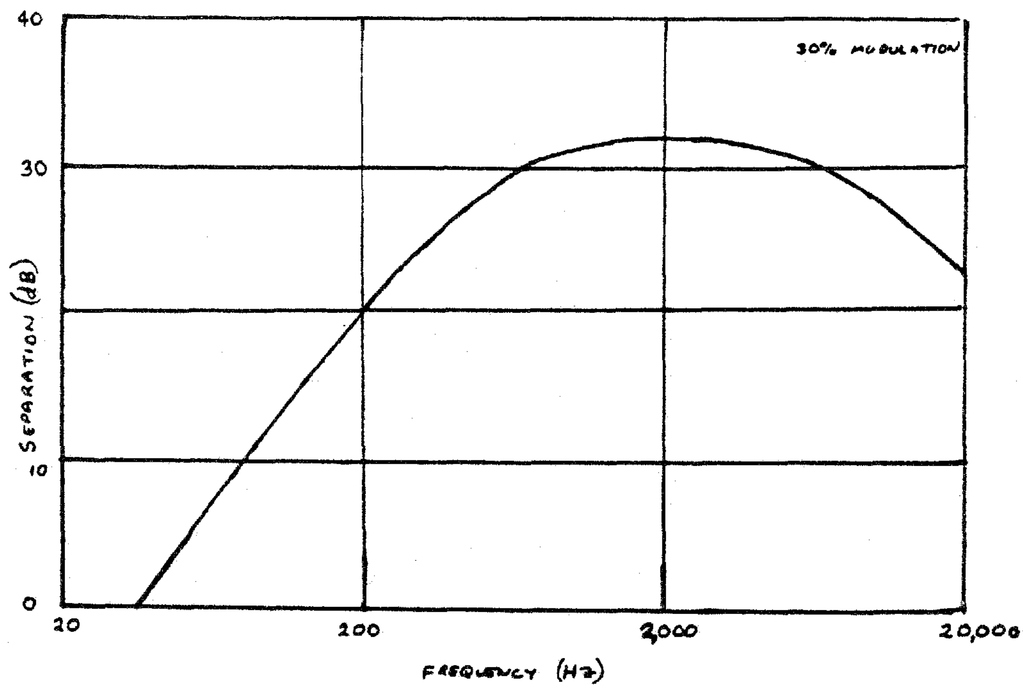



FIGURE 15 SEPARATION VS FREQUENCY

$$L\ (\text{HENRIES}) \simeq C k \quad (14)$$

$k = 1.8 \times 10^{10}$ H/µF

C in µF

For 600H, we need a 0.033µf capacitor. A 100kΩ resistor is shunted across Pins 15 and 16 to prevent peaking in the low pass filter.

Alignment of the detector (in fact the entire alignment for the decoder) is straightforward. The blend input is shorted to ground and the coil is tuned for resonance at 455kHz by adjustment until the voltage on the capacitor at Pin 14 matches the reference voltage at Pin 19. Because the charge current for the capacitor is only 1µA, this point is easily loaded and the best way to connect a DVM is <u>between</u> Pins 14 and 19 rather than from Pin 14 to ground. Next, with Left only or Right only information modulating the carrier, the potentiometer between Pins 17 and 19 is adjusted for maximum separation. For example, with Right only signals, the potentiometer is set to minimize the Left output signal at Pin 9. At 1kHz, 30% PM the Left signal level should be -30dB down, Figure 15.

The detected (L - R) signal is connected internally to the matrix through a variable gain block controlled by the average level of the I.F. carrier - the voltage developed at Pin 5. By this means the separation adjustment carried out above will not be impaired by the a.g.c. characteristics of the receiver. A second gain control is placed between the (L - R) signal and the matrix. This gain block is controlled by the mute/blend input at Pin 11 and enables stereo/mono switching or a gradual blend from stereo to mono as the r.f. signal deteriorates. The control amplifier is equivalent to a differential pair biassed at $V_{REF}$ with 5kΩ

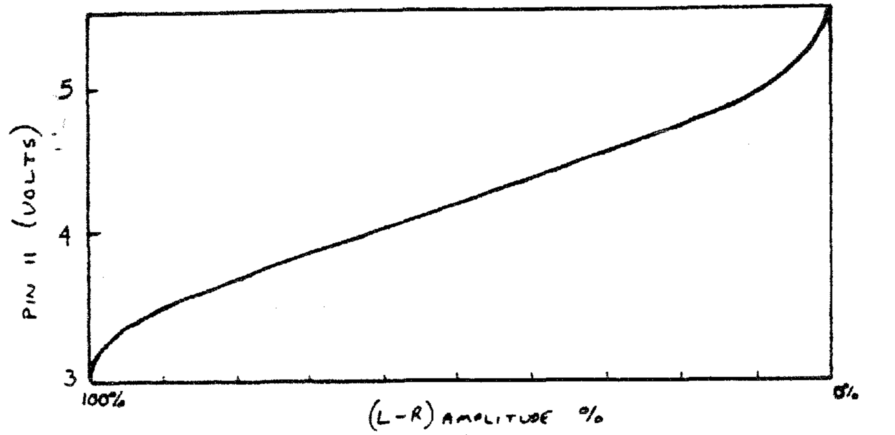



FIGURE 16 STEREO/MONO BLEND CONTROL CHARACTERISTIC

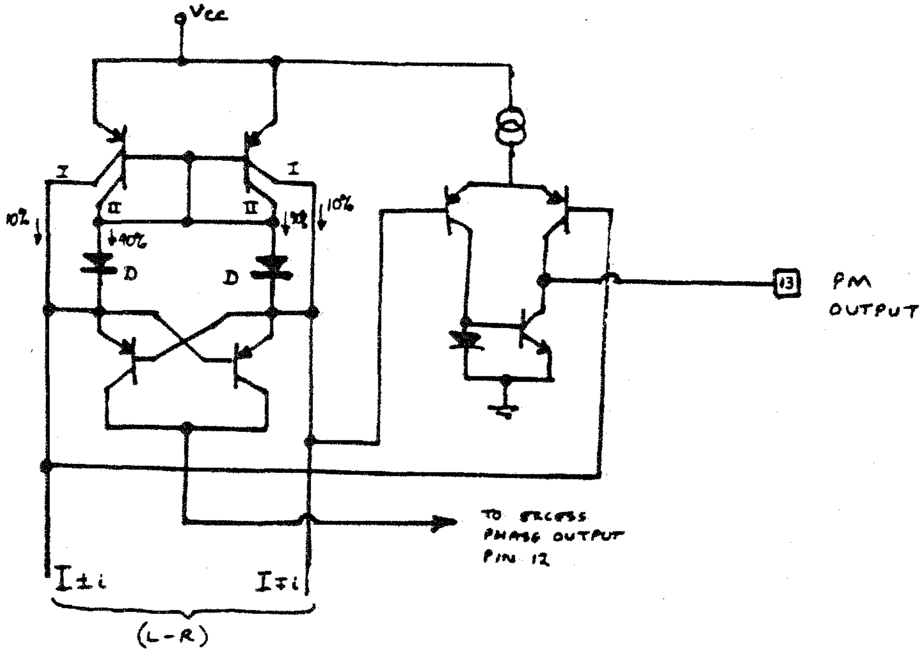



FIGURE 17 EXCESS PHASE DETECTOR

between the bases and a series 50kΩ to Pin 11. For a 100mV differential across the pair

$$V_{PIN 11} \gtrless V_{REF} \pm 100 \times 10^{3} \times \left(\frac{50+5}{5}\right)$$

$$= V_{REF} \pm 1.1 \text{ Volts}$$

A control curve is shown in Figure 16 and above 5.36V the decoder will be in the mono mode; below 3.16V the decoder will be in the stereo mode.

The last part of the decoder to be described is the PM output and excess phase detector, Figure 17. A buffered differential (L - R) signal current from the PM integrating capacitor is supplied to this circuit which has a dc to ac ratio such that each degree of detected phase deviation causes a 1.2% change in the current drawn from each side of the detector. For each side, with no signal, 10% of the total current is supplied by collector I of the upper PNP device. The remaining 90% is supplied by collector II through a diode D. When a signal is present, as the peak phase deviation increases, one side will draw more current and one side correspondingly less. The differential current component is buffered to Pin 13 to provide an output for the stereo identification tone detector. A 30% modulated audio signal will cause Pin 13 to sink and source 54µA and the stereo identification tone, reduced in level by the PM detector low pass filter, produces 14µA peak.

When the peak phase deviation exceeds 75° this indicates that noise must be present and the peak current drawn in one side is less than 10% of the quiescent value. Collector II will be transferring all its current to the other side (which will be drawing greater than 190% of the quiescent

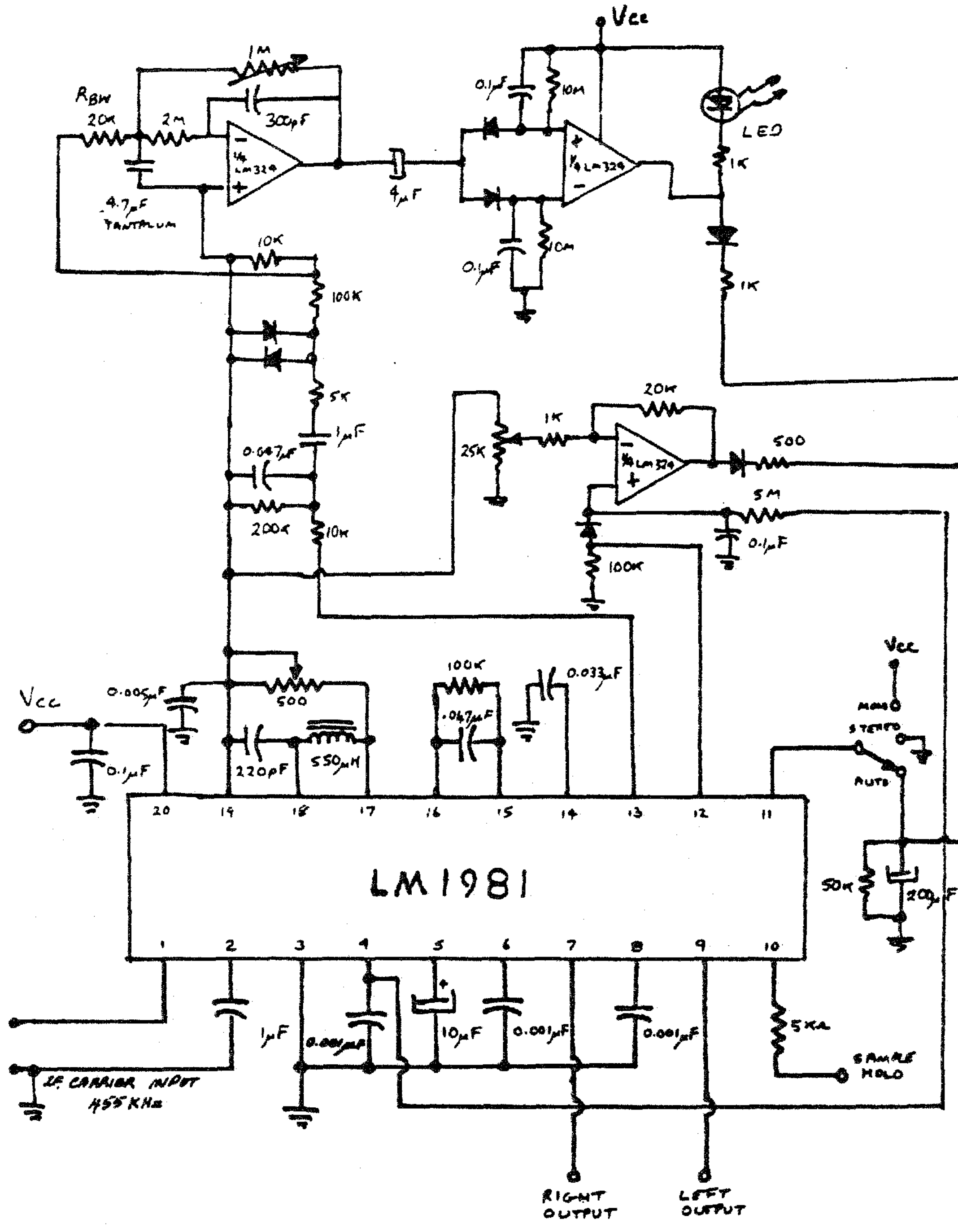



FIGURE 18 MAGNAVOX SYSTEM DECODER WITH 5H2 DETECTOR

current) and the diode for collector II will cut off. The difference between the current demanded, and that delivered by collector I is coupled over to Pin 12 which then provides an excess phase indication.

A complete Magnavox system decoder is shown in Figure 18, including a suggested stereo tone detector. This consists of a 5Hz filter followed by a full-wave rectifier connected to the stereo/mono blend input Pin 11. The excess phase output is filtered and applied to Pin 11, as is a filtered voltage from the absolute value detector. Excess phase outputs will force Pin 11 above $V_{REF}$, giving automatic switching into mono in the presence of noise in the PM channel. Similarly a weak r.f. signal will cause switching into mono. As the r.f. signal improves, the dc level at Pin 4 will go below $V_{REF}$ enabling the stereo mode if a stereo tone is simultaneously present.

Decoding other AM Stereo Systems

This note has described the Mangavox AM/PM system in some detail in order to show the system requirements for adding stereo information to the present monophonic AM broadcast signal. Alternative compatible AM stereo systems have been proposed by Motorola, Belar, Harris and Kahn. Since all these alternate proposals depend on some form of angle modulation of the r.f. carrier to convey the additional information, the LM1981 can be used as a decoder. The following is not intended as a complete description of such decoders, or to imply that a universal decoder is practical, but more as a suggestion for the circuit modifications that will be necessary if the AM stereo test signal source is other than the Magnavox AM/PM signal.

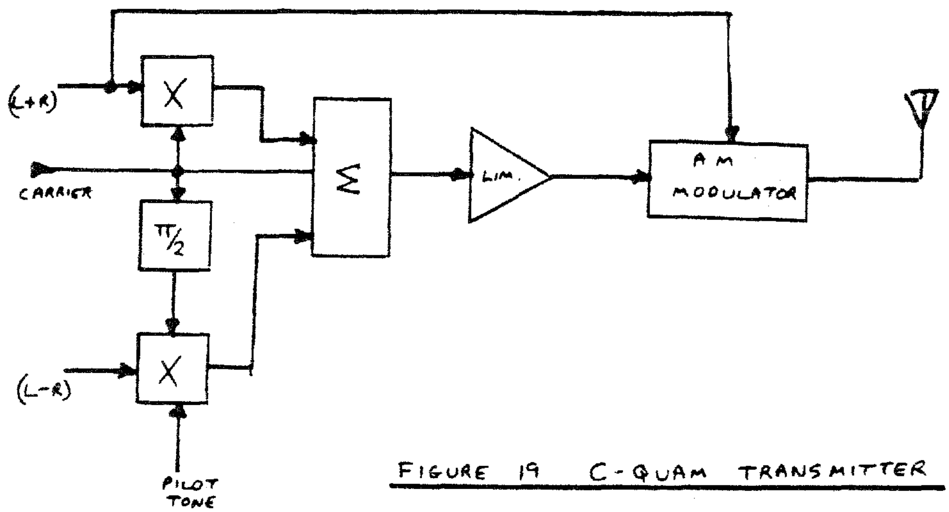



FIGURE 19 C-QUAM TRANSMITTER

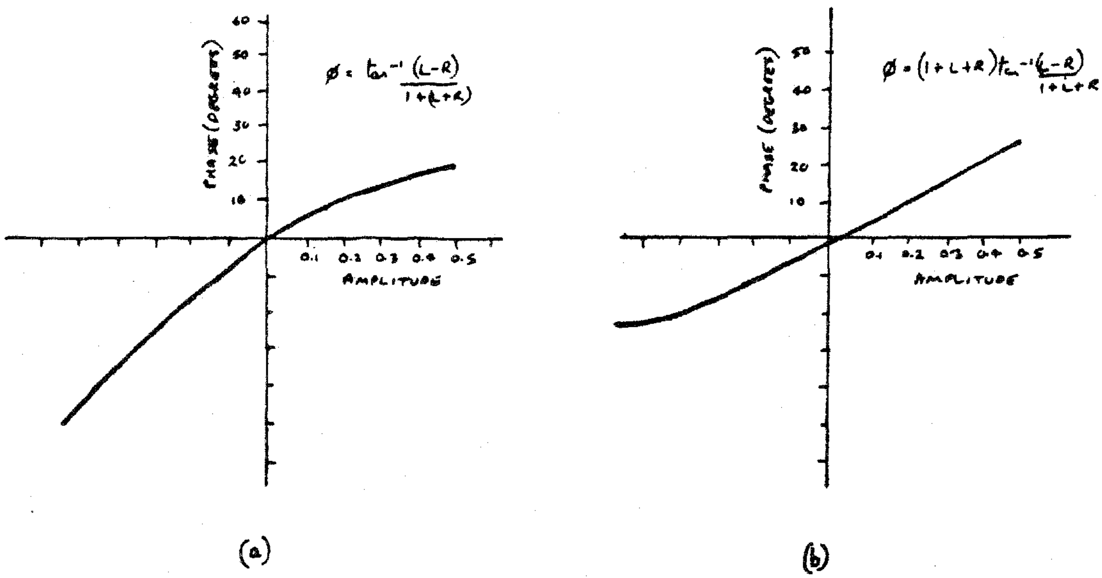



FIGURE 20. DETECTOR TRANSFER FUNCTIONS

Motorola C-QUAM

This system for compatible AM stereo uses a technique similar to that employed in color television for the simultaneous transmission of two independent color signals on the same color subcarrier. The (L - R) and (L + R) signal components are quadrature modulated onto the r.f. carrier as shown in the block diagram of Figure 19. After limiting to retain only the phase variations, the carrier is amplitude modulated with the monophonic (L + R) signal. A stereo identification tone of 25Hz is included with the (L - R) modulating signal. The equation of the C-QUAM carrier is

$$e_c = E_o\left[1 + m\cos\omega_m t\right]\cos\left[\omega_c t + \tan^{-1}\left(\frac{m\cos\omega_s t + 0.05\sin 50\pi t}{1 + m\cos\omega_m t}\right)\right] \quad (15)$$

Notice the similarity between Equation (15) and Equation (6) with the exception of the carrier phase modulating term. Ignoring the pilot term we have

For Magnavox $\theta = m\cos\omega_s t$ — (16)

For Motorola $\theta = \tan^{-1}\dfrac{m\cos\omega_s t}{(1 + m\cos\omega_m t)}$ — (17)

Therefore, if we use the decoder of Figure 18, for a Left only or Right only signal the detector transfer function would be similar to Figure 20(a) and the (L - R) audio signal would be distorted if the signal source is the Motorola system. Now consider the function

$$\theta' = (1 + m\cos\omega_m t)\tan^{-1}\frac{m\cos\omega_s t}{(1 + m\cos\omega_m t)} \quad (18)$$

The transfer function changes to that of Figure 20(b) which is much more linear, at least up to 50% modulation. Above 50% modulation the distortion, predominantly second harmonic, begins to increase. Recalling that extremely high stereo modulation depths are unlikely to be encountered in practice, if we modify the detected PM function of the LM1981 with a $(1 + M \cos \omega_{mt})$ term, then this decoder will do a reasonable job of detecting a Motorola compatible AM stereo signal. Since $(1 + M \cos \omega_{mt})$ is the amplitude modulation signal (L + R), our correction term is already available at Pin 4 of the I/C. Instead of adjusting the (L - R) detected level in response to the average carrier level, we can remove the filter from Pin 5 allowing the (L - R) level to change with the amplitude modulation. Practical experiments with this circuit have shown that the distortion level can be reduced if the correction term is actually $(1.14 + M \cos \omega_{mt})$. This modification is implemented by decreasing the a-c term as shown in Figure 21. Re-adjustment of the potentiometer across Pins 17 and 19 restores the stereo separation.

BELAR AM-FM

The Belar system uses the same (L + R) and (L - R) signal components but with the (L - R) signal frequency modulating the carrier. A maximum frequency deviation of ±1.25kHz and a pre-emphasis time constant of 100μS ($f_o$ = 1.6kHz) are the significant parameters that need to be considered for the decoder modification. The Belar carrier equation is

$$e_c = E_o \left[ 1 + m \cos \omega_m t \right] \cos \left[ \omega_c t + \frac{1250}{f_s} \sqrt{1 + \left(\frac{f_s}{f_o}\right)^2} \times m \sin \left( \omega_s t + \tan^{-1} \frac{f_s}{f_o} \right) \right]$$

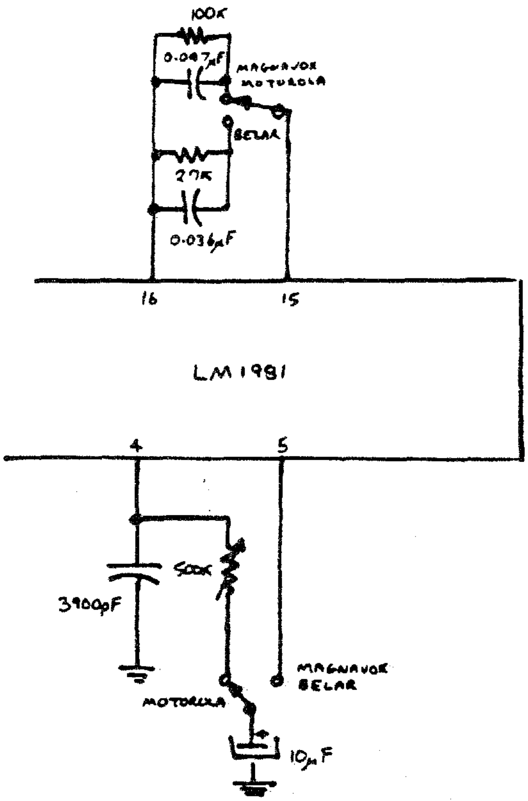


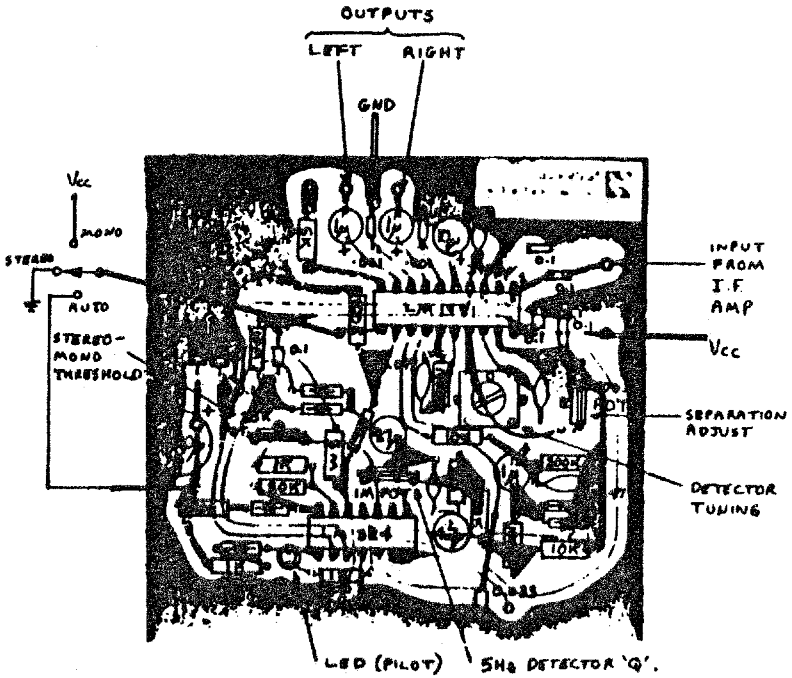

FIGURE 21 DECODER MODIFICATIONS FOR MOTOROLA/BELAR SYSTEMS

For this signal, the LM1981 will operate as a conventional FM demodulator with de-emphasis above 1.6kHz as shown in Figure 21. The detected signal level with this modulation method is reduced (compared to the Magnavox system) by the factor

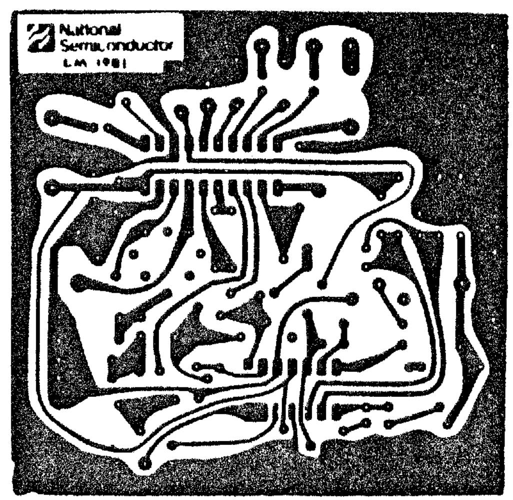
$$\frac{1250}{f_s}\sqrt{1+\left(\frac{f_s}{f_o}\right)^2} = 0.75 \; @ \; 1.6\text{KHz}$$

To compensate for this the capacitor between Pins 15 and 16 is reduced to 3600pF, thus determining the resistor value as 27kΩ for a 1.6kHz corner frequency.

A complete decoder p.c.b. for the Magnavox system, based on the circuit of Figure 18 is shown in Figure 22 along with a component stuffing guide. Set-up is straightforward, following the procedure outlined earlier. Time constraints have prevented a full evaluation of the board modified for the Motorola system and the development of the detector for the Motorola pilot tone. Operation of the I/C with the other AM stereo systems appears feasible but time and the lack of appropriate encoders has prevented practical implementation at present.




COMPONENT SIDE




COPPER SIDE

FIGURE 22 MAGNAVOX DECODER P.C.B.

# LM1866N APPLICATION CIRCUITS

## DESCRIPTION

LM1866N is a single chip AM/FM receiver designed for high quality receiver applications. It has excellent characteristics in the basic AM/FM performance. Moreover, it also has the features that are essential for building high end consumer products ranging from the low voltage portable radio to HI-FI sound equipment. The key features are:

(1) Matched level AM/FM signal strength meter.
(2) FM centre tuned meter.
(3) Biased AFC output voltage for excellent controlling linearity.
(4) Deviation and noise operated audio muting.
(5) 3V—15V operation with excellent power supply ripple rejection.

Six application circuits are presented in this booklet. They are the options for various combinations of cost and performance. The circuit using 4 can coils + 2 ceramic filters is treated as the standard circuit and the others are its alternatives. Brief descriptions are given on each circuit to point out the major differences between the standard and the selected circuit. Customer can easily select the most suitable one for their products.

- STANDARD AM/FM RADIO — 4 CAN COILS + 2 CERAMIC FILTERS
- AM/FM RADIO — 3 CAN COILS + 2 CERAMIC FILTERS + 1 CERAMIC DISCRIMINATOR
- AM/FM RADIO — 5 CAN COILS + 2 CERAMIC FILTERS
- AM/FM RADIO — 6 CAN COILS
- LM/MW/SW/FM MULTI-BAND RADIO
- AM/FM/STEREO RADIO

**Prepared by**
**K.H. Chiu**
**Linear Applications Engineering — CTSC**

# STANDARD AM/FM RADIO
# (4 Can Coils + 2 Ceramic Filters)

The circuit using 4 can coils and 2 ceramic filters as IF selective elements is considered as the standard AM/FM radio application for LM1866N. It offers the overall performance that matches the currently available high quality radios with great improvement in circuit simplicity.

Considering the cost, performance and ever precious space encountered in a design, this single chip circuit definitely meets the wide variety of radio applications ranging from the portables to the HI-FI sets.

FREQUENCY COVERAGE

| | |
|---|---|
| * FM | 88 MHz — 108 MHz |
| * AM | 525 KHz — 1650 KHz |

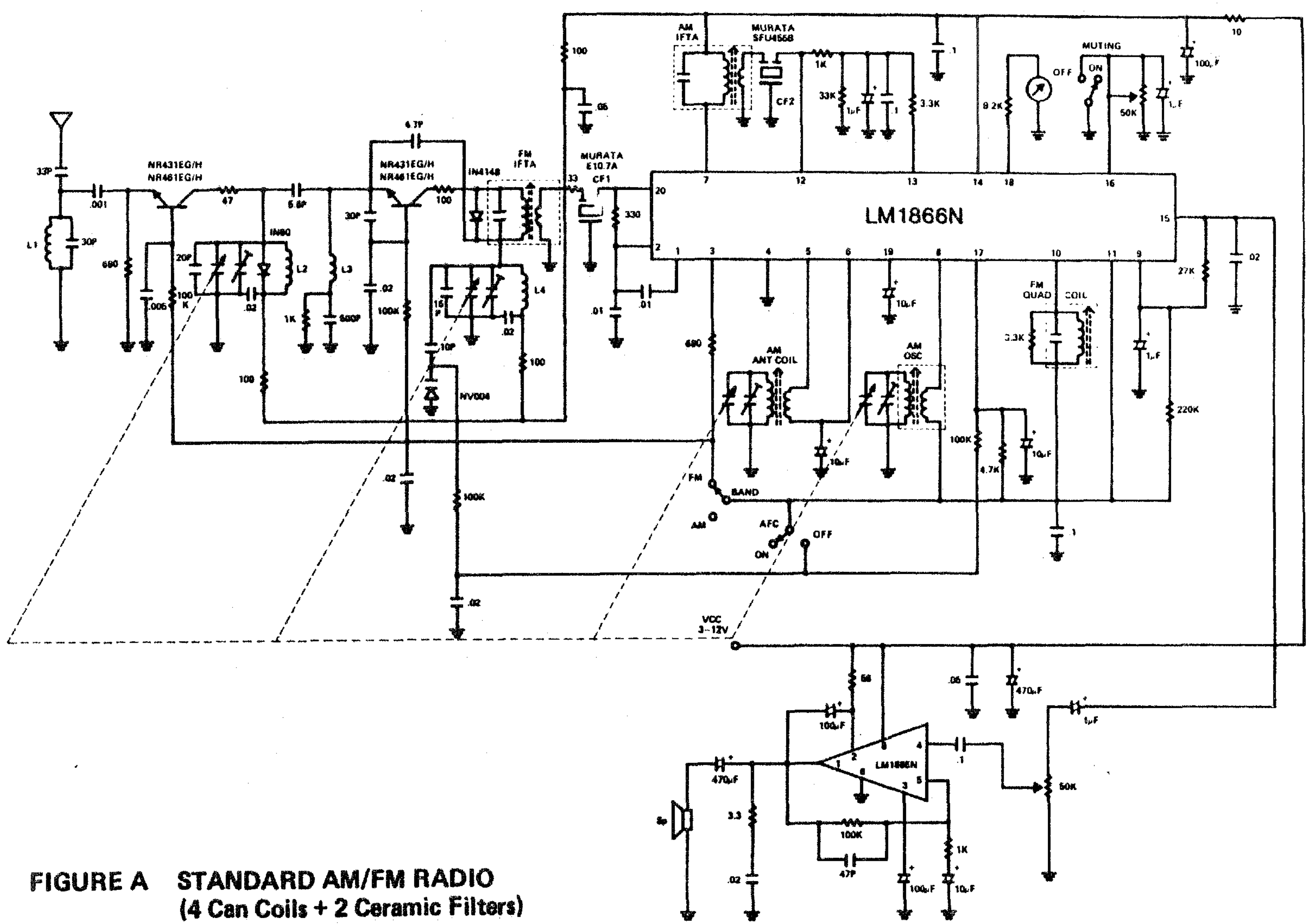



**FIGURE A STANDARD AM/FM RADIO**
**(4 Can Coils + 2 Ceramic Filters)**

PERFORMANCE

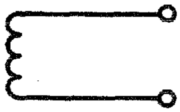
| AM V+ = 6V, RL = 8Ω, Ref Output = 50mW, Mod = 30%, otherwise specified | | |
|---|---|---|
| **PARAMETERS** | **VALUE** | **UNITS** |
| Max Sens and S+N/N at Max Sens at 600 KHz | 60/7.5 | μV/M/dB |
| 1000 KHz | 70/7.5 | μV/M/dB |
| 1400 KHz | 55/6 | μV/M/dB |
| 20dB Quieting Sens at 600 KHz | 320 | μV/M |
| 1000 KHz | 310 | μV/M |
| 1400 KHz | 300 | μV/M |
| IF Rejection at 600 KHz | >70 | dB |
| Image Rejection at 1400 KHz | 48 | dB |
| A.C.A. ± 10 KHz | 31/27 | dB |
| —6dB/—40dB Bandwidth at Max Sens | 8/31 | KHz |
| AGC Figure of Merit at 100mV/M | 55 | dB |
| Overload Distortion at 100mV/M 80% Mod | 1.8 | % |
| Tweet Modulation at Worst Case | 5 | % |
| Overall Distortion at 5mV/M | 1.3 | % |
| FM V+ = 6V, RL = 8Ω, Ref Output = 50mW, Dev = 22.5 KHz, otherwise specified | | |
| Max Sens at 88 MHz | 1.6 | μV |
| 98 MHz | 1.2 | μV |
| 108 MHz | 1.3 | μV |
| 30dB Quieting Sens and —3dB Limiting Sens at 88 MHz | 5.6/4 | μV |
| 98 MHz | 5/3.8 | μV |
| 108 MHz | 5.4/4 | μV |
| IF Rejection at 88 MHz | 68 | dB |
| Image Rejection at 108 MHz | 28 | dB |
| —6dB Bandwidth at Max Sens | 150 | KHz |
| App. Peak Separation at Max Sens/1100μV | 190/590 | KHz |
| Deviation Sens at 1100μV, Ref Output | 3.5 | KHz |
| Max Deviation Handling at 1100μV, 10% THD | 180 | KHz |
| THD at 1100μV, 22.5 KHz/75 KHz Deviation | 0.32/0.65 | % |
| AM Rejection at 110/1100μV | 50/40 | dB |
| Overload Capacity at 10% THD | >500 | mV |
| S+N/N Ratio at 1100μV | 65 | dB |
| Deviation mute at 110/1100μV | ±70/±70 | KHz |
| AFC Holding Range at 110/1100μV | 850/890 | KHz |
| AUDIO V+ = 6V, RL = 8Ω, Ref Output = 50mW, otherwise specified | | |
| Audio Sens at Ref Output | 6.5 | mV |
| Overall Distortion at Ref Output | 0.1 | % |
| 10% THD Output power at 6V/9V | 0.6/1.3 | W |

## COIL DATA

### L1 and L2 (FM ANT and RF COIL)

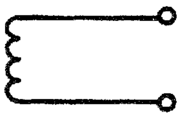
SWG # 20
N = 3½T    Inner Diameter = 4.5 mm

### L3 (IF TRAP COIL)



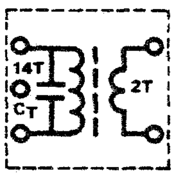
L = 0.47 μH    Qu = 70 at *f* = 10.7 MHz
N = 18T    Inner Diameter = 3.0 mm

### L4 (FM OSC COIL)



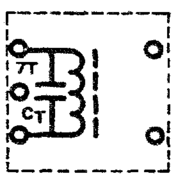
SWG # 20
N = 2½T    Inner Diameter = 4.5 mm

### FM IFT A



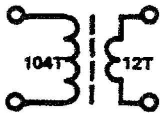

F = 10.7 MHz    Qu = 100 ± 15%    $C_T$ = 47 pF
Part No. 10F—147—F1 (Jackson Electric HK Ltd) or Equivalent

### FM QUAD COIL



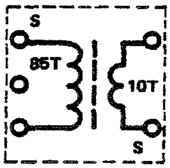

F = 10.7 MHz    Qu = 60 ± 15%    $C_T$ = 300 pF
Part No. 10BC—042 (Jackson Electric HK Ltd) or Equivalent

### AM ANT COIL



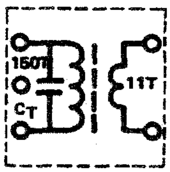

L = 650 μH Qu = 200 at 796 KHz
Part No. LAM—650 (Apollo Elec Corp) or Equivalent
Bar Length = 100 mm

### AM OSC COIL




L = 260 μH Qu = 120 ± 15% at *f* = 796 KHz
Part No. 10MO—019 (Jackson Electric HK Ltd) or Equivalent

### AM IFT A



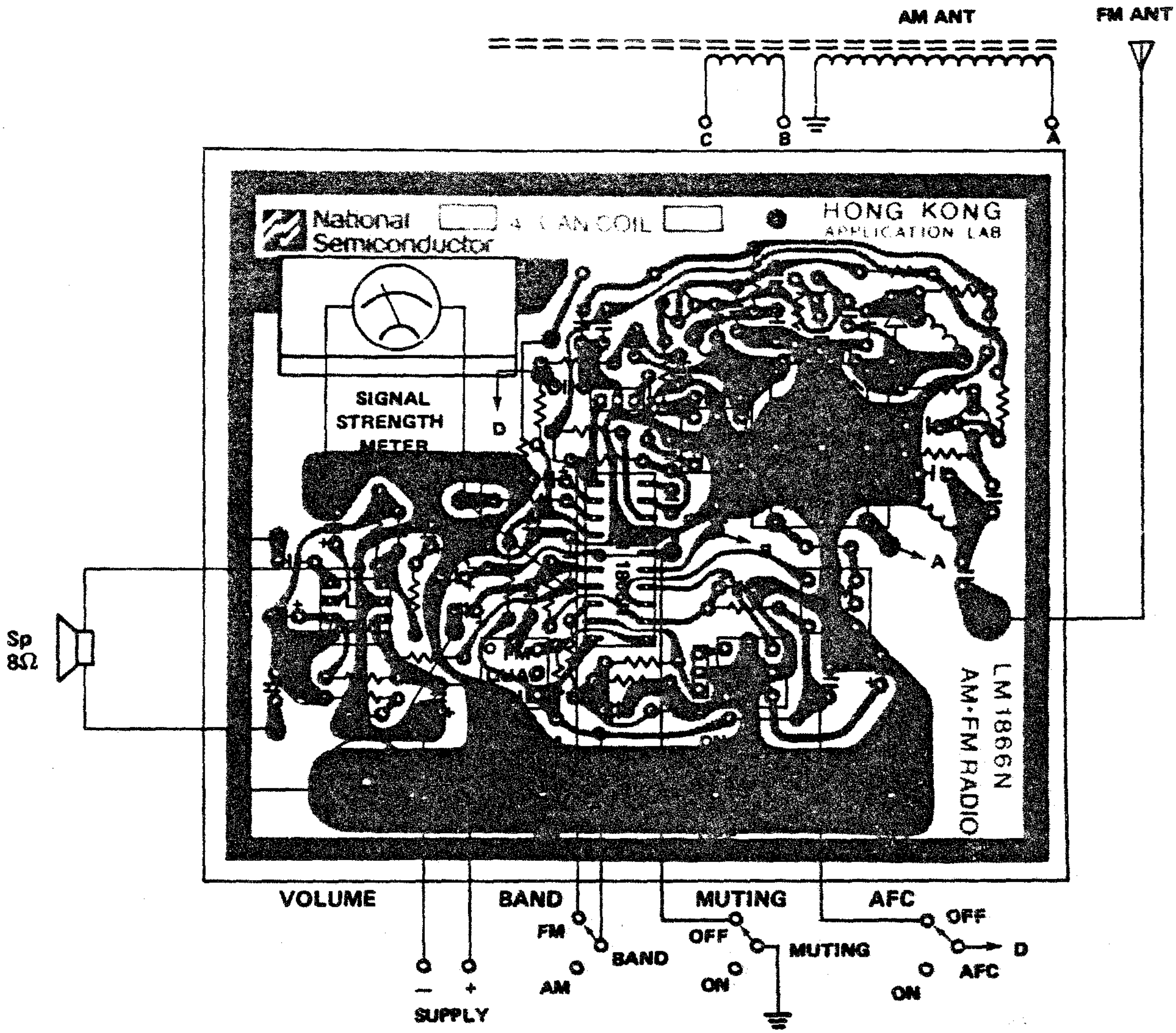

F = 455 KHz Qu = 110 ± 15% $C_T$ = 180 pF
Part No. 10A—040 (Jackson Electric HK Ltd) or Equivalent

### CERAMIC FILTERS

| | |
|---|---|
| CF1 | SFE 10.7 MA5 (Murata Company Ltd) or Equivalent |
| CF2 | SFU 455B (Murata Company Ltd) or Equivalent |

### VARIABLE CAPACITOR

| | | | | |
|---|---|---|---|---|
| Type | : | QT—22124 (Toko Incorp) or Equivalent | | |
| Capacitance | : | AM ANT | : | 4 pF — 142 pF |
| | | AM OSC | : | 4 pF — 60 pF |
| | | FM 1 and 2 | : | 2.5 pF — 20 pF |
| | | Effective Capacitance of Trimmer | : | 8 pF |




COMPONENT LAYOUT AND WIRING
(BOTTOM VIEW)

# AM/FM RADIO
# (3 Can Coils + 2 Ceramic Filters + 1 Ceramic Discriminator)

The advantages of using ceramic discriminator in place of Quad Coil in a FM radio design are: firstly, saving space; secondly, simplifying alignment procedures; and lastly, frequency stability even over a wide range of input signal strength.

LM1866N is designed to well match with the ceramic discriminator. All its intrinsic features are retained without any degradation when ceramic discriminator is used. The circuit shown in figure B exhibits both of the inherent advantages possessed by LM1866N and ceramic discriminator. It is specially designed for limited space but high performance radio application. It is an ideal design for minimum-effort in AM/FM radio alignment.

FREQUENCY COVERAGE

* FM    88 MHz — 108 MHz
* AM    525 KHz — 1650 KHz

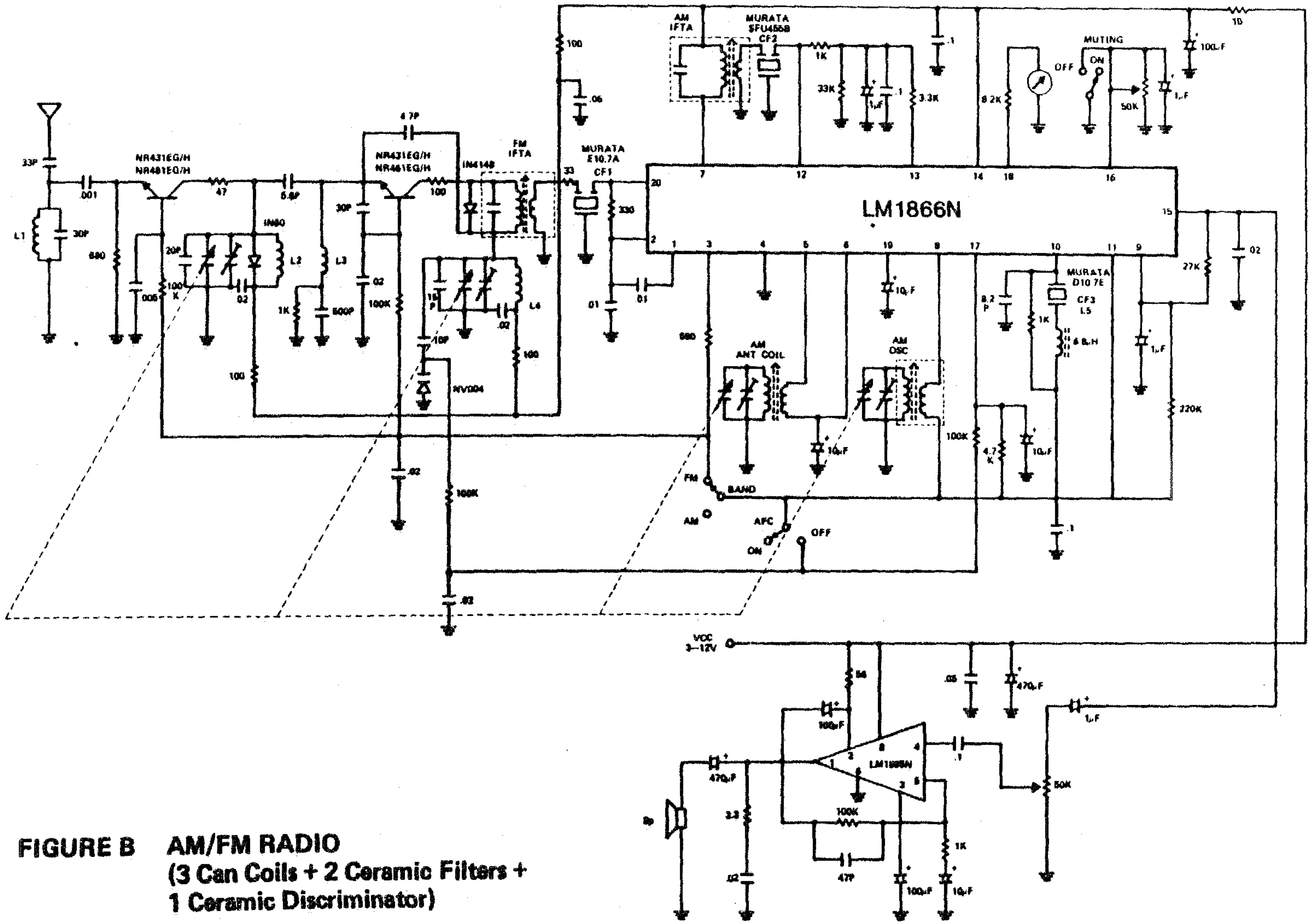



FIGURE B AM/FM RADIO
(3 Can Coils + 2 Ceramic Filters +
1 Ceramic Discriminator)

PERFORMANCE

| AM V+ = 6V, RL = 8Ω, Ref Output = 50mW, Mod = 30%, otherwise specified | | |
|---|---|---|
| PARAMETERS | VALUE | UNITS |
| Max Sens and S+N/N at Max Sens at 600 KHz | 60/7.5 | μV/M/dB |
| 1000 KHz | 70/7.5 | μV/M/dB |
| 1400 KHz | 55/6 | μV/M/dB |
| 20dB Quieting Sens at 600 KHz | 320 | μV/M |
| 1000 KHz | 310 | μV/M |
| 1400 KHz | 300 | μV/M |
| IF Rejection at 600 KHz | >70 | dB |
| Image Rejection at 1400 KHz | 48 | dB |
| A.C.A. ± 10 KHz | 31/27 | dB |
| —6dB/—40dB Bandwidth at Max Sens | 8/31 | KHz |
| AGC Figure of Merit at 100mV/M | 52 | dB |
| Overload Distortion at 100mV/M 80% Mod | 1.8 | % |
| Tweet Modulation at Worst Case | 5 | % |
| Overall Distortion at 5mV/M | 1.3 | % |
| FM V+ = 6V, RL = 8Ω, Ref Output = 50mW, Dev = 22.5 KHz, otherwise specified | | |
| Max Sens at 88 MHz | 1.5 | μV |
| 98 MHz | 1.5 | μV |
| 108 MHz | 1.5 | μV |
| 30dB Quieting Sens and —3dB Limiting Sens at 88 MHz | 5.5/3.5 | μV |
| 98 MHz | 5.5/3.5 | μV |
| 108 MHz | 5.8/3.6 | μV |
| IF Rejection at 88 MHz | 70 | dB |
| Image Rejection at 108 MHz | 28 | dB |
| —6dB Bandwidth at Max Sens | 85 | KHz |
| App. Peak Separation at Max Sens/1100μV | 148/500 | KHz |
| Deviation Sens at 1100μV, Ref Output | 3.6 | KHz |
| Max Deviation Handling at 1100μV, 10% THD | 250 | KHz |
| THD at 1100μV, 22.5 KHz/75 KHz Deviation | 0.25/0.64 | % |
| AM Rejection at 110/1100μV | 48/38 | dB |
| Overload Capacity at 10% THD | >1 | V |
| S+N/N Ratio at 1100μV | 65 | dB |
| Deviation mute at 110/1100μV | ±70/±75 | KHz |
| AFC Holding Range at 110/1100μV | 710/740 | KHz |
| AUDIO V+ = 6V, RL = 8Ω, Ref Output = 50mW, otherwise specified | | |
| Audio Sens at Ref Output | 6.5 | mV |
| Overall Distortion at Ref Output | 0.1 | % |
| 10% THD Output power at 6V/9V | 0.6/1.3 | W |

## COIL DATA AND CERAMIC FILTER

**NOTE :** The coils and ceramic filters shown in the "Standard AM/FM Radio" are applicable to this circuit except the FM Quad Coil. The following parts are for replacing the Quad Coil.

### L5 (Choke Coil)


$L = 6.8\ \mu H$ $Q_u = 100 \pm 15\%$ at $f = 7.96$ MHz

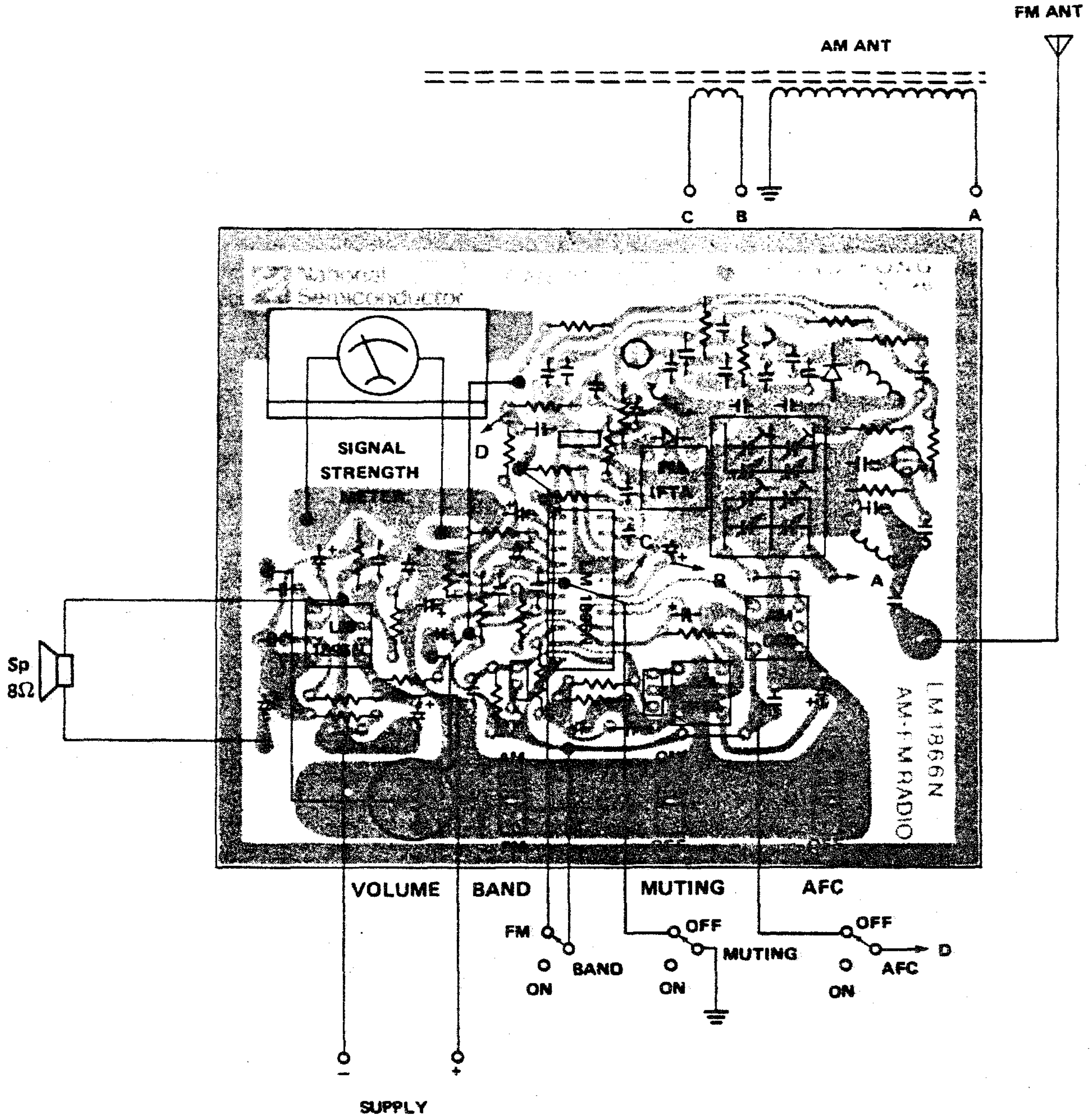
Part No. JC—4E—6R8K (Jackson Electric HK Ltd) or Equivalent

### CERAMIC DISCRIMINATOR

CF3 CDA 10.7 ME (Murata Co. Ltd) or Equivalent

### VARIABLE CAPACITOR

| | | | |
|---|---|---|---|
| Type | : QT—22124 (Toko Incorp) or Equivalent | | |
| Capacitance | : AM ANT | : | 4 pF—142 pF |
| | AM OSC | : | 4 pF—60 p F |
| | FM 1 and 2 | : | 2.5 pF—20 pF |
| | Effective Capacitance of Trimmer | : | 8 pF |




COMPONENT LAYOUT AND WIRING
(BOTTOM VIEW)

# AM/FM RADIO
# (5 Can Coil + 2 Ceramic Filters)

This is the full circuit for LM1866N in AM/FM radio application. 5 can coils and 2 ceramic filters are used as IF selective elements and the AM IFT B is an additional coil as compared with the "Standard AM/FM Radio". The AM IFT B may be omitted from the circuit unless a very low AM tweet modulation is required for the radio. With the additional AM IFT B, the AM tweet modulation is improved from 5% to less than 1%.

Due to the incorporation of AM IFT B, an adjustment of gain distribution for the AM IF strip is required. It is accomplished by re-designing the AM IFT A. Its specification is given in the attached coil data sheet.

FREQUENCY COVERAGE

| | |
|---|---|
| ★ FM | 88 MHz — 108 MHz |
| ★ AM | 525 KHz — 1650 KHz |

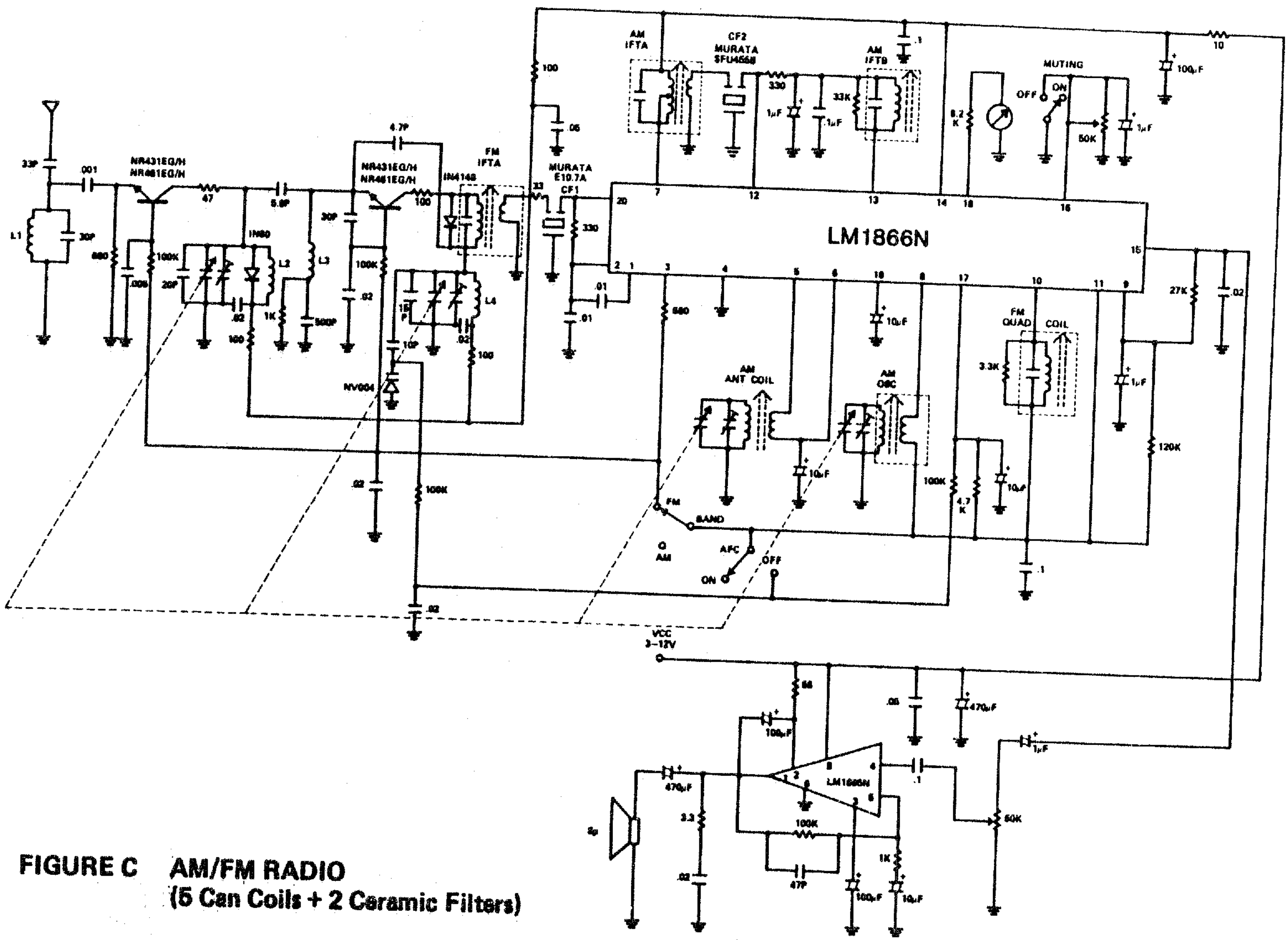



**FIGURE C AM/FM RADIO**
**(5 Can Coils + 2 Ceramic Filters)**

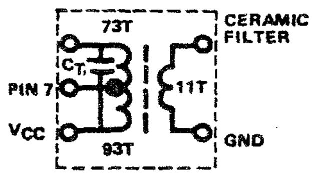
PERFORMANCE

| PARAMETERS | VALUE | UNITS |
|---|---|---|
| **AM** V+ = 6V, RL = 8Ω, Ref Output = 50mW, Mod = 30%, otherwise specified | | |
| Max Sens and S+N/N at Max Sens at 600 KHz | 70/9 | μV/M/dB |
| 1000 KHz | 80/9 | μV/M/dB |
| 1400 KHz | 60/7 | μV/M/dB |
| 20dB Quieting Sens at 600 KHz | 330 | μV/M |
| 1000 KHz | 320 | μV/M |
| 1400 KHz | 300 | μV/M |
| IF Rejection at 600 KHz | 70 | dB |
| Image Rejection at 1400 KHz | 49 | dB |
| A.C.A. ± 10 KHz | 29/29 | dB |
| —6dB/—40dB Bandwidth at Max Sens | 7/32 | KHz |
| AGC Figure of Merit at 100mV/M | 50 | dB |
| Overload Distortion at 100mV/M 80% Mod | 1.5 | % |
| Tweet Modulation at Worst Case/100mV/M | 1.6/0.3 | % |
| Overall Distortion at 5mV/M | 1.2 | % |
| **FM** V+ = 6V, RL = 8Ω, Ref Output = 50mW, Dev = 22.5 KHz, otherwise specified | | |
| Max Sens at 88 MHz | 1.6 | μV |
| 98 MHz | 1.2 | μV |
| 108 MHz | 1.3 | μV |
| 30dB Quieting Sens and —3dB Limiting Sens at 88 MHz | 5.6/4 | μV |
| 98 MHz | 5/3.8 | μV |
| 108 MHz | 5.4/4 | μV |
| IF Rejection at 88 MHz | 68 | dB |
| Image Rejection at 108 MHz | 28 | dB |
| —6dB Bandwidth at Max Sens | 150 | KHz |
| App. Peak Separation at Max Sens/1100μV | 190/590 | KHz |
| Deviation Sens at 1100μV, Ref Output | 3.5 | KHz |
| Max Deviation Handling at 1100μV, 10% THD | 180 | KHz |
| THD at 1100μV, 22.5 KHz/75 KHz Deviation | 0.32/0.65 | % |
| AM Rejection at 110/1100μV | 50/40 | dB |
| Overload Capacity at 10% THD | >500 | mV |
| S+N/N Ratio at 1100μV | 65 | dB |
| Deviation mute at 110/1100μV | ±70/±70 | KHz |
| AFC Holding Range at 110/1100μV | 850/890 | KHz |
| **AUDIO** V+ = 6V, RL = 8Ω, Ref Output = 50mW, otherwise specified | | |
| Audio Sens at Ref Output | 6.5 | mV |
| Overall Distortion at Ref Output | 0.1 | % |
| 10% THD Output power at 6V/9V | 0.6/1.3 | W |

## COIL DATA AND CERAMIC FILTER

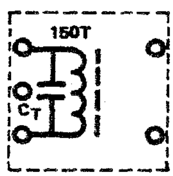
NOTE : The coils and ceramic filters shown in the "Standard AM/FM Radio" are applicable to this circuit except AM IFT A. The coil data of AM IFT A and the additional AM IFT B are shown below.

### AM IFT A




$f$ = 455 KHz    Qu = 80 ± 15%    $C_T$ = 180 pF

### AM IFT B




$f$ = 455 KHz    Qu = 140 ± 15%    $C_T$ 180 pF

Part No. 10A—007 (Jackson Electric Ltd) or Equivalent

### VARIABLE CAPACITOR

| | | |
|---|---|---|
| Type | : | QT—22124 (Toko Incorp) or Equivalent |
| Capacitance | : | AM ANT : 4 pF — 142 pF |
| | | AM OSC : 4 pF — 60 pF |
| | | FM 1 and 2 : 2.5 pF — 20 pF |
| | | Effective Capacitance of Trimmer : 8 pF |

# AM/FM RADIO (6 Can Coils)

This circuit is designed with consideration that the component costing is more important than space occupation and alignment manipulations. The ceramic filters are replaced by IF transformers in this circuit. AM IFT A/B and FM IFT A/B are connected in double-tuned configurations for AM and FM IF selectivity purpose respectively. The —6 dB bandwidth in AM is 5.5 KHz, and in FM is 150 KHz. The end performances are comparable to most of the medium to top class radios in the market.

As IFT is not required for the final AM stage in LM1866N, it is always one less coil than the competitors in radio application. For designing low cost radios, LM1866N is an ideal choice.

FREQUENCY COVERAGE

| | |
|---|---|
| ★ FM | 88 MHz — 108 MHz |
| ★ AM | 525 KHz — 1650 KHz |

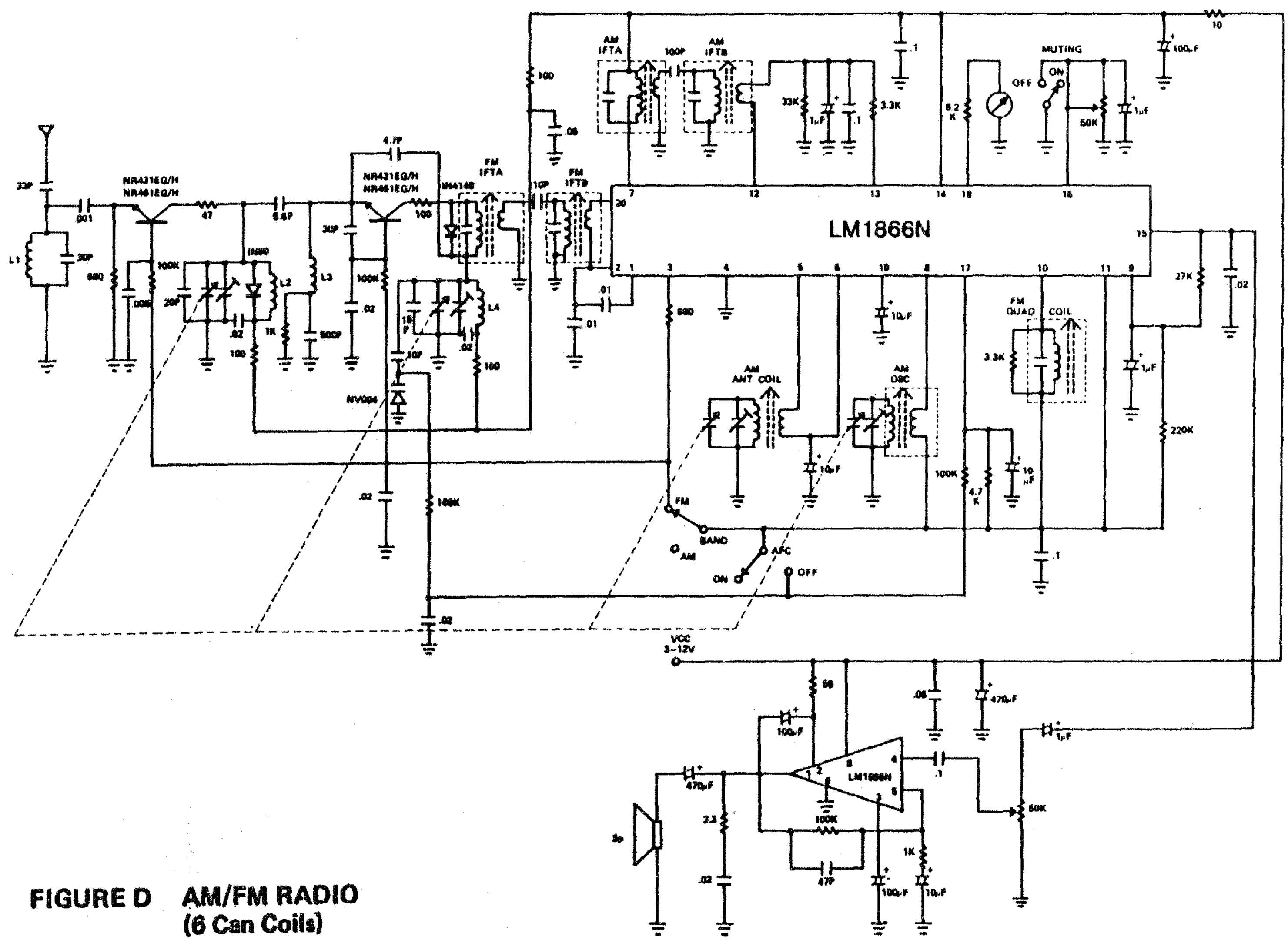


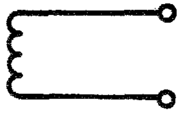

FIGURE D AM/FM RADIO (6 Can Coils)

PERFORMANCE

| AM V+ = 6V, RL = 8Ω, Ref Output = 50mW, Mod = 30%, otherwise specified | | |
|---|---|---|
| PARAMETERS | VALUE | UNITS |
| Max Sens and S+N/N at Max Sens at 600 KHz | 120/12 | μV/M/dB |
| 1000 KHz | 95/11 | μV/M/dB |
| 1400 KHz | 90/11 | μV/M/dB |
| 20dB Quieting Sens at 600 KHz | 350 | μV/M |
| 1000 KHz | 330 | μV/M |
| 1400 KHz | 330 | μV/M |
| IF Rejection at 600 KHz | 60 | dB |
| Image Rejection at 1400 KHz | 48 | dB |
| A.C.A. ± 10 KHz | 28/28 | dB |
| —6dB/—40dB Bandwidth at Max Sens | 6/31 | dB |
| AGC Figure of Merit at 100mV/M | 50 | dB |
| Overload Distortion at 100mV/M 80% Mod | 1.8 | % |
| Tweet Modulation at Worst Case/100mV/M | 5 | % |
| Overall Distortion at 5mV/M | 1.3 | % |
| FM V+ = 6V, RL = 8Ω, Ref Output = 50mW, Dev = 22.5 KHz, otherwise specified | | |
| Max Sens at 88 MHz | 1.6 | μV |
| 98 MHz | 1.6 | μV |
| 108 MHz | 1.6 | μV |
| 30dB Quieting Sens and —3dB Limiting Sens at 88 MHz | 6.5/5 | μV |
| 98 MHz | 6.5/5 | μV |
| 108 MHz | 6.5/5 | μV |
| IF Rejection at 88 MHz | 70 | dB |
| Image Rejection at 108 MHz | 28 | dB |
| —6dB Bandwidth at Max Sens | 150 | KHz |
| App. Peak Separation at 1100μV | 200/650 | KHz |
| Deviation Sens at 1100μV, Ref Output | 3.8 | KHz |
| Max Deviation Handling at 1100μV, 10% THD | 250 | KHz |
| THD at 1100μV, 22.5 KHz/75 KHz Deviation | 0.35/0.7 | % |
| AM Rejection at 110/1100μV | 42/40 | dB |
| Overload Capacity at 10% THD | >500 | mV |
| S+N/N Ratio at 1100μV | 65 | dB |
| Deviation mute at 110/1100μV | ±80/±85 | KHz |
| AFC Holding Range at 110/1100μV | 750/800 | KHz |
| AUDIO V+ = 6V, RL = 8Ω, Ref Output = 50mW, otherwise specified | | |
| Audio Sens at Ref Output | 6.5 | mV |
| Overall Distortion at Ref Output | 0.1 | % |
| 10% THD Output power at 6V/9V | 0.6/1.3 | W |

## COIL DATA

### L1 and L2 (FM ANT and RF COIL)



SWG # 20
N = 3½T    Inner Diameter = 4.5 mm

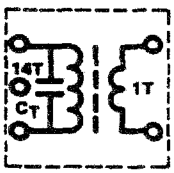
### L3 (IF TRAP COIL)

L = 0.47 μH    Qu = 70 at $f$ = 10.7 MHz
N = 18T    Inner Diameter = 3.0 mm

### L4 (FM OSC COIL)

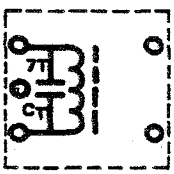
SWG # 20
N = 2½T    Inner Diameter = 4.5 mm

### FM IFT A and FM IFT B



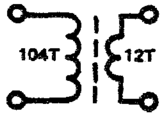

F = 10.7 MHz    Qu = 120 ± 15%    $C_T$ = 47 pF
Part No. FEF—129 (Jackson Electric HK Ltd) or Equivalent

### FM QUAD COIL



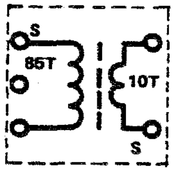

F = 10.7 MHz    Qu = 60 ± 15%    $C_T$ = 300 pF
Part No. 10BC—042 (Jackson Electric HK Ltd) or Equivalent

## AM ANT COIL



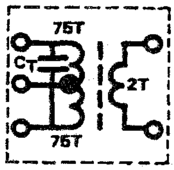

L = 650 μH　　Qu = 200 at 796 KHz
Part No. LAM—650 (Apollo Elec Corp) or Equivalent
Bar Length = 100 mm

## AM OSC COIL



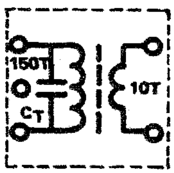

L = 260 μH　　Qu = 120 ± 15% at $f$ = 796 KHz
Part No. 10MO—019 (Jackson Electric HK Ltd) or Equivalent

## AM IFT A




F = 455 KHz　　Qu = 140 ± 15%　　$C_T$ = 180 pF
Part No. 10A—055 (Jackson Electric Ltd) or Equivalent

## AM IFT B

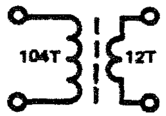



F = 455 KHz　　$C_T$ = 82 pF (Int) + 100 pF (Ext)
Qu = 140 ± 15%

## VARIABLE CAPACITOR

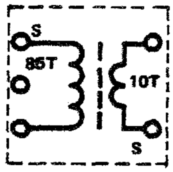
| | | | |
|---|---|---|---|
| Type | : | QT—22124 (Toko Incorp) or Equivalent | |
| Capacitance | : | AM ANT | : 4 pF — 142 pF |
| | | AM OSC | : 4 pF — 60 pF |
| | | FM 1 and 2 | : 2.5 pF — 20 pF |
| | | Effective Capacitance of Trimmer | : 8 pF |

AM ANT COIL



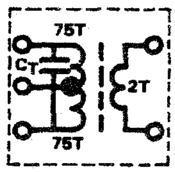

L = 650 $\mu$H Qu = 200 at 796 KHz
Part No. LAM—650 (Apollo Elec Corp) or Equivalent
Bar Length = 100 mm

AM OSC COIL



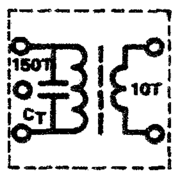

L = 260 $\mu$H Qu = 120 ± 15% at $f$ = 796 KHz
Part No. 10MO—019 (Jackson Electric HK Ltd) or Equivalent

AM IFT A




F = 455 KHz Qu = 140 ± 15% $C_T$ = 180 pF
Part No. 10A—055 (Jackson Electric Ltd) or Equivalent

AM IFT B




F = 455 KHz $C_T$ = 82 pF (Int) + 100 pF (Ext)
Qu = 140 ± 15%

VARIABLE CAPACITOR

| | | |
|---|---|---|
| Type | : | QT—22124 (Toko Incorp) or Equivalent |
| Capacitance | : | AM ANT : 4 pF — 142 pF |
| | | AM OSC : 4 pF — 60 pF |
| | | FM 1 and 2 : 2.5 pF — 20 pF |
| | | Effective Capacitance of Trimmer : 8 pF |

# LW/MW/SW/FM MULTI-BAND RADIO

LM1866N is a versatile device, its fully balanced mixer stage in AM section gives excellent performance in MW frequency band as well as in LW and SW receiver design. It makes LM1866N well suited for multi-band radio application.

The circuit shown in Figure E is a LW/MW/SW/FM multi-band radio. It covers the receiving bands of LW/MW broadcasting, the 5.8 — 16 MHz extended European SW band, and the FM broadcasting band. High circuit stability is always critical at the SW receiver front-end. The component used and the operating voltage are playing important role in this aspect. The operating supply voltage of 6V or above is recommended for the radio when SW band is included in the design.

FREQUENCY COVERAGE

| | |
|---|---|
| ★ LW | 150 KHz — 270 KHz |
| ★ MW | 525 KHz — 1650 KHz |
| ★ SW | 5.8 MHz — 16 MHz |
| ★ FM | 88 MHz — 108 MHz |

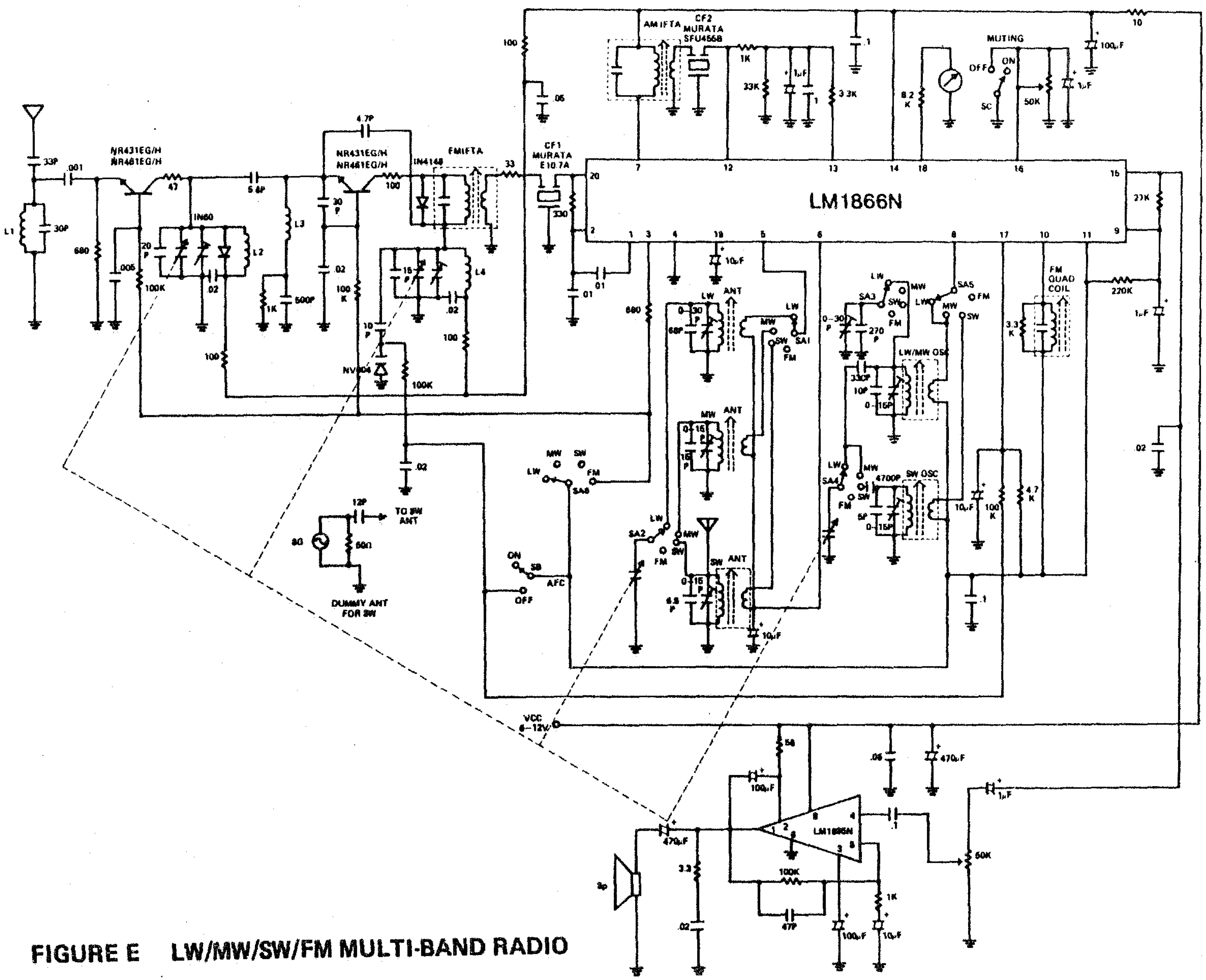



FIGURE E LW/MW/SW/FM MULTI-BAND RADIO

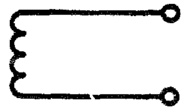
PERFORMANCE

| MW (525—1650 KHz) V+ = 6V, RL = 8Ω, Ref Output = 50mW, Mod Depth = 30%, otherwise specified | | |
|---|---|---|
| **PARAMETERS** | **VALUE** | **UNITS** |
| Max Sens and S+N/N at Max Sens at 600 KHz | 110/8 | μV/M/dB |
| 1000 KHz | 100/8 | μV/M/dB |
| 1400 KHz | 100/9 | μV/M/dB |
| 20dB Quieting Sens at 600 KHz | 440 | μV/M |
| 1000 KHz | 400 | μV/M |
| 1400 KHz | 400 | μV/M |
| IF Rejection at 600 KHz | 60 | dB |
| Image Rejection at 1400 KHz | 45 | dB |
| A.C.A. ± 10 KHz | 28/29 | dB |
| —6dB/—40dB Bandwidth at Max Sens | 7/31 | KHz |
| AGC Figure of Merit at 100mV/M | 50 | dB |
| Overload Distortion at 100mV/M 80% Mod | 1.8 | % |
| Tweet Modulation at Worst Case/100mV/M | 4.8 | % |
| Overall Distortion at 5mV/M | 1.4 | % |
| LW (150—270 KHz) V+ = 6V, RL = 8Ω, Ref Output = 50mW, Mod Depth = 30%, otherwise specified | | |
| Max Sens and S+N/N at Max Sens at 160 KHz | 240/9 | μV/M/dB |
| 200 KHz | 180/7.5 | μV/M/dB |
| 260 KHz | 150/7.5 | μV/M/dB |
| 20dB Quieting Sens at 160 KHz | 1000 | μV/M |
| 200 KHz | 800 | μV/M |
| 260 KHz | 600 | μV/M |
| IF Rejection at 160 KHz | 65 | dB |
| Image Rejection at 260 KHz | 48 | dB |
| A.C.A. ± 10 KHz | 37/38 | dB |
| 6dB/40dB Bandwidth at Max Sens | 5/20 | KHz |
| SW (5.8—16MHz) V+ = 6V, RL = 8Ω, Ref Output = 50mW, Direct Injection through Dummy Ant, otherwise specified | | |
| Max Sens & S+N/N at Max Sens at 6.5 MHz | 9/10 | μV/dB |
| 10 MHz | 4/10 | μV/dB |
| 15 MHz | 3/9 | μV/dB |
| 20dB Quieting Sens at 6.5 MHz | 28 | μV |
| 10 MHz | 12 | μV |
| 15 MHz | 7 | μV |
| IF Rejection at 6.5 MHz | 100 | dB |
| Image Rejection at 15 MHz | 13 | dB |
| —6dB/—40dB Bandwidth at Max Sens | 6.6/45 | KHz |

| FM (88—108 MHz) V+ = 6V, RL = 8Ω, Ref Output = 50mW, Deviation = 22.5 KHz, otherwise specified | | |
|---|---|---|
| PARAMETERS | VALUE | UNITS |
| Max Sens at 88 MHz | 1.5 | μV |
| 98 MHz | 1.4 | μV |
| 108 MHz | 1.4 | μV |
| 30dB Quieting Sens and —3dB Limiting Sens at 88 MHz | 6/5 | μV |
| 98 MHz | 6/5 | μV |
| 108 MHz | 6/5 | μV |
| IF Rejection at 88 MHz | 70 | dB |
| Image Rejection at 108 MHz | 28 | dB |
| —6dB Bandwidth at Max Sens | 150 | KHz |
| App. Peak Separation at Max Sens/1100μV | 190/580 | KHz |
| Deviation Sens at 1100μV, Ref Output | 3.5 | KHz |
| Max Deviation Handling at 1100μV, 10% THD | 200 | KHz |
| THD at 1100μV, 22.5 KHz/75 KHz Deviation | 0.35/0.6 | % |
| AM Rejection at 110/1100μV | 45/40 | dB |
| Overload Capacity at 10% THD | >500 | mV |
| S+N/N Ratio at 1100μV | 65 | dB |
| Deviation mute at 110/1100μV | ±70/±70 | KHz |
| AFC Holding Range at 110/1100μV | 850/890 | KHz |

## COIL DATA

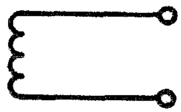
### L1 and L2 (FM ANT and RF COIL)



SWG # 20
N = 3½T

Inner Diameter = 4.5 mm

### L3 (IF TRAP COIL)



L = 0.47μH
N = 18T

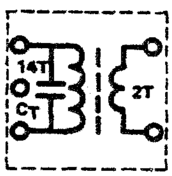
Qu = 70 at $f$ = 10.7 MHz
Inner Diameter = 3.0 mm

### L4 (FM OSC COIL)

SWG # 20
N = 2½T

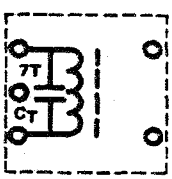
Inner Diameter = 4.5 mm

### FM IFT A



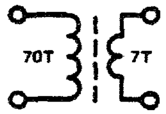

F = 10.7 MHz  Qu = 100 ± 15%  $C_T$ = 47 pF
Part No. 10F—147—F1 (Jackson Electric Ltd) or Equivalent

### FM QUAD COIL



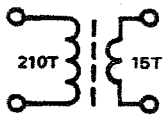

F = 10.7 MHz  Qu = 60 ± 15%  $C_T$ = 300 pF
Part No. 10BC—042 (Jackson Electric Ltd) or Equivalent

## MW ANT COIL



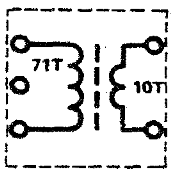

L = 300 $\mu$H Qu = 200 at 796 KHz
Bar Length = 120 mm

## LW ANT COIL



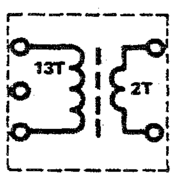

L = 3.5 mH Qu = 200 at 252 KHz
*Honeycone Winding Bar Length = 120 mm

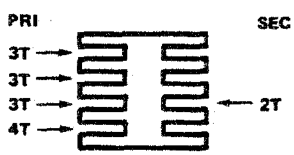
## LW/MW OSC COIL




L = 170 $\mu$H Qu = 160 at 796 KHz

## SW ANT COIL

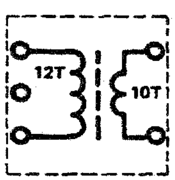


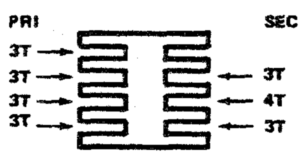




(INNER BOBBIN)
WINDING METHOD

L = 2.5 $\mu$H Qu = 80 at 7.96 MHz
Tuning Frequency = 5.8 MHz — 16 MHz

## SW OSC COIL

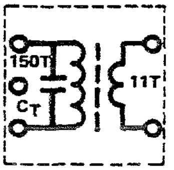



(INNER BOBBIN)
WINDING METHOD

L = 2.2 $\mu$H Qu = 80 at 7.96 MHz
Tuning Frequency = 6.255 MHz — 16.455 MHz

## AM IFT A



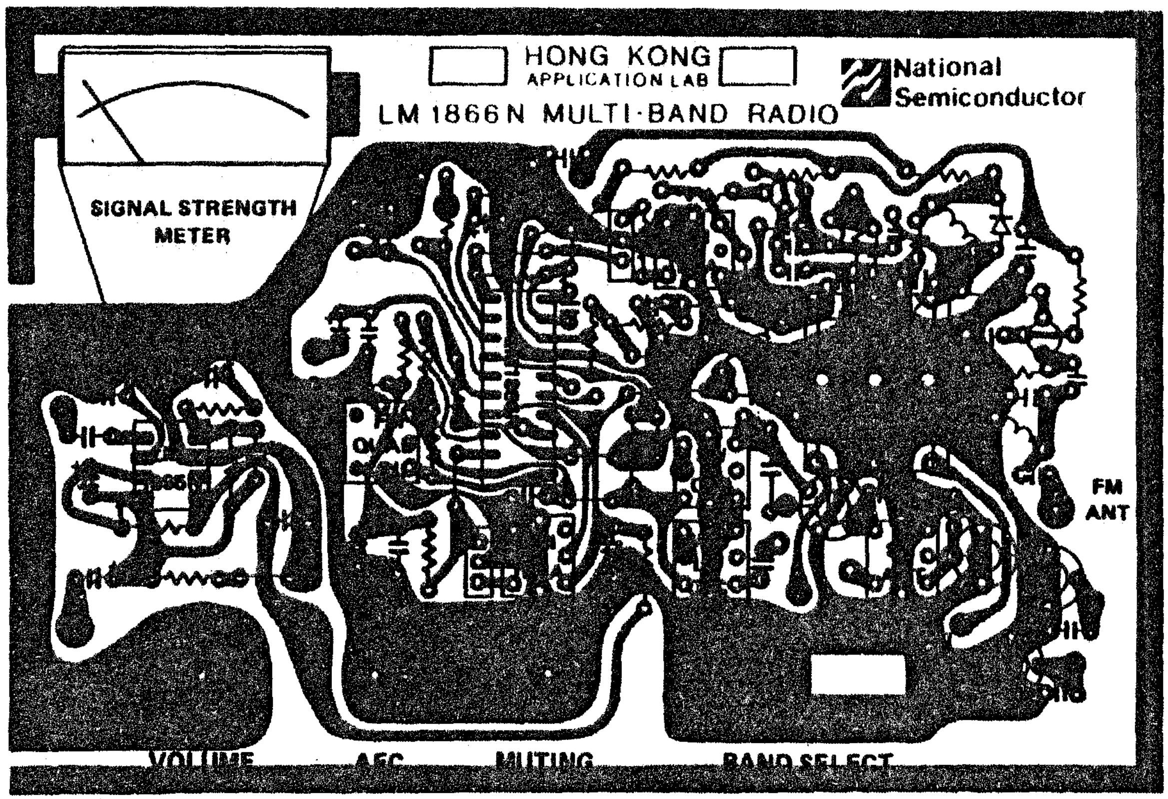

F = 455 KHz        Qu = 110 ± 15%        $C_T$ = 180 pF
Part No. 10A — 040 (Jackson Electric Ltd) or Equivalent

## CERAMIC FILTERS

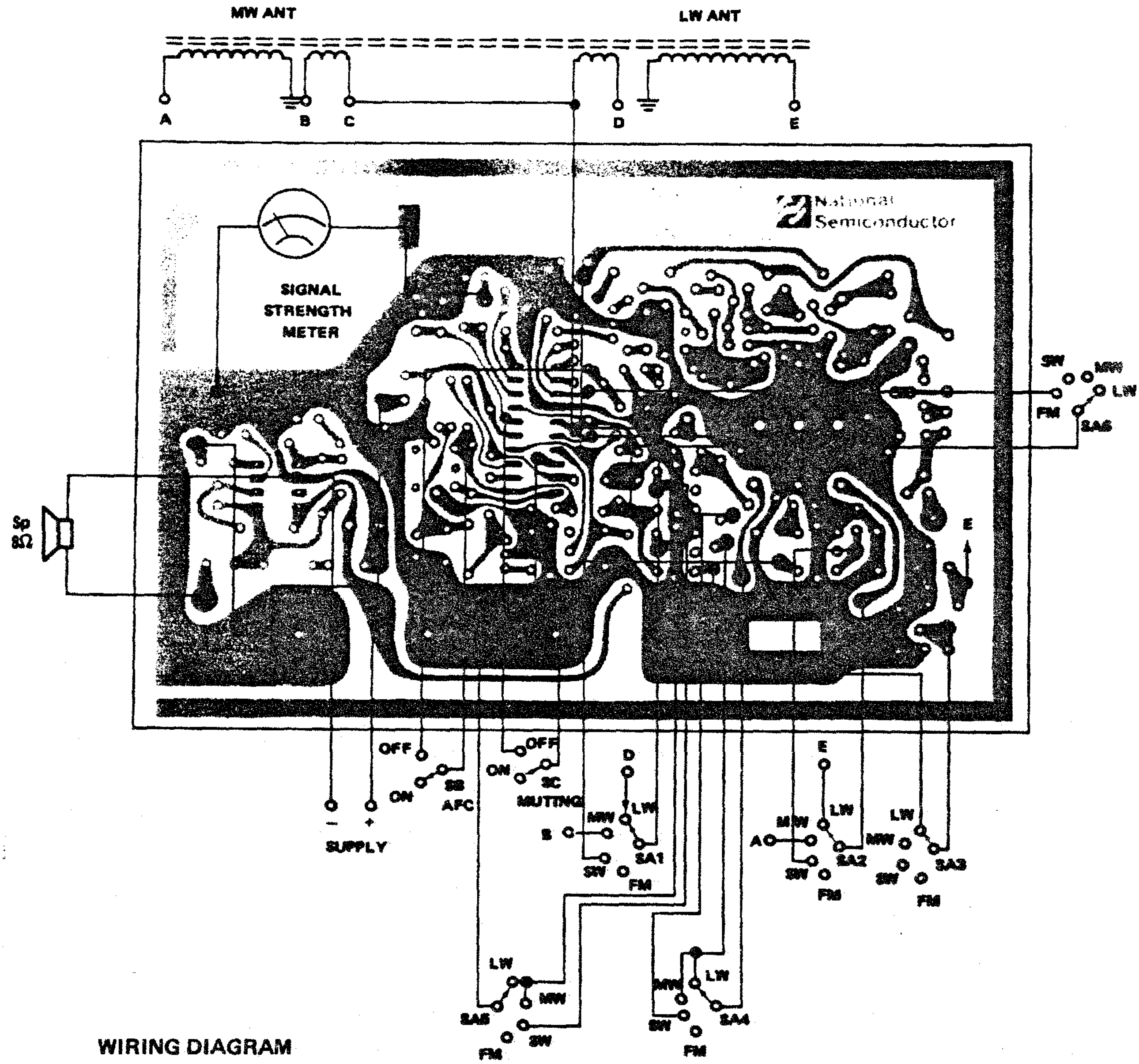
| | |
|---|---|
| CF1 | SFE 10.7 MA5 (Murata Co. Ltd) or Equivalent |
| CF2 | SFU 455B (Murata Co. Ltd) or Equivalent |

## VARIABLE CAPACITOR

Type : PVC — 2AF (Mitsumi Co. Ltd) or Equivalent
Capacitance : AM1 and 2 : 4 pF — 266 pF
FM1 and 2 : 2.5 pF — 20 pF
Effective Capacitance of Trimmers:
MW and FM : 8 pF (Attached to PVC — 2AF)
LW : 30 pF (Separated)
SW : 15 pF (Separated)



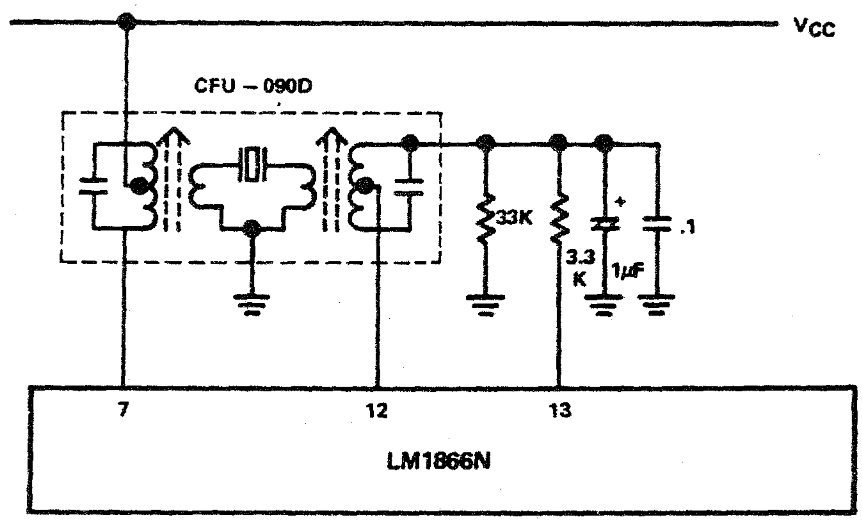

COMPONENT LAYOUT
(BOTTOM VIEW)



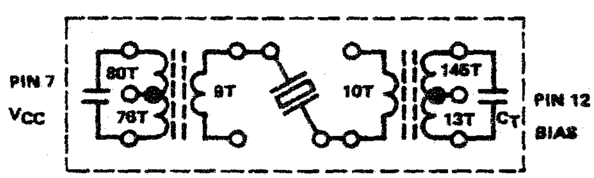

WIRING DIAGRAM

# APPENDICES

For some top class SW radio applications, the AM IF strip can be modified by replacing the AM IFT A and CF2 with a IFT/Ceramic composed filter for better selectivity. The circuit is shown below.




## COIL DATA




F = 455 KHz　　　$C_T$ = 180 pF
Qu = 120
Part No. CFU—090D (Toko Inc) or Equivalent

## PERFORMANCE

| | | |
|---|---|---|
| * −6 dB Bandwidth | : | 6 KHz |
| * −40 dB Bandwidth | : | 25 KHz |
| * A.C.A. ± 10 KHz | : | 36/36 dB |

# AM/FM/STEREO RADIO

The features that LM1866N possesses are comparable to the high end HI-FI tuners, and designing it into HI-FI products is very straightforward. The circuit shown in Figure F gives professional system performance in conventional radio costing.

The FM tuner circuit is differed from the previously described circuits. A FET RF stage and a separated Oscillator/Mixer stages are adopted for better noise figure, cross-modulation and signal handling capability. The FM Quad Coil is re-designed for lower audio distortion (The Quad Coil described in the previous circuits give higher output level). The AM IFTB is included in the circuit for excellent tweet modulation. Apart from the signal strength meter, a FM centre tuned meter is also incorporated in the circuit for accurate manual tuning. It is connected in series with a resistor from the AFC output pin (17) to the Regulator output pin (11).

The MPX decoder LM1870N is used in this circuit. It is a high quality MPX decoder with blend control. Blending function is controlled by the meter output voltage (pin 18) from LM1866N. For obtaining optimum blend performance, the blend level in LM1870N must be carefully adjusted to match with the meter output voltage and a resistor of 6.8K from Pin 16 of LM1870N to ground is selected for that purpose.

FREQUENCY COVERAGE

| | |
|---|---|
| * FM | 88 MHz — 108 MHz |
| * AM | 525 KHz — 1650 KHz |

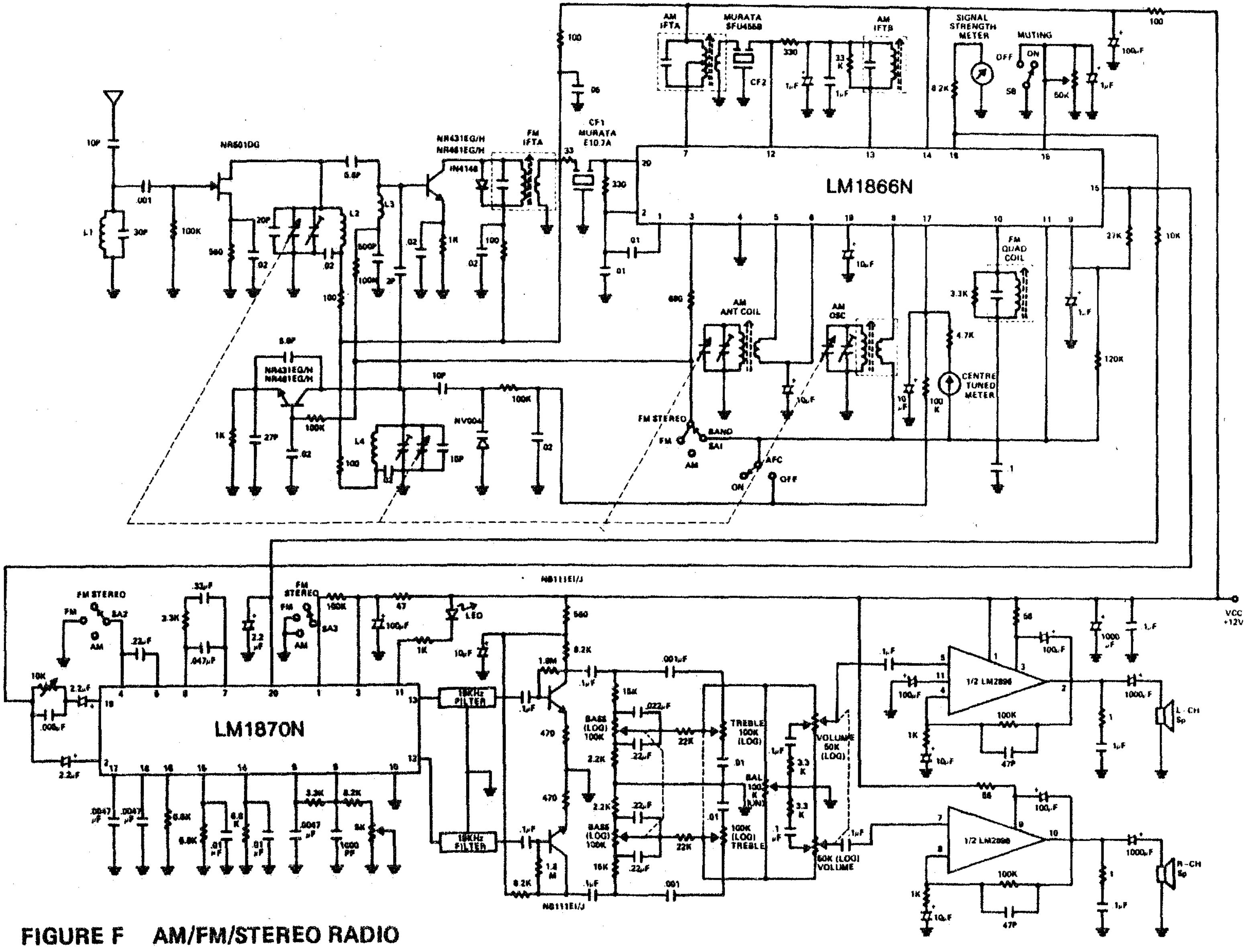


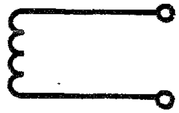

FIGURE F AM/FM/STEREO RADIO

PERFORMANCE

| PARAMETERS | VALUE | UNITS |
|---|---|---|
| **AM** V+ = 12V, RL = 8Ω, Ref Output = 50mW, Mod = 30%, otherwise specified | | |
| Max Sens and S+N/N at Max Sens at 600 KHz | 60/7.5 | μV/M/dB |
| 1000 KHz | 70/7.5 | μV/M/dB |
| 1400 KHz | 55/6 | μV/M/dB |
| 20dB Quieting Sens at 600 KHz | 320 | μV/M |
| 1000 KHz | 310 | μV/M |
| 1400 KHz | 300 | μV/M |
| IF Rejection at 600 KHz | >70 | dB |
| Image Rejection at 1400 KHz | 49 | dB |
| A.C.A. ± 10 KHz | 29/29 | dB |
| −6dB/−40dB Bandwidth at Max Sens | 7/32 | KHz |
| AGC Figure of Merit at 100mV/M | 50 | dB |
| Overload Distortion at 100mV/M 80% Mod | 1.5 | % |
| Tweet Modulation at Worst Case/100mV/M | 1.6/0.3 | % |
| Overall Distortion at 5mV/M | 1.2 | % |
| **FM** V+ = 12V, RL = 8Ω, Ref Output = 50mW, Dev = 22.5 KHz, otherwise specified | | |
| Max Sens at 88 MHz | 1 | μV |
| 98 MHz | 1 | μV |
| 108 MHz | 1 | μV |
| 30dB Quieting Sens and −3dB Limiting Sens at 88 MHz | 4/3 | μV |
| 98 MHz | 4/3 | μV |
| 108 MHz | 4/3 | μV |
| IF Rejection at 88 MHz | 70 | dB |
| Image Rejection at 108 MHz | 32 | dB |
| −6dB Bandwidth at Max Sens | 150 | KHz |
| App. Peak Separation at Max Sens/1100μV | 190/590 | KHz |
| Deviation Sens at 1100μV, Ref Output | 3.5 | KHz |
| Max Deviation Handling at 1100μV, 10% THD | 320 | KHz |
| THD at 1100μV, 22.5 KHz/75 KHz Deviation | 0.18/0.25 | % |
| AM Rejection at 110/1100μV | 50/45 | dB |
| Overload Capacity at 10% THD | >1 | V |
| S+N/N Ratio at 1100μV | 65 | dB |
| Deviation mute at 110/1100μV | ±70/±70 | KHz |
| Signal Strength for Overcoming Mute | 30 | μV |
| AFC Holding Range at 110/1100μV | 850/900 | KHz |
| **MPX** V+ = 12V, RL = 8Ω, Ref Output = 50mW, Dev = 22.5 KHz modulated by Standard Composite Signal | | |
| Input Signal for Pilot Lamp "ON" (Blend Off) | 4 | μV |
| Input Signal for Pilot Lamp "OFF" (Blend Off) | 2.8 | μV |
| Channel Separation at 1100μV, 1 KHz Mod | 35 | dB |
| Input Signal for Blend Function | 30 | μV |
| Channel Balance | 0.2 | dB |
| **AUDIO** V+ = 12V, RL = 8Ω, Ref Output = 50mW, otherwise specified | | |
| Audio Sens at Ref Output (Tone Controls at Flat Position) | 5 | mV |
| Tone at Max Boost 100 Hz/10 KHz | 11 | dB |
| Tone at Full Cut 100 Hz/10 KHz | 14 | dB |
| 10% THD Output Power | 2.4 | W |

## COIL DATA

### L1 and L2 (FM ANT and RF COIL)



SWG # 20

N = 3½T

Inner Diameter = 4.5 mm

### L3 (IF TRAP COIL)

L = 0.47 μH

N = 18T

Qu = 70 at $f$ = 10.7 MHz

Inner Diameter = 3.0 mm

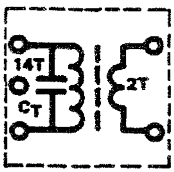
### L4 (FM OSC COIL)

SWG # 20

N = 2½T

Inner Diameter = 4.5 mm

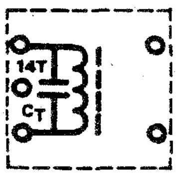
### FM IFT A




F = 10.7 MHz     Qu = 100 ± 15%     $C_T$ = 47 pF

Part No. 10F—147—F1 (Jackson Electric Ltd) or Equivalent

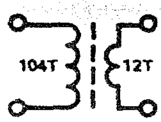
### FM QUAD COIL




F = 10.7 MHz     Qu = 70 ± 15%     $C_T$ = 82 pF

Part No. 10BC—038 (Jackson Electric Ltd) or Equivalent

## AM ANT COIL

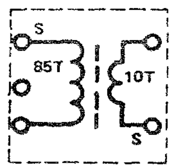



L = 650 $\mu$H   Qu = 200 at 796 KHz

Part No. LAM—650 (Apollo Elec Corp) or Equivalent

Bar Length = 100 mm

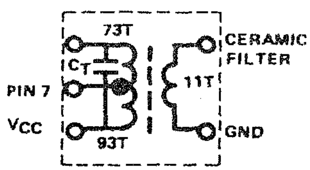
## AM OSC COIL




L = 260 $\mu$H   Qu = 120 ± 15% at $f$ = 796 KHz

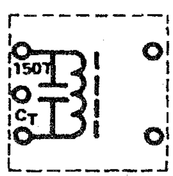
Part No. 10MO—019 (Jackson Electric Ltd) or Equivalent

## AM IFT A




$f$ = 455 KHz   Qu = 80 ±15%   $C_T$ = 180 pF

## AM IFT B




$f$ = 455 KHz   Qu = 140   $C_T$ = 180 pF

Part No. 10A—007 (Jackson Electric Ltd) or Equivalent

## CERAMIC FILTERS

| | |
|---|---|
| CF1 | SFE 10.7 MA5 (Murata Co. Ltd) or Equivalent |
| CF2 | SFU 455B (Murata Co. Ltd) or Equivalent |

## VARIABLE CAPACITOR

| | | |
|---|---|---|
| Type | : | QT—22124 (Toko Incorp) or Equivalent |
| Capacitance | : | AM Ant : 4 pF — 142 pF |
| | | AM OSC : 4 pF — 60 pF |
| | | FM 1 and 2 : 2.5 pF — 20 pF |
| | | Effective Capacitance of Trimmer : 8 pF |

National Semiconductor

ENGINEERING REPORT
GL–2701
JULY 1982

# A COMPATIBLE AM STEREO RECEIVER

# MAGNAVOX SYSTEM

Prepared by
K.H. Chiu & Eddy Cheng
Linear Applications Engineering – CTSC

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| | Coil Data | P. 5-7 |
| | Schematic Diagram | P. 8-9 |
| | Component Layout and Wiring Diagram | P. 10-11 |
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## INTRODUCTION

Stereo is a perferred program source for most people. Nowadays, the sound equipment such as record players, cassettes and FM receivers are all offering stereophonic programming. On March, 1982, FCC decided to allow AM stereo broadcasting in the United States. According to the commission's "Best Engineering Judgment", the Magnavox system received the highest score among the five proposed systems; the evaluations were based on categories including monophonic compatibility, interference characteristic, coverage, transmitter stereo performance and receiver stereo performance.

National Semiconductor has introduced the first AM stereo decoder IC LM1981N to the industry. This exceptional device was developed using National's proprietary linear integrated circuit technology. It decodes the stereo information which is amplitude and phase modulated on a carrier wave into Left and Right audio channels. In addition, the chip also incorporates other functional blocks that are essential for building a practical AM stereo receiver. They are an excess phase detector, a stereo pilot tone output, a stereo/mono blend circuit, two output sample and hold circuits and an internally regulated reference voltage.

The circuit described in this report is a Magnavox AM stereo receiver together with a complete FM stereo receiver, which was built in our applications engineering laboratory for system performance evaluation. It is reference material for the people who are interested in building AM stereo receivers. This report also consists the detailed performance data, the PCB layout and coil specifications. Detailed information for building an AM stereo generator is also included.

## THE RECEIVER

Fig. 1 is the schematic of an AM stereo/FM stereo receiver with the AM section designed to decode the Magnavox stereo information. The circuit consists the functional blocks of an AM/FM receiver (LM1866N), a FM MPX decoder (LM1870N), an AM stereo decoder (LM1981N) and peripheral circuits (LM324N), and a dual channel audio power amplifier (LM2896P). It is a standard AM/FM stereo receiver with the additional circuitries for AM stereo decoding. The RF AM stereo information is received and mixed down in a superhet front end to intermediate frequency in a conventional fashion. The IF signal is then amplified in the IF stages and the output signal is extracted from the final IF stage for the AM stereo decoder LM1981N. Basically the receiver front end for AM stereo is similar to that of an AM mono receiver, except care must be taken in certain areas to obtain optimum performance. They are high stability local oscillator frequency with low phase jittering and pulling, symmetrical IF response and high AGC figure of merit. Fortunately, the LM1866N fulfills all the requirements in these areas.

Although LM1981N has been working perfectly in automobile radios, special care must be taken when the LM1981N is designed into a portable radio which incorporated ferrite bar antenna. Since the AM stereo decoder consists of an envelope detector, a quadrature detector and a high gain limiter. They may produce radiation which will interfere with the receiver's front end. Although serious considerations have already been taken to minimize the radiation when the chip was designed, external circuit arrangement is also important to keep other problems to a minimum. The peripheral circuits formed by LM324N are playing important roles in these aspect.

(1) Shunting the signal by AC grounding the quadrature detector coil during weak or absence of signal condition:-

The limiter is a very high gain amplifier working at IF frequency, any input noise burst will drive it into saturation easily. At that instant some harmonics may be generated and cause interference to the receiver. Transistor Q3 in the circuit shunts the quadrature tuned circuit to ground during the deteriorated receiving condition. The ON/OFF of the transistor is controlled by a comparator A1 which monitors the carrier level at pin 5. The reference voltage of the comparator is set at the level point such that the receiver gives a S+N/N ratio of 26dB; hence the receiver will operate in stereo mode only under an acceptable quieting condition.

(2) Disable the stereo indicator during searching for stations:-

When the receiver is being tuned for a station, the local oscillator frequency produces some low frequency noise that is detected by the phase detector and transferred to the pilot tone output pin. This low frequency noise triggers the AM stereo indicator lamp and makes it flicker. The comparator A1 is also used to switch off the LED indicator when no station is detected.

(3) RC roll off filter:-

RC roll off filters are required at the Left and Right channel output pins (7 and 9) to limit the recovered audio bandwidth. As an unlimited bandwidth audio signal may cuase feedback to the loopstick antenna and results in a poor signal to noise performance. The value of the RC filters may vary from different PCB designs, as placing the decoder chip farther away from the bar antenna will result in less unwanted feedback. The RC filter must be selected properly otherwise the overall audio bandwidth will be sacrified.

The other functional blocks of the LM324N serve as pilot tone active filter (A3), stereo indicator driver (A4) and excess phase output driver (A2) for providing blending command to pin 11 of the decoder. The envelope detector in LM1866N serves as a driver for the Sample/Hold circuit in LM1981N.

The overall performance of the AM stereo receiver is much better than expected, especially in channel separation. In our evaluation, the channel separation is well above 26dB over a wide range of signal strength. At the optimum point, it is as high as 30dB. The monophonic compatibility of the receiver is also found to be very satisfactory. From these facts we believe that the LM1981N is a perfect device in AM stereo radio manufacturing.

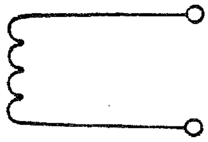
PERFORMANCE

| AM V+ = 12V, RL = 8Ω, Ref Output = 50mW, Mod = 30%, otherwise specified | | |
|---|---|---|
| PARAMETERS | VALUE | UNITS |
| Max Sens and S+N/N at Max Sens at 600 KHz | 220/9 | µV/M/dB |
| 1000 KHz | 180/10 | µV/M/dB |
| 1400 KHz | 160/11 | µV/M/dB |
| 20dB Quieting Sens at 600 KHz | 480 | µV/M |
| 1000 KHz | 440 | µV/M |
| 1400 KHz | 400 | µV/M |
| IF Rejection at 600 KHz | >60 | dB |
| Image Rejection at 1400 KHz | 48 | dB |
| A.C.A. ±10 KHz | 24/26 | dB |
| -6dB/-40dB Bandwidth at Max Sens | 7/42 | KHz |
| AGC Figure of Merit at 100mV/M | 50 | dB |
| Overload Distortion at 100mV/M 80% Mod | 1.4 | % |
| Tweet Modulation at 100mV/M | 3.5 | % |
| Overall Distortion at 5mV/M | 0.7 | % |
| Channel Separation at 100mV/M, 1 KHz Modulation | 28 | dB |
| Channel Balance | 0.5 | dB |

| FM V+ = 12V, RL = 8Ω, Ref Output = 50mW, Dev = 22.5KHz, otherwise specified | | |
|---|---|---|
| Max Sens at 88 MHz | 1.2 | µV |
| 98 MHz | 1.3 | µV |
| 108 MHz | 1.2 | µV |
| 30dB Quieting Sens and -3dB Limiting Sens at 88 MHz | 5.2/5 | µV |
| 98 MHz | 5.3/5 | µV |
| 108 MHz | 5.5/5.2 | µV |
| IF Rejection at 88 MHz | 88 | dB |
| Image Rejection at 108 MHz | 32 | dB |
| -6dB Bandwidth at Max Sens | 150 | KHz |
| App. Peak Separation at 1100µV | 400 | KHz |
| Deviation Sens at 1100µV, Ref Output | 2 | KHz |
| Max Deviation Handling at 1100µV, 10% THD | 210 | KHz |
| THD at 1100µV, 22.5 KHz/75 KHz Deviation | 0.5/0.7 | % |
| AM Rejection at 110/1100µV | 42/32 | dB |
| Overload Capacity at 10% THD | >1 | V |
| S+N/N Ratio at 1100µV | 55 | dB |
| Deviation mute at 110/1100µV | ±70/±70 | KHz |
| AFC Holding Range at 110/1100µV | 810/830 | KHz |

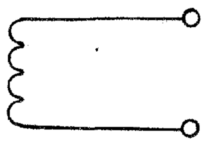
COIL DATA

L1 and L2 (FM ANT and RF COIL)



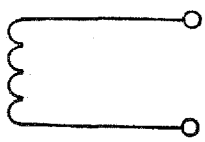
SWG #20
N = 3½T     Inner Diameter = 4.5mm

L3 (IF TRAP COIL)



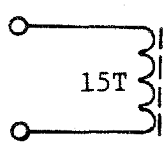
L = 0.47μH     Qμ = 70 at f = 10.7MHz
N = 18T     Inner Diameter = 3.0mm

L4 (FM OSC COIL)



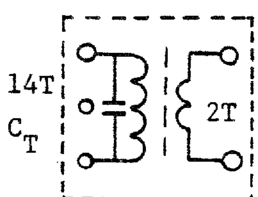
SWG #20
N = 2½T     Inner Diameter = 4.5mm

L5 (CHOKE COIL)



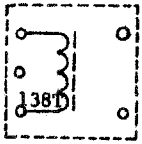

L = 6.8μH     Qμ = 100 ±15% at f = 7.96MHz
Part No. JC-4E-6R8K (Jeckson Electric HK Ltd) or Equivalent

FM IFT A




F = 10.7MHz     Qμ = 100 ±15%     $C_T$ = 47pF
Part No. 10F-147-F1 (Jeckson Electric HK Ltd) or Equivalent

AM IFT C




F = 796KHz L = 556μH Qμ = 70 ±15%
Part No. 10A-042 (Jeckson Electric HK Ltd) or Equivalent

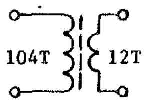
CERAMIC FILTERS

| | |
|---|---|
| CF1 | SFE 10.7 MA5 (Murata Company Ltd) or Equivalent |
| CF2 | SFU 455B (Murata Company Ltd) or Equivalent |
| CF3 | CDA 10.7 ME (Murata Company Ltd) or Equivalent |

VARIABLE CAPACITOR

| | | | | |
|---|---|---|---|---|
| Type | : | QT-22124 (Toko Incorp) or Equivalent | | |
| Capacitance | : | AM ANT | : | 4pF - 142pF |
| | | AM OSC | : | 4pF - 60pF |
| | | FM 1 and 2 | : | 2.5pF - 20pF |
| | | Effective Capacitance of Trimmer : 8pF | | |

AM ANT COIL

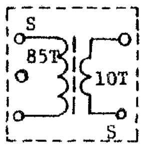



L = 650μH    Qμ = 200 at 796KHz

Part No. LAM-650 (Apollo Elec Corp) or Equivalent

Bar Length = 100mm

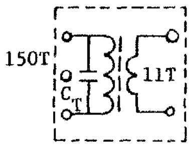
AM OSC COIL




L = 260μH    Qμ = 120 ±15% at f = 796KHz

Part No. 10MO-019 (Jeckson Electric HK Ltd) or Equivalent

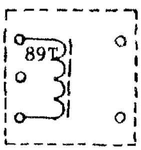
AM IFT A




F = 455KHz    Qμ = 110 ±15%    $C_T$ = 180pF

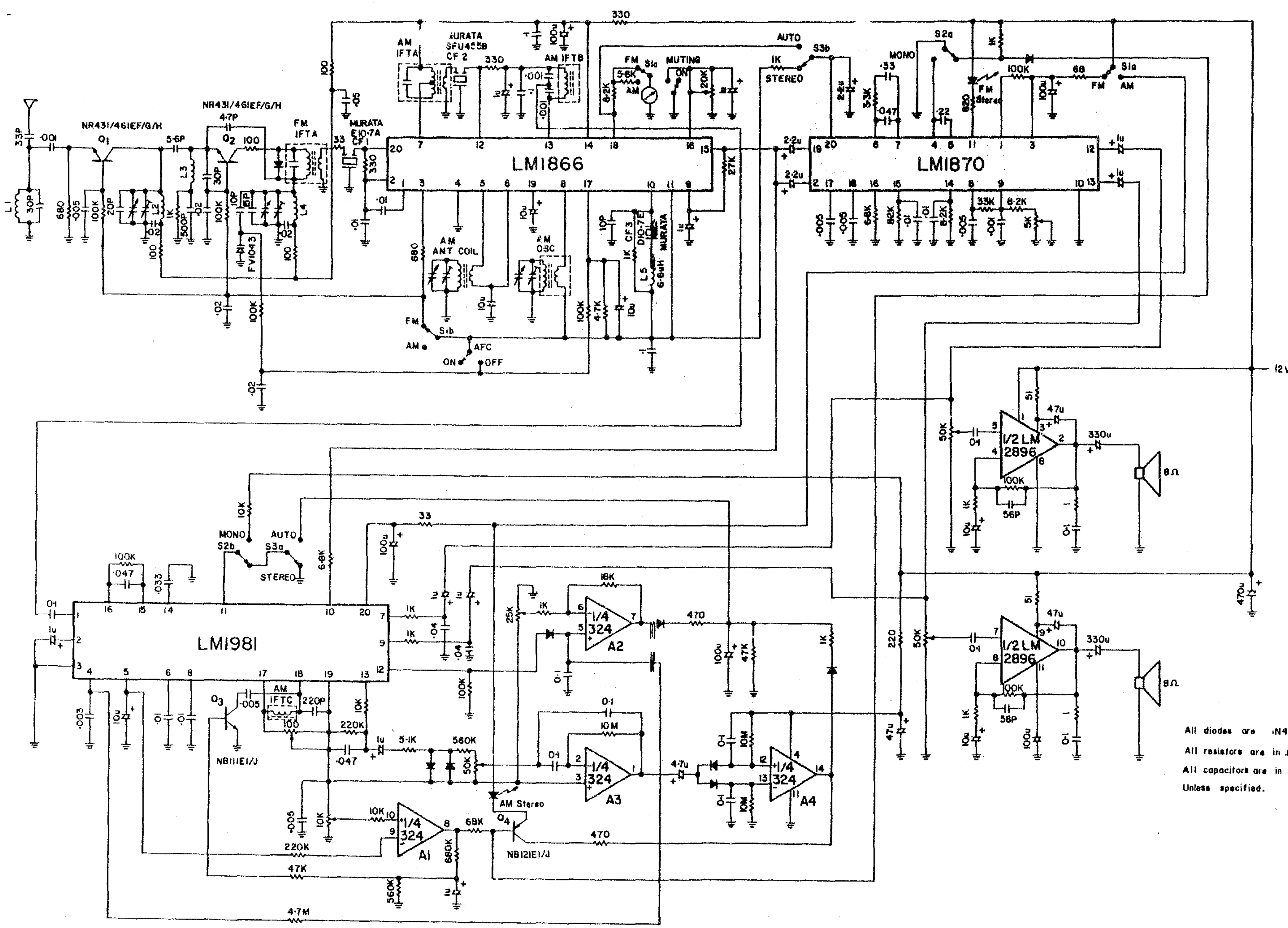
Part No. 10A-040 (Jeckson Electric HK Ltd) or Equivalent

AM IFT B



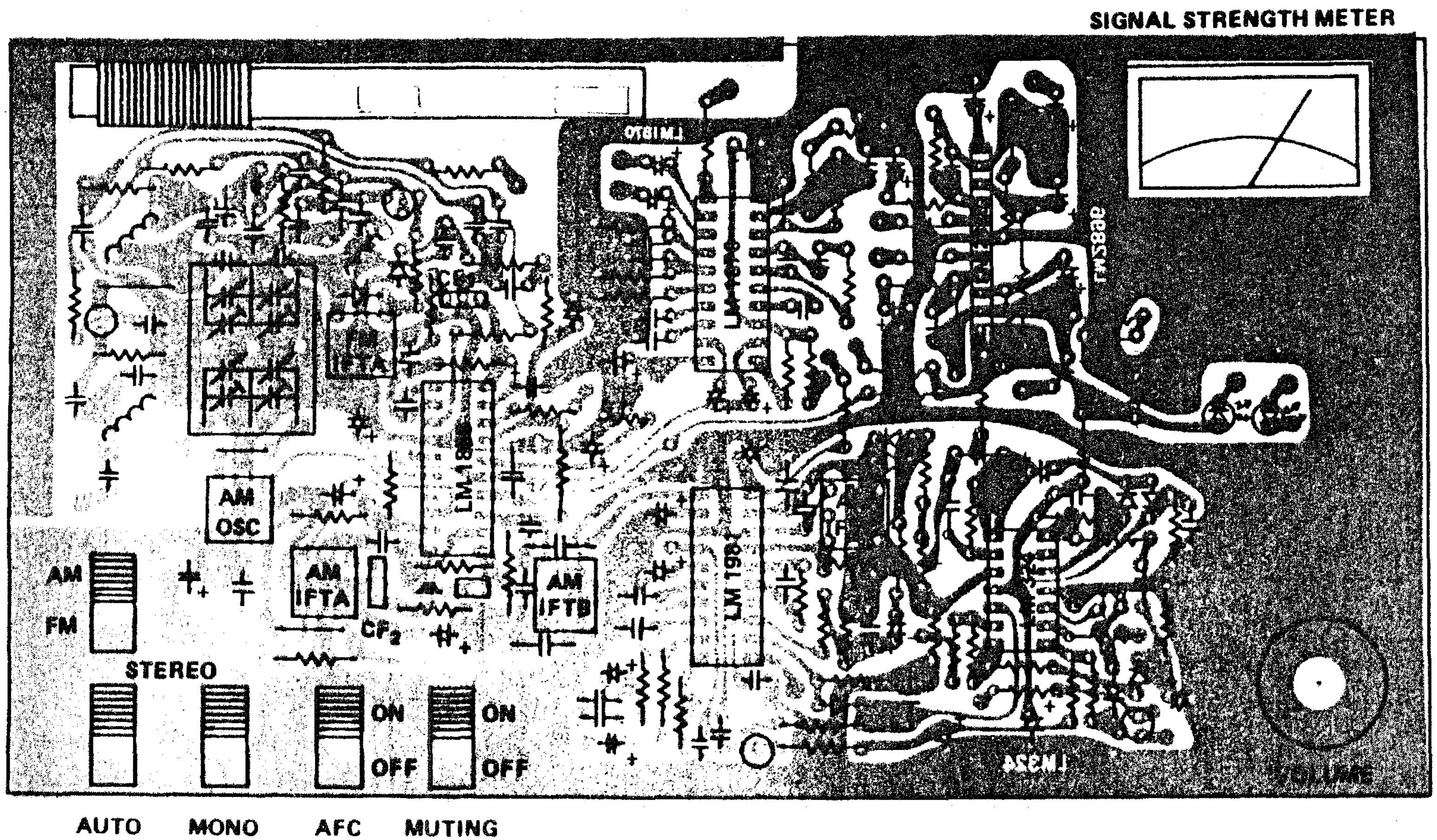

F = 455KHz    L = 288μH    Qμ = 70 ±15%

Part No. 10A-058 (Jeckson Electric HK Ltd) or Equivalent



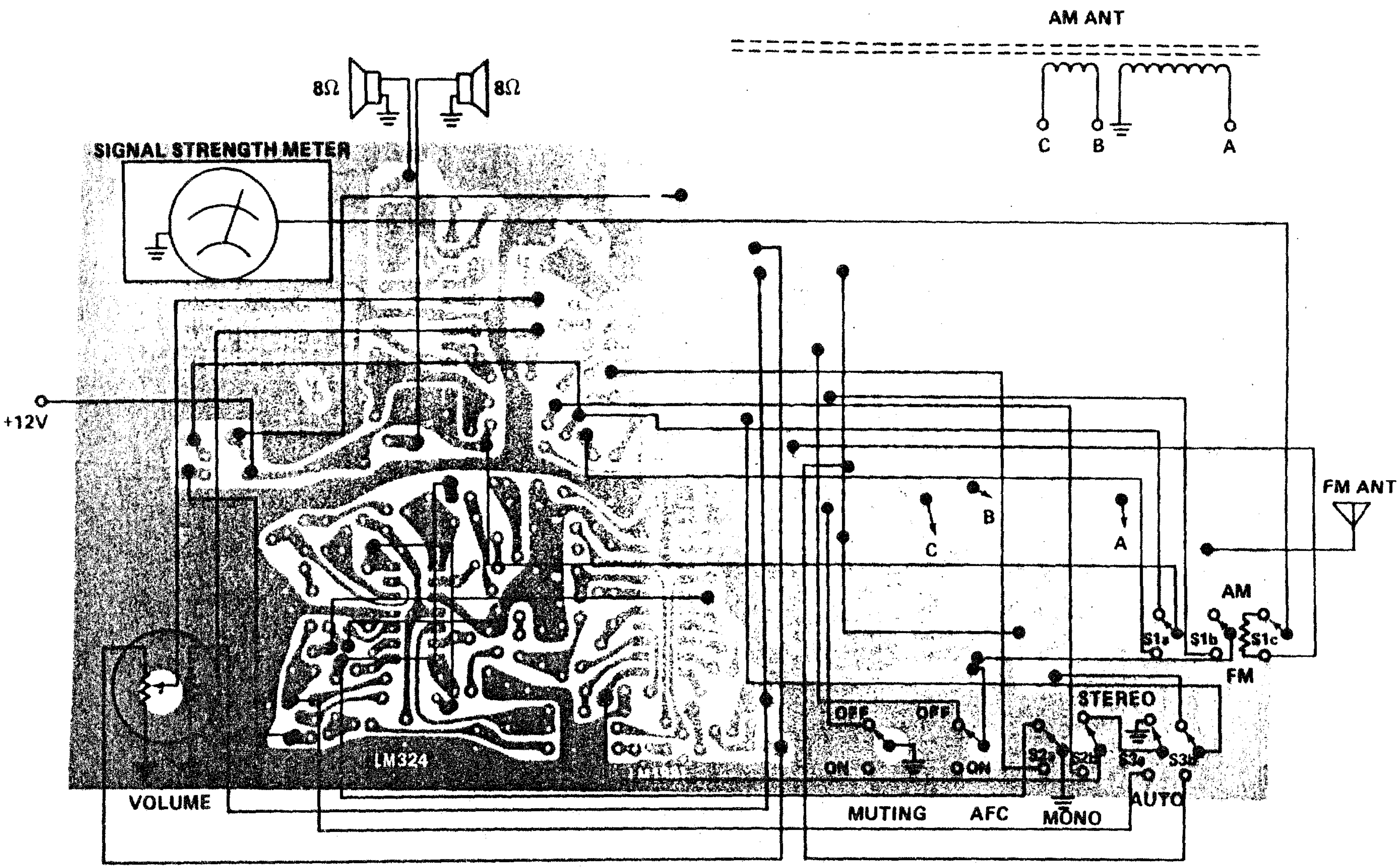

All diodes are 1N4148.
All resistors are in Ω.
All capacitors are in uF.
Unless specified.

**Fig. 1**




COMPONENT LAYOUT

(Component Side)




**WIRING DIAGRAM**

(Bottom View)

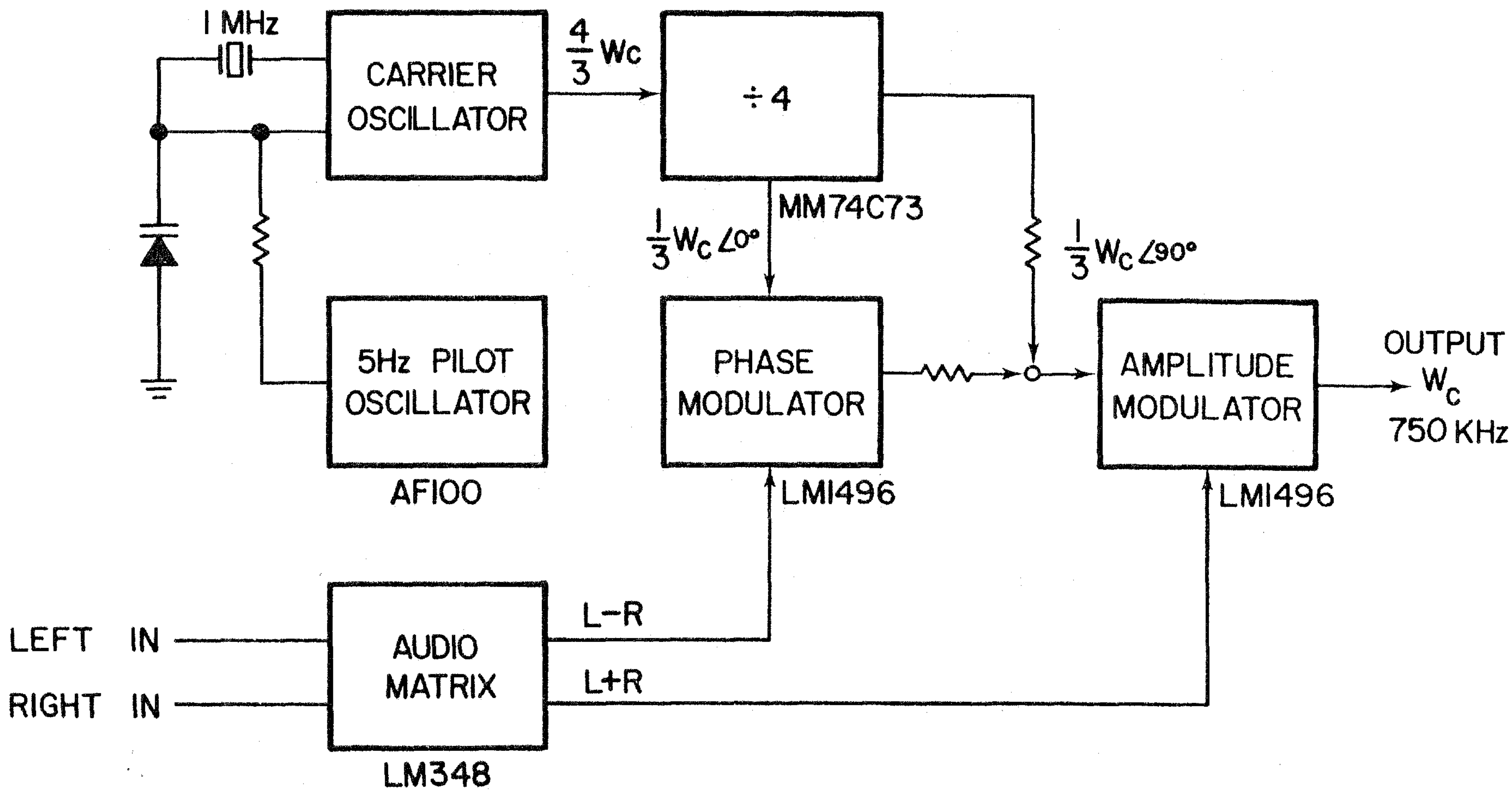
<u>THE AM STEREO TRANSMITTER</u>

AM stereo is a new broadcasting system and AM stereo station is not available in most places at the moment. In order to evaluate and test receiver decoder circuits, a source of program material is necessary. Fig. 2 shows a block diagram of a simple AM stereo transimtter which is designed for demonstration of AM stereo receivers. The transmitter consists of a crystal controlled oscillator, an Armstrong phase modulator, an audio matrix and an amplitude modulator. Its transmitting frequency is 750 KHz. A full detailed circuit diagram of the transmitter is shown in Fig. 3.

Adjustment of the generator may be made by applying sufficient audio signal to either the Left or Right input to obtain 1 radian of (L - R) modulation (the L + R channel switch off). The level can be verified by spectrum analyzer data — the carrier will decrease by 2.33dB below no modulation, and the first and second sidebands will be 4.77dB and 16.47dB below the carrier at 1 radian (100%). When this level is obtained, the L + R level can then be set for 100% modulation through the (10KΩ) trimmer at pin 4 of the amplitude modulator (LM1496).

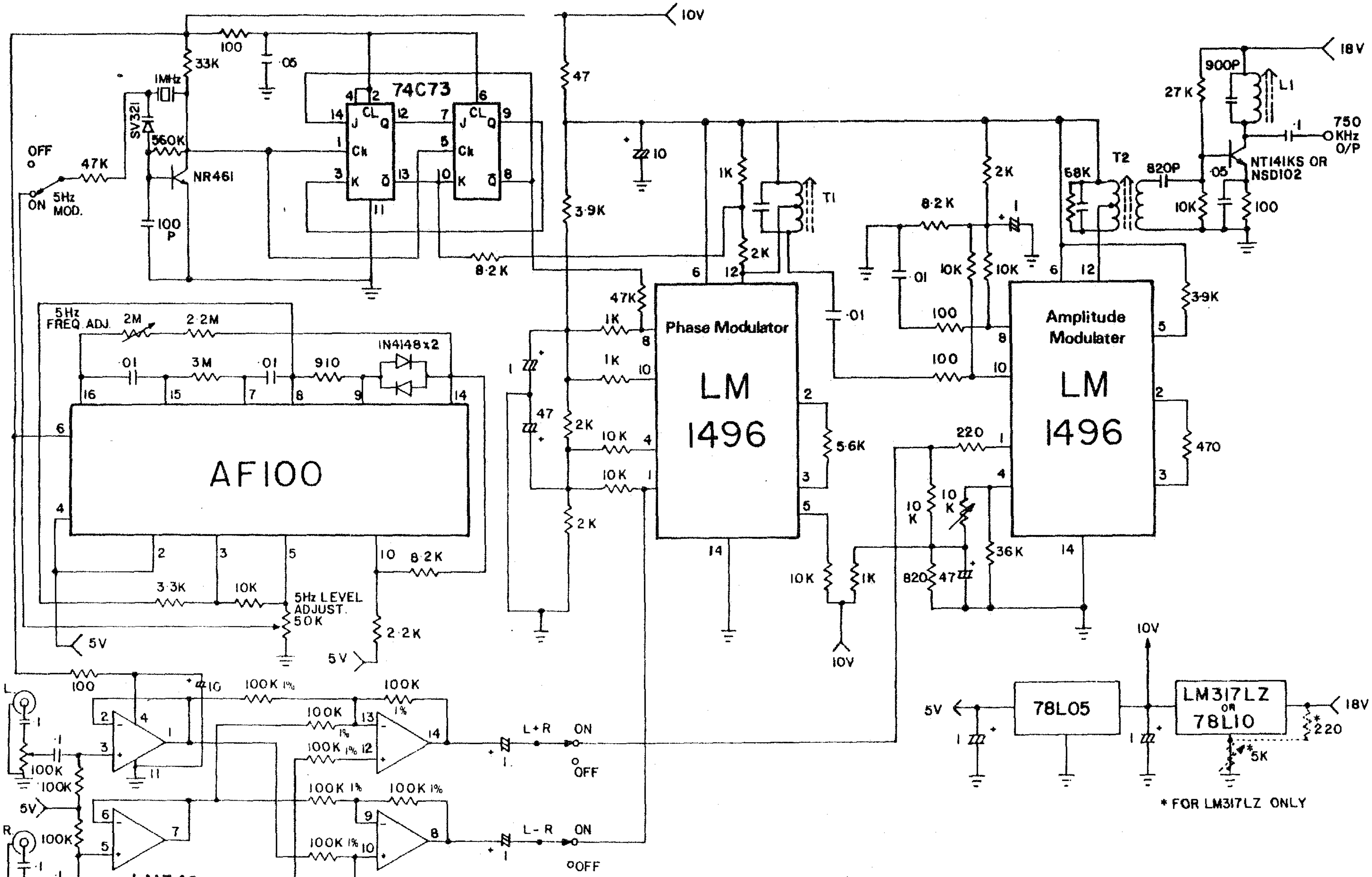
For those customers who do not have a spectrum analyzer readily available, they can simply apply an audio signal of 300 - 320mV at 1 KHz to either Left or Right channel input of the matrix network and adjust the 10KΩ trimmer at pin 4 of the amplitude modulator (LM1496) for 100% amplitude modulation. Under this condition, the phase modulator will also give a phase modulation of approximately 1 radian to the carrier. This approximation adjustment is true only if all the component values specified in the circuit are followed.

For maximum channel separation, the audio input level for Left and Right channels must be equal and the output level of the (L + R) and (L - R) signals for modulation must be matched as well. To achieve that the resistors used in the matrix circuit are required to be ±1% in tolerance.




Block diagram of AM stereo generator

**Fig. 2**



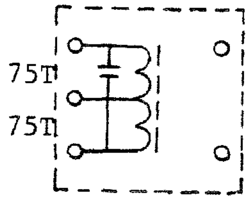

AM STEREO GENERATOR

**Fig. 3**

RESISTORS ARE IN OHMS AND CAPACITORS ARE IN UF, UNLESS SPECIFIED

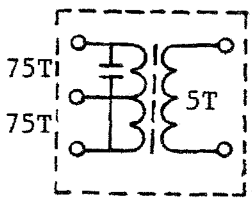
Coil Data For AM Stereo Generator

T1



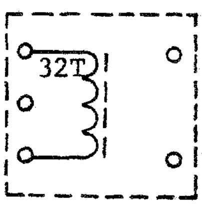

L = 670μH  $C_T$ = 470pF  Qμ = 120 ±15%
P/N 10A-062 (Jeckson Electric HK Ltd) or Equivalent

T2

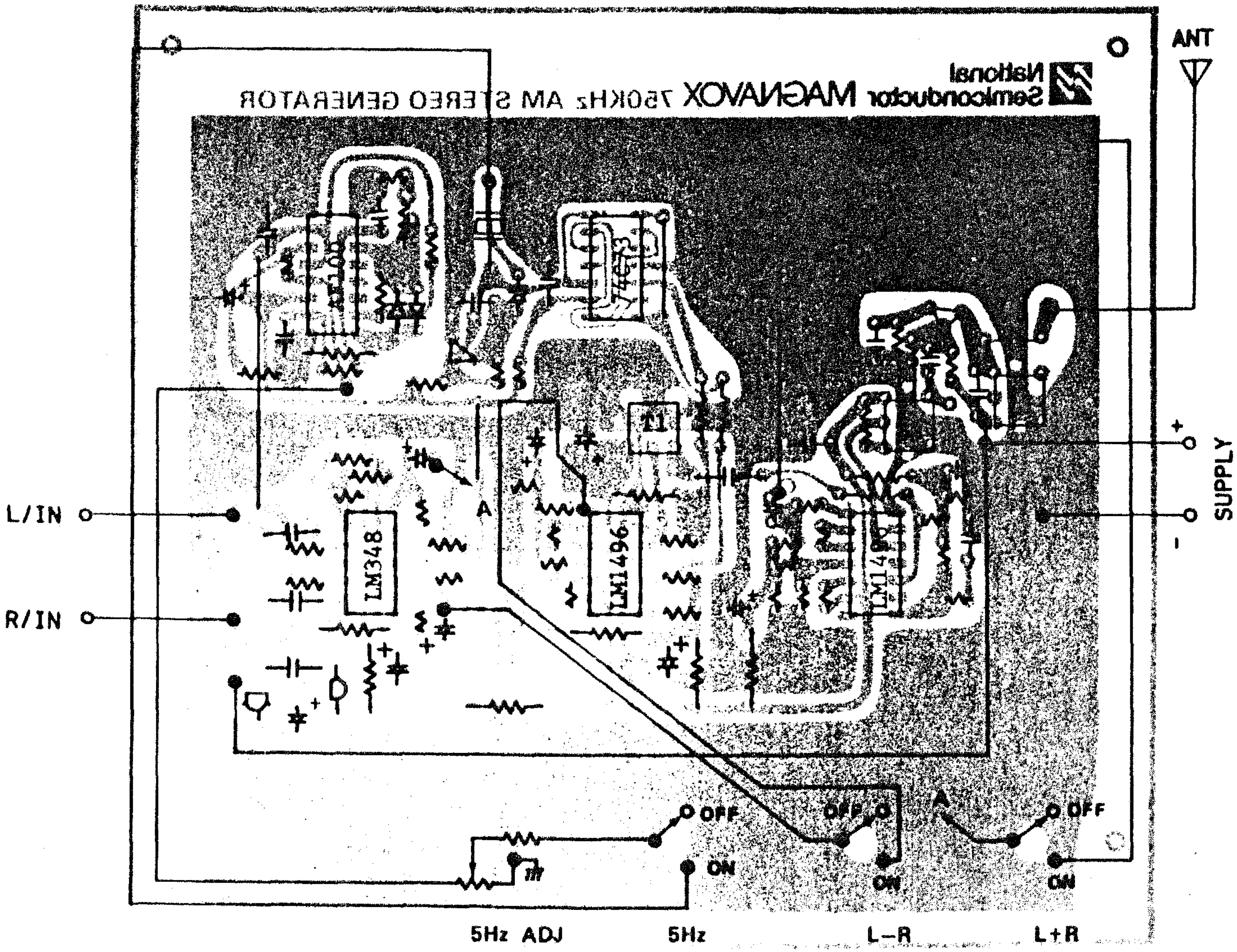



L = 670μH  $C_T$ = 68pF  Qμ = 130 ±15%
P/N 10A-061 (Jeckson Electric HK Ltd) or Equivalent

L1




L = 55μH  $C_{T(EXT)}$ = 900pF  Qμ= 120 ±15%
P/N 10MO-028 (Jeckson Electric HK Ltd) or Equivalent




COMPONENT AND WIRING DIAGRAM

(Component Side)