

# FM Remote Speaker System

National Semiconductor  
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FM Remote Speaker System

## INTRODUCTION

A high quality, noise free, wireless FM transmitter/receiver may be made using the LM566 VCO and LM565 PLL Detector. The LM566 VCO is used to convert the program material into FM format, which is then transformer coupled to standard power lines. At the receiver end the material is detected from the power lines and demodulated by the LM565.

The important difference between this carrier system and others is its excellent quality and freedom from noise. Whereas the ordinary wireless intercom uses an AM carrier and exhibits a poor signal-to-noise ratio (S/N), the system described here uses an FM carrier for inherent freedom from noise and a PLL detection system for additional noise rejection.

The complete system is suitable for high-quality transmission of speech or music, and will operate from any AC outlet anywhere on a one-acre homesite. Frequency response is 20–20,000 Hz and THD is under 1/2% for speech and music program material.

Transmission distance along a power line is at least adequate to include all outlets in and around a suburban home and yard. Whereas many carrier systems operate satisfactorily only when transmitter and receiver are plugged into the same side of the 120–240/V power service line, this system operates equally well with the receiver on either side of the line.

The transmitter is plugged into the AC line at a radio or stereo system source. The signal for the transmitter is ideally taken from the MONITOR or TAPE OUT connectors provided on component system Hi-Fi receivers. If these outputs are not available, the signal could be taken from the main or extra speaker terminals, although the remote volume would then be under control of the local gain control. The carrier system receiver need only be plugged into the AC line at the remote listening location. The design includes a 2.5W power amplifier to drive a speaker directly.

## TRANSMITTER

Two input terminals are provided so that both LEFT and RIGHT signals of a stereo set may be combined for mono transmission to a single remote speaker if desired.

The input signal level is adjustable by  $R_1$  to prevent over-modulation of the carrier. Adding  $C_2$  across each input resistor  $R_7$  and  $R_8$  improves the frequency response to 20 kHz as shown in *Figure 5*. Although casual listening does not demand such performance, it could be desired in some circumstances.

The VCO free-running frequency, or carrier frequency  $f_c$ , determined by  $R_4$  and  $C_4$  is set at 200 kHz which is high enough to be effectively coupled to the AC line. VCO sensitivity under the selected bias conditions with  $V_S = 12V$  is about  $\pm 0.66 f_c/V$ . For minimum distortion, the deviation should be limited to  $\pm 10\%$ ; thus maximum input at pin #5

of the VCO is  $\pm 0.15V$  peak. A reduction due to the summing network brings the required input to about 0.2V rms for  $\pm 10\%$  modulation of  $f_c$ , based on nominal output levels from stereo receivers. Input potentiometer  $R_1$  is provided to set the required level. The output at pin #3 of the LM566, being a frequency modulated square wave of approximately 6V pk-pk amplitude, is amplified by a single transistor  $Q_1$  and coupled to the AC line via the tuned transformer  $T_1$ . Because  $T_1$  is tuned to  $f_c$ , it appears as a high impedance collector load, so  $Q_1$  need not have additional current limiting. The collector signal may be as much as 40–50V pk-pk. Coupling capacitor  $C_8$  isolates the transformer from the line at 60 Hz.

A Voltage regulator provides necessary supply rejection for the VCO. The power transformer is sized for peak secondary voltage somewhat below the regulator breakdown voltage spec (35V) with a 125V line.

## RECEIVER

The receiver amplifies, limits, and demodulates the received FM signal in the presence of line transient interference sometimes as high as several hundred volts peak. In addition, it provides audio mute in the absence of carrier and 2.5W output to a speaker.

The carrier signal is capacitively coupled from the line to the tuned transformer  $T_1$ . Loaded Q of the secondary tank  $T_1C_2$  is decreased by shunt resistor  $R_1$  to enable acceptance of the  $\pm 10\%$  modulated carrier, and to prevent excessive tank circuit ringing on noise spikes. The secondary of  $T_1$  is tapped to match the base input impedance of  $Q_{1A}$ . Recovered carrier at the secondary of  $T_1$  may be anywhere from 0.2 to 45V p-p; the base of  $Q_{1A}$  may see pk-to-pk signal levels of from 12 mV to 2.6V.

$Q_{1A}$ – $Q_{1D}$  operates as a two-stage limiter amplifier whose output is a symmetrical square wave of about 7V pk-pk with rise and fall times of 100 ns.

The output of the limiting amplifier is applied directly to the mute peak detector, but is reduced to 1V pk-pk for driving the PLL detector.

The PLL detector operates as a narrow band tracking filter which tracks the input signal and provides a low-distortion demodulated audio output with high S/N. The oscillator within the PLL is set to free-run at or near the carrier frequency of 200 kHz. The free-run frequency is  $f_o \approx 1/(3.7 R_{16}C_{13})$ . Since the PLL will lock to a carrier near its free-run frequency, an adjustment of  $R_{16}$  is not strictly necessary;  $R_{16}$  could be fixed at 4700 or 5100 $\Omega$ . Actually, the PLL with the indicated value of  $C_{11}$  can lock on a carrier within about  $\pm 40$  kHz of its center frequency. However, rejection of impulse noise in difficult circumstances can be maximized by carefully adjusting  $f_o$  to the carrier frequency  $f_c$ . Adding

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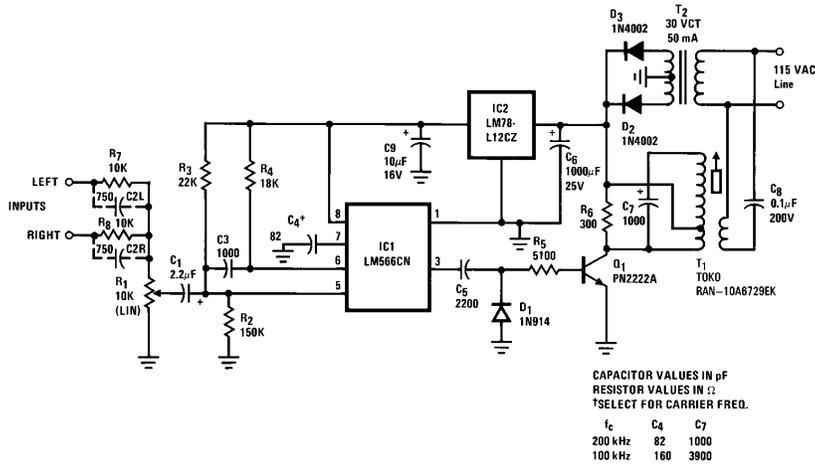


FIGURE 1. Carrier System Transmitter

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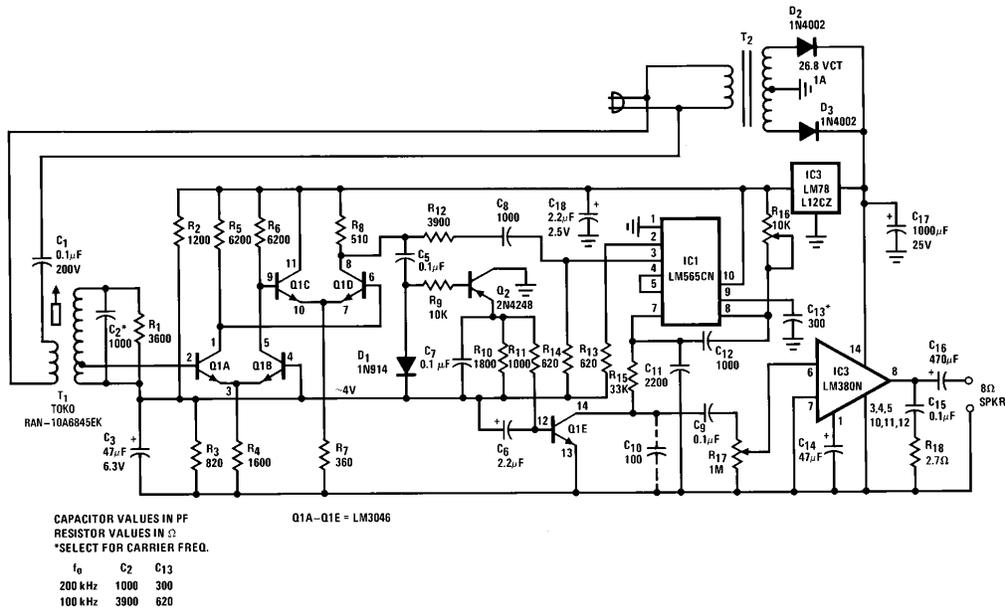


FIGURE 2. Carrier System Receiver

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$C_{10} = 100 \text{ pF}$  will reduce the carrier level fed to the power amplifier. Even though the listener cannot hear the carrier, the audio amplifier could overload due to carrier signal power.

A mute circuit is included to quiet the receiver in the absence of a carrier. Otherwise, when the transmitter is turned OFF, an excessive noise level would result as the PLL attempts to lock on noise. The mute detector consists of a voltage doubling peak detector  $D_1Q_2C_7$ . The peak detector shunts the 1–2 mA bias away from  $Q_{1E}$  without loading the limiter amplifier. When no carrier is present, the +4V line biases  $Q_{1E}$  ON via  $R_{10}$  and  $R_{11}$ ; and the audio signal is shorted to ground. When a carrier is present, the 7V square wave from the limiter amplifier is peak detected\*, and the resultant negative output is integrated by  $R_9C_7$ , averaged by  $R_{10}$  across  $C_7$ , and further integrated by  $R_{11}C_6$ . The resultant output of about -4V subtracts from the +4V bias supply, thus depriving  $Q_{1E}$  of base current. Peak detector integration and averaging prevents noise spikes from deactivat-

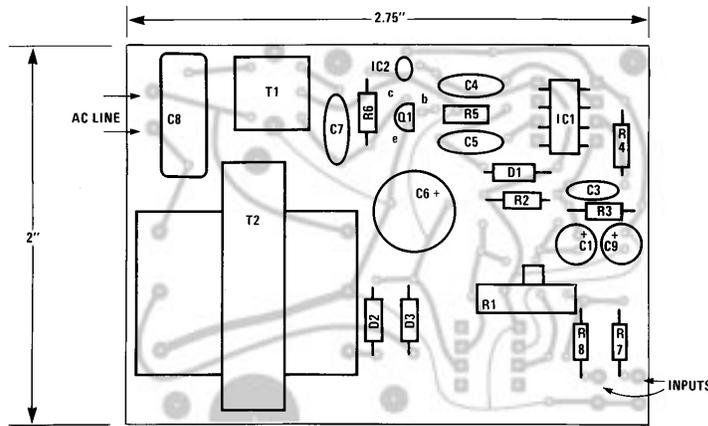
ing the mute in the absence of a carrier when the limiter amplifier output is a series of narrow 7V spikes.

The LM380 supplies 2.5W of audio power to an 8Ω load. Although this is adequate for casual listening in the kitchen or garage, for hi-fi listening, a larger amplifier may be direct.

### CONSTRUCTION

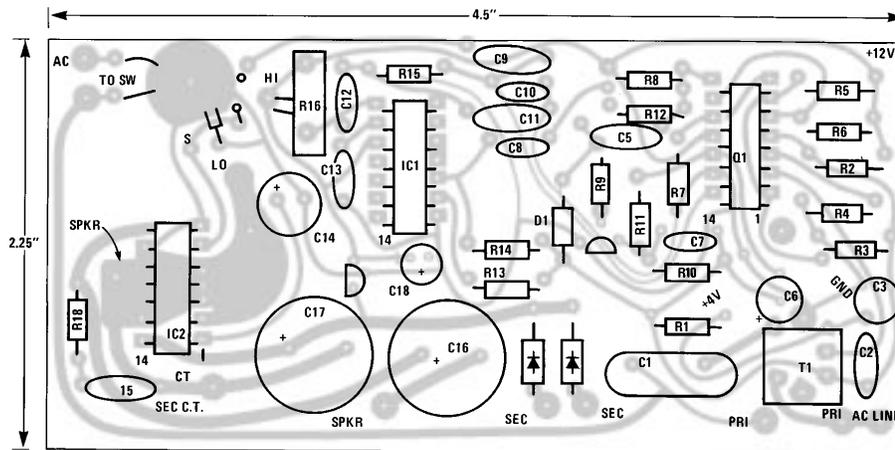
PC board layout and stuffing diagrams are shown in *Figures 3 & 4*. After the receiver board has been loaded and checked, the power transformer is mounted to the foil side of the board with a piece of fish-paper or electrical insulating cloth between board and transformer. Insulating washers of 1/16–1/4 inch thickness can be used to advantage in holding the transformer away from the foil. The board is laid out so that the volume control potentiometer may be mounted on either side of the board depending on the desired mounting to a panel.

The line coupling coils are available in production quantities from TOKO AMERICA, INC. 1250 Feehanville Drive, Mount Prospect, IL 60056. TEL: (312) 297-0070



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FIGURE 3. Carrier System Transmitter PC Layout and Loading Diagram (Not Full Scale)



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FIGURE 4. Carrier System Receiver PC Layout and Loading Diagram (Not Full Scale)

**ADJUSTMENT**

Adjustments are few and extremely simple. Transmitter carrier frequency  $f_c$  is fixed near 200 kHz by  $R_4$  and  $C_4$ ; the exact frequency is unimportant.  $T_1$  for both transmitter and receiver are tuned for maximum coupling to and from the AC line. Plug in both receiver and transmitter; no carrier modulation is necessary. Insure that both units are operative. Observe or measure with an AC VTVM the waveform at  $T_1$  secondary in the receiver. Tune  $T_1$  of the transmitter for maximum observed signal amplitude. Then tune  $T_1$  of the receiver for a further maximum. Repeat on the transmitter, then the receiver. Tuning is now complete for the line coupling transformers and should not have to be repeated for either. If the receiver is located some distance from the transmitter in use, or on the opposite side of the 110–220V service line, a re-adjustment of the receiver  $T_1$  may be made to maximize rejection of SCR dimmer noise. The receiver PLL free-running frequency is adjusted by  $R_{16}$ . Set  $R_{16}$  near the center of its range. Rotate slowly in either direction until the PLL loses lock (evidenced by a sharp increase in noise and a distorted output). Note the position and then repeat, rotating in the other direction. Note the new position and then center  $R_{16}$  between the two noted positions. A fine adjustment may be made for minimum noise with an SCR dimmer in operation. The final adjustment is for modulation amplitude at the transmitter. Connect the audio signal to the transmitter input and adjust the input potentiometer  $R_1$  for a signal maximum of about 0.1V rms at the input to the LM566. Adjustment is now complete for both transmitter and receiver and need not be repeated.

**A STEREO SYSTEM**

If full stereo or the two rear channels of a quadraphonic system are to be transmitted, both transmitter and receiver must be duplicated with differing carriers. Omit  $R_8$  and include  $R_7$  &  $C_2$  on the transmitter if desired. Carriers could be set to 100 and 200 kHz for the two channels. Actually, they need only be set a distance of 40 kHz apart.

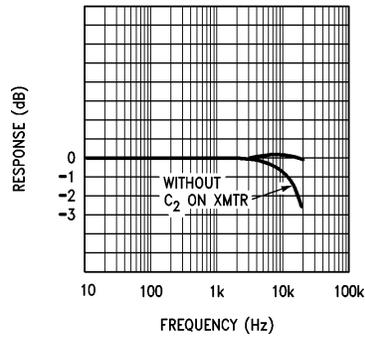
**PERFORMANCE**

Overall S/N is about 65 dB. Distortion is below about 1/4% at low frequencies, and in actual program material it should not exceed 1/2% as very little signal power occurs in music above about 1 kHz.

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



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**FIGURE 5. Overall System Performance  
Transmitter Input to Input of Receiver Power Amplifier**

The 2.5W audio amplifier provides an adequate sound level for casual listening. The LM380 has a fixed gain of 50. Therefore for a 2.5W max output, the input must be 89 mV. This is slightly less than the  $\pm 10\%$  deviation level so we are within design requirements. Average program level would run a good 10 dB below this level at 28 mV input.

Noise rejection is more than adequate to suppress line noise due to fluorescent lamps and normal line transients. Appliance motors on the same side of the 110–220V line may produce some noise. Even SCR dimmers produce only a background of impulse noise depending upon the relative location of receiver and SCR. Otherwise, performance is noise-free anywhere in the home. Satisfactory operation was observed in a factory building so long as transmitter and receiver were connected to the same phase of the three-phase service line.

**APPLICATIONS**

Additional applications other than home music systems are possible. Intercoms are one possibility, with a separate transmitter and receiver located at each station. A microphone can serve as the source material and the system can act as a monitor for a nursery room. Background music may be added to existing buildings without the expense of running new wiring.



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