

# TRICOLOR LIGHT EMITTING DIODE DOT MATRIX DISPLAY SYSTEM WITH AUDIO OUTPUT

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## ABSTRACT

In this paper, a novel tricolor dot matrix display system in which all the LEDs are modulated and encoded with audio information is presented. The novelty is on the concurrent use of the tricolor LEDs for simultaneous visual message display and audio signal transmission in a free space optical link. The system is comprised of a tricolor LED dot matrix display panel with an interface circuit to a computer, an audio signal transmitter, and a receiver. The system further comprises an executive program that runs on the computer for the display control of characters, decorative pattern or messages on the display panel. The receiver, combined with a speaker, is located at some distance from the display system. The receiver is designed to demodulate the optically transmitted audio information and reproduce the messages with the speaker. For modulating emission of tricolor LEDs, an oscillator is used to vary the frequency of on/off periods of the LEDs. The frequency of flicker is high enough to be indistinguishable by human eye and hence display appears to be constantly illuminated. This is a new generation of tricolor LED dot matrix display where in addition to the usual function of LED display, they concurrently provide audio broadcasting through the visible light rays transmitted by the display panel or assembly.

**Keywords:** light emitting diodes; tricolor display; audio communication.

## I. Introduction

This paper relates to a tricolor dot matrix display that provides visual signals for transmitting audio information to a receiver located some distance away from the display system. The basic idea is based on the fact that LEDs are semiconductor devices and are capable of fast switching with the

addition of appropriate electronics. That is, the visible light emitted by the LEDs can be modulated and encoded with audio information. Therefore, in addition to their normal function of indication and illumination, LEDs can be used as a communication device for the transmission of audio information. Optical signals have been used for communication and information processing in the field of fiber optics for many years. In this paper, a different use of optical signals for communication is described. As for dot matrix display, the basic working principle is that information is encoded in each row. Each glowing row will transmit a portion of the information. As long as the receiver can cover all rows, the complete information is received as if it is transmitted from a single source.

There has been rapid advance in the LED technology in recent years. Today, visible light LEDs can reach a luminous efficacy beyond 15 lm/W, which is typical for incandescent lamps [1]. Even higher performance can be achieved in the yellow-orange spectral range. The AlInGaP technology has produced high brightness LEDs from red-orange to green. [2,3] This advancement has led to the production of large-area full-color LED displays for outdoors, as well as many new applications in the industry.

There are a wide range of applications that require monochrome, bicolor, and full-color graphics and alphanumeric displays. For outdoors, they include highway message signs, traffic lights, billboards, advertising signs, bus and train signaling signs. When used for indoors, LEDs are used at airport terminal signs, bus and train station signs, exit signs, one-line scrolling advertising signs, stock market signs etc. In all the above, LEDs are used for signaling as an illumination device. This paper describes a novel use of LEDs. The idea is to

modulate the visible light emitted from the LEDs for communication purpose [4]. This concurrent use of LEDs for simultaneous signaling and communication leads to many new applications. In this paper, a new type of LED dot matrix display that can provide audio broadcasting is described.

LEDs have been used as basic components in dot matrix display for years. Some researchers have worked on improved light emitting diode display that includes a printed circuit board, a reflector and one or more LED chips [5]. The parabolic reflector surrounding the surface is used to collimate light waves emitted by LEDs along the axis of parabola. However, no work has been reported regarding its use for simultaneous audio transmission. The work reported in this paper differs from the use of infrared (IR) radiation as a medium for short-range wireless communications [6,7]. Currently, infrared links and local-area networks are available. IR transceivers for use as IR data links are commercially available at economic prices. Comparison between the infrared and other media such as radio and microwave is given in [8]. Somehow, there has been very little work on the use of visible light as a communication medium. Recent availability of high brightness LEDs makes the visible light medium even more feasible now. Essentially, all products with visible LED components (like LED traffic signal head) can be turned into an information beacon. This paper focuses on its use for audio transmission through a dot matrix display.

## **II. System description**

This paper describes the concurrent use of tricolor light emitting diode (LED) display for simultaneous signaling and broadcasting of audio information. It relates to a dot matrix tricolor LED display panel or any tricolor LED display assembly for providing a visual signal in the form of light rays and for using the light rays to transmit information. It is a very versatile dot matrix display of characters (Chinese or English), picture, graphics or any decorative pattern. The LED display is controlled with a computer through a hardware interface. An executive program runs on the computer for the visual display and control of characters, decorative patterns or messages on the display panel. The system is comprised of a transmitter and a receiver. The transmitter consists of an audio signal source that provides the audio information to be transmitted by the display assembly. The key component of the transmitter is a modulator that includes a voltage-controlled

oscillator (VCO) for varying the on/off frequency of light emitting diodes on the dot matrix display. The frequency is high enough so that the perceivable light appears to be constantly illuminated to the human eye.

The receiver consists of a lens system for focusing the light waves from the tricolor LEDs to the photo detector. The optical link employs intensity modulation of LEDs with direct detection. With appropriate electronics, the information in the light ray is demodulated to detect the audio signal, which is reproduced with a speaker for the broadcasting and announcement of the audio messages. The advantages of this circuit over single color LED displays are as follows:

### **(a) Tri-color LEDs**

As tri-color LEDs are used, the background of the display can also be lighted up using a color which is different from the main character to be displayed. Yet the LEDs from the same row will be transmitting the same information. So for the receiver, there will always be LED lit up in each row and so it will receive information from each row at any time, and no information would be lost. Also, the pattern or graphics displayed will be more attractive and flexible as more colors can be added for the display in each panel.

### **(b) Brightness**

With all LEDs glowing, the brightness of transmitter is dramatically enhanced. This makes the audio transmission more effective and immune to noise as the attenuation in the medium becomes negligibly small for line-of-sight (LOS) reception. Also, the receiver's distance from the transmitter can be increased.

### **(c) Lowercase characters**

As the background is lighted up, the characters displayed will not be confined to the set that does not have an inactive row. In particular, lowercase characters (e.g. "i") can be displayed without loss of any information during transmission.

### **(d) One column coverage is sufficient**

As virtually all the LEDs are lighted up in the course of pattern display, and each LED in a single row is transmitting exactly the same information, the receiver in principle needs to locate one column to receive all information. This will relax the previous restriction that the lens used in the receiver should cover all columns.

### III. Audio broadcasting using the tricolor LED display system

A block diagram of the tricolor light emitting diode dot matrix display system is shown in Figure 1. The visible light from the LED display panel is used for transmitting information in addition to providing a visual signal. The display is linked to a computer through an interface circuit, which provides the control of characters to display and the addition of audio signals.

The LED display has a plurality of tricolor LEDs for transmitting an optical signal. The display, which acts as a transmitter, includes a voltage-controlled oscillator (VCO) for varying the switching frequency of light emitting diodes on the dot matrix display. The on/off frequency is high enough such that the perceivable light appears to be constantly illuminated to the human eye. The present system has achieved to modulate the visual light rays emitted by the LEDs for the transmission of audio information. As shown in figure 2, the transmitter provides a modulated audio signal from a cassette tape player or CD player by frequency modulation (FM). The receiver makes use of a photo-detector to detect high frequency variations in the light flux. This detected signal is passed to appropriate amplifying and detecting stages to reproduce audio signal transmitted. Both the transmitter and the receiver require low power supply, which increases transportability of the system. As the majority of the circuitry is TTL based, power supply requirements are in the vicinity of five volts.

Referring to Figure 2, the audio output from the cassette tape or CD player has small amplitude and hence amplification of this audio signal is necessary. The audio amplifier is used to amplify the weak audio signal and to shift the average voltage level of the audio signal to an appropriate level so that the signal is suitable for input to the voltage controlled oscillator (VCO).

Incoming audio signal modulates the VCO and generates FM signal at the output, according to change in voltage level of the signal. A VCO chip is used. A square wave VCO is used instead of sine wave because there are only two states (ON and OFF) for the LEDs. The carrier frequency is set at 100 KHz with a maximum frequency deviation of  $\pm 50$  KHz. The modulated signal is transmitted by the switching of the LEDs, through a driving

circuit.

A block diagram representation of the receiver design is shown in Figure 3. The circuit of the receiver is divided into eight portions. The photo-detector is used to detect modulated light signal from the transmitter and convert the signal into an electrical signal. The limiting pre-amplifier is used to amplify the electrical signal from the photo-detector for the next stage. Pulse shaping and detecting circuits are used to reconstruct the square wave. Square wave pulses from previous output stages are differentiated and its negative trailing edges are clipped when transmitted through a diode. Next, a pulse generator is used to convert the pulses from the differentiator into sharp pulses, to be used by the integrator and envelope detector in the next stage for the demodulation of the signal. The band-pass filter is then used to smooth out the distortions from the integrator and envelope detector to produce an appropriate waveform. Finally, an audio power amplifier is used to amplify the weak signal from the band-pass filter so that the audio signal would be comfortable for hearing. A speaker, head phone or ear jack can be used for the delivery of the audio messages or music sent from the transmitter. The receiver can be battery powered, or powered by any electrical system.

The interface circuit, which is connected to the parallel port of the computer, is shown in Figure 4. There are seven parts for this circuit. Below is a description of the major components:

- Row Counter Decode System - The counter is driven by the information signal, and a decoder would select the row for display.
- Segment Counter Decode System - This contains a counter, driven by a fast oscillator, and a decoder for color/segment selection.
- Pattern Storage System - SRAM is used to store the desired pattern for each row and segment color of the displayed characters.
- Address Comparison Unit - It compares the system-generated address against the address sent out by the computer. It contains a bit comparator and a register. This register is to hold the data until the system is ready to write the data to the SRAM.
- Status Indicator - It contains a D-type flip-flop with Asynchronous inputs of Preset and Clear. The non-inverted flip-flop output pin (strobe pin) is used for indication of a successful write. On such

occasion, this pin will be set high and enables the computer so send next data.

- **LED Display Unit** - It temporarily stores the LED information and hold the LEDs in place. This unit also contains registers to isolate the LEDs with the circuit. Figure 5 gives a schematic of a tricolor LED dot matrix array. In order for a light emitting diode to be on, the corresponding row signal should be high and associated segment selection signal should be low.
- **Parallel Port**- This is the interface to the hardware electronics. Data and control signals are sent out from this port and strobe (status) information is delivered to the computer via this port.

#### IV. Special features of the tricolor display

##### 4.1 Timing signal for information update

There are two main techniques in this design of the tricolor display.

- (a) A fast clock used with the information signal

There are two timing signals in the system. The first one is the information signal. As in the previous design, whenever the information signal changes, the active row will also be changed. In short, the row represents a bit of information. 100 KHz information signal is used in the current implementation. Audio signal is modulated into this signal which occupies frequency range of  $(100 \pm 44.1)$  KHz.

The other timing signal is derived from an oscillator. In this implementation, 12MHz oscillator frequency is used. This signal is used to switch between different segments (i.e. different colors in different characters). It must switch at much higher rate than the information signal so that before the information signal is changed (i.e. before the active row is switched), all the segments should have been scanned at least once and updated. Otherwise, some segments will not be lit as expected.

While the common (row) is changed at a frequency of the information signal (e.g. 100kHz), the segment ("column") is changed at a higher frequency of about 12MHz. However, this 12MHz will be divided by the counter (since it acts as a frequency divider also) and the counter output is in fact running at 6MHz only. In addition, only half of the 100kHz period is used for segment selection. Therefore, during the period that a row is active,

the number of times the segment address is changed is:

$$\frac{6\text{MHz}}{100\text{KHz}} * \frac{1}{2} = 30$$

Each segment has about three times to be updated. Actual number of times depends on the information signal that can be changed from time to time.

- (b) Updating is carried out during the period when the LEDs are off

This circuit is synchronized with the information signal at any time, including the time when the patterns are updated. The technique is to do the updating when the row is not active. Then no noise will be heard because no data will be transmitted during the pattern update process.

##### 4.2 Pattern update

The register is used for storing the display data. The comparator would be used for comparing with the system-generated address, and it would be driven low to put the data stored in the register to the input data pins of the SRAM when there is a match. The matched address would be already loaded in the address pins of the SRAM. The matched event will trigger the write enable pin of the SRAM, causing the data to be written to the SRAM at that particular address. Another pin affected is the strobe pin at the output of a flip-flop. The pin is enabled high by the event, which will indicate to the computer that the write has been successful and it could continue to write the next data.

##### 4.3 Pattern update

The first part of the address for the data is from the information signal that specifies the row at which the LEDs are active. The other part is from the 12MHz oscillator that specifies the segment for which data is to be latched to the display register. The data address is then loaded in the SRAM for data request. After the data is retrieved, it is loaded in the appropriate display register and is displayed.

##### 4.4 Software for display and pattern update

A software program is used for the display control and pattern update. For the write cycle, data is first put onto the bus and latched. The corresponding address is then loaded in the same bus and compared with the system-generated address. If they are matched, data is written in the

SRAM at the corresponding address. A signal is sent back to the computer, indicating a successful write.

Display effects such as scrolling and running can be carried out as follows. Suppose there is a five character buffer, with the first four in the active display window (i.e. data contained will be transmitted to the dot matrix display). The fifth character buffer is introduced to accommodate the next character to be displayed because as the text is scrolled, the data from the fifth character is required. Source codes have been written to shift the data logically to the left to generate the scrolling effect.

A special character data set used for the tricolor display has been used. The 6 x 6 characters are used on an 8 x 8 display so that the characters can be clearly distinguished when two characters are put side by side. The residue LEDs form a border around the character, which are displayed as background color.

## V. Applications of the LED dot matrix display

The tricolor LED dot matrix display with audio output can be applied to a large variety of applications. As shown in Figure 6, the LED display system can include a table, a target such as a person standing in a room in front of the table, an LED display and a receiver. Typically, an exhibit or any physical object is placed on the table. The indoor environment can be a room in a museum. The guest holding the portable receiver with an ear jack can listen to the audio messages transmitted through the LEDs of the dot matrix display. A quiet atmosphere can be maintained while the guests stroll around in the room. A major advantage over conventional broadcasting system is that an individual with a receiver has the freedom of choice in receiving specific messages without hearing any unwanted announcement, music or commercials.

In another application in an exhibition hall as shown in Figure 7, the information on individual product or specific announcement of the company can be broadcast via the LED dot matrix display. When the visitor is looking at display panel, he is automatically in the line of sight and thus receives audio messages about the specific announcement. Thus, the sound level of the exhibition hall can be minimized.

In front of any business or commercial installations, it is common to find LED dot matrix displays which visually show some messages or announcements (Figure 8). The light emitted from the LEDs in the display can be used to optically transmit audio information to the user with a receiver located some distance away from the display system. Thus, the visual display can also transmit audio information simultaneously. Hence, all commercial billboards can be used to transmit additional information such as daily specials, discount, latest attractions or any merchandise, reservation telephone number etc. for advertisement purpose.

## VI. Implementation and Results

The tricolor LED dot matrix display system described in this paper has been implemented in the Industrial Automation Laboratory at The University of Hong Kong. Figures 9 and 10 are photographs of the tricolor dot matrix display and receiver implemented respectively. The display consists of an 8 by 8 LED dot matrix. The receiver was placed at two meters away from the display and satisfactory audio output was obtained. Without a 50 mm focusing lens in front of the photodiode, the distance has reduced to 40 cm. It should be noted that the type of tricolor LED used for the construction of the implemented dot matrix display is commonly available. Large audio transmission range can be achieved by employing high brightness tricolor LEDs [1,3]. It is found that audio signal transmission can also be achieved outdoors. The positions of the transmitter and receiver were essentially stationary. However, performance will not degrade with normal relative motion between the two as long as dopplar shift is negligible.

The specifications of the tricolor dot matrix display is given below:

Color	red, green, orange
Construction	64 tricolor LEDs
Size	4 cm square
Nominal usage	5 V; 0.24 A
Nominal power consumption	1.2 W
Luminous intensity	180 cd
Viewing angle $2\theta_{1/2}$ (half power)	80 degrees
Distance for audio transmission (indoors)	40 cm (no lens); 200 cm (with focusing lens)

## VII. Conclusions

A tricolor light emitting diode (LED) dot matrix display system which provides a visual signal and uses the visual light rays for transmitting audio messages to a remotely located target is described. The display characters (Chinese or English, uppercase or lowercase), picture, graphics or any decorative pattern can be conveniently implemented. Scrolling of the pattern on the LED display panel is allowed. During pattern updates, no noise is received at the receiver. The receiver needs to cover only one column in order to recover all information transmitted from the dot matrix display. A software program is used to control the tricolor LEDs in each row and column of the display panel to display the desired pattern.

The LED dot matrix display described in this paper belongs to a new generation of dot matrix displays, as the visual light emitted from the display contains audio messages. It has long been realized that visible light has the potential to be modulated and used as a communication channel with high entropy. This application makes use of free space as communication medium and the receiver is required to be in LOS with the transmitter. The locations of the audio signal broadcasting system and the receiver were relatively stationary, and performance will not degrade as the dopplar frequency shift is negligible with normal relative motion. It should be noted that the transmitter provides easy target for the line-of-sight reception by the receiver. This is because the LEDs, being on all times, are also

indicators of the locations of the transmitter. This development can lead to many new applications in the industry. With diverse commercial and industrial applications the experimental results in this paper have demonstrated that the proposed idea is totally feasible.

## References

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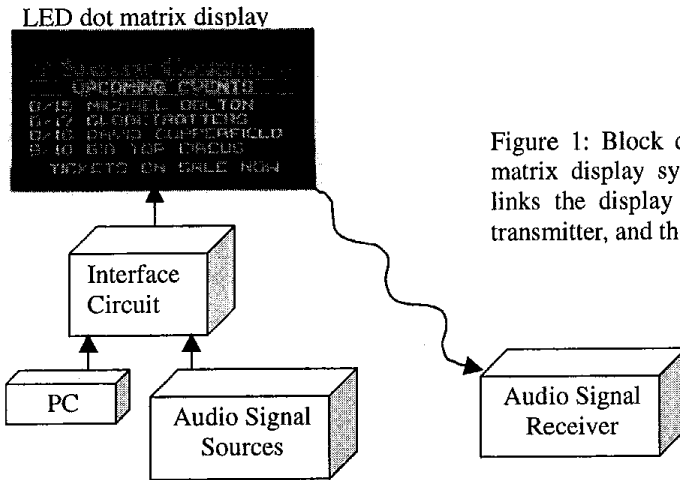


Figure 1: Block diagram of the tricolor LED dot matrix display system, an interface circuit which links the display to a computer, an audio signal transmitter, and the companion receiver.

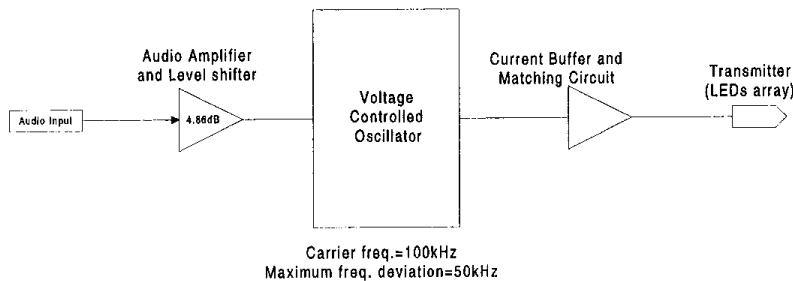


Figure 2: Block diagram representation of the schematic diagram of the audio signal transmitter.

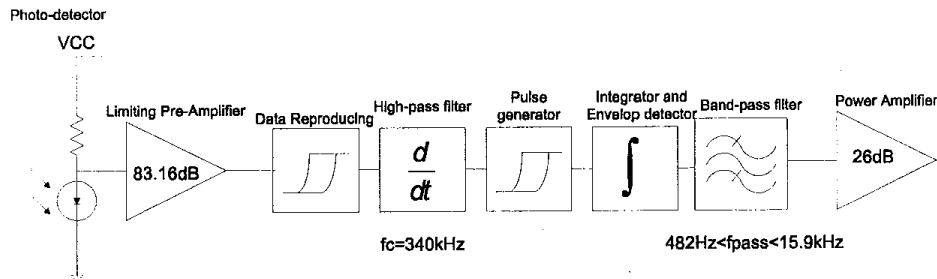


Figure 3: Block diagram representation of the receiver.

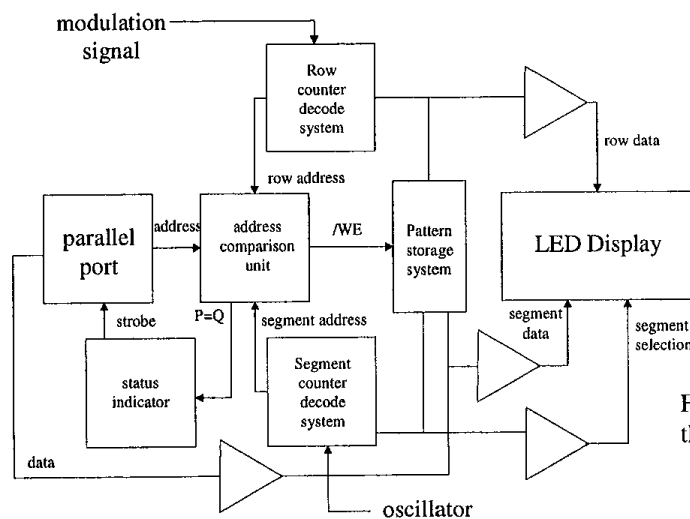


Figure 4: Circuit diagram of the interface design.

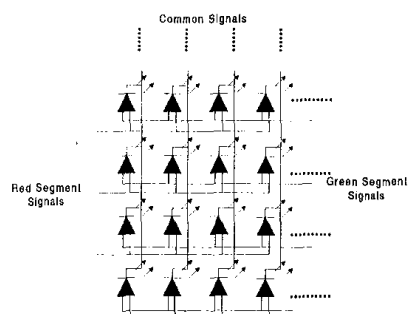


Figure 5: Schematic of a tricolor dot matrix display using light emitting diodes.

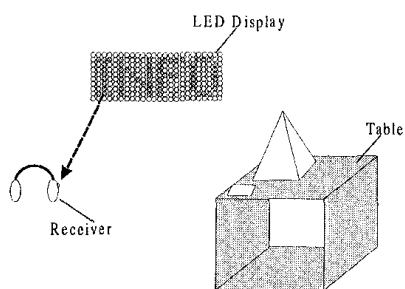


Figure 6 : A perspective view of the present system in a museum environment.

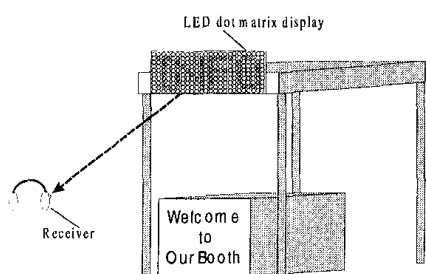


Figure 7: A perspective view of the present system in an exhibition hall environment.

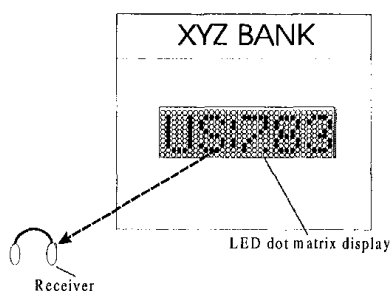


Figure 8: A perspective view of the present system used outside a business or financial institution.

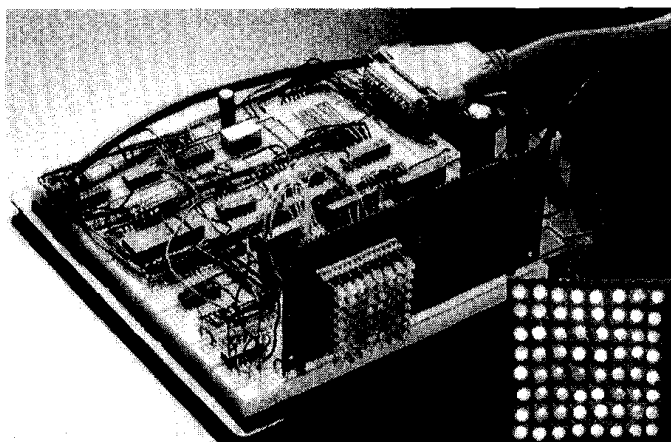


Figure 9: Photograph of the tricolor LED dot matrix display.

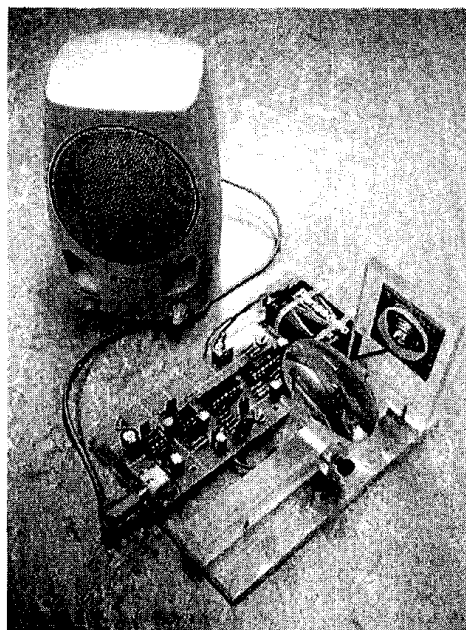


Figure 10: Photograph of the receiver.