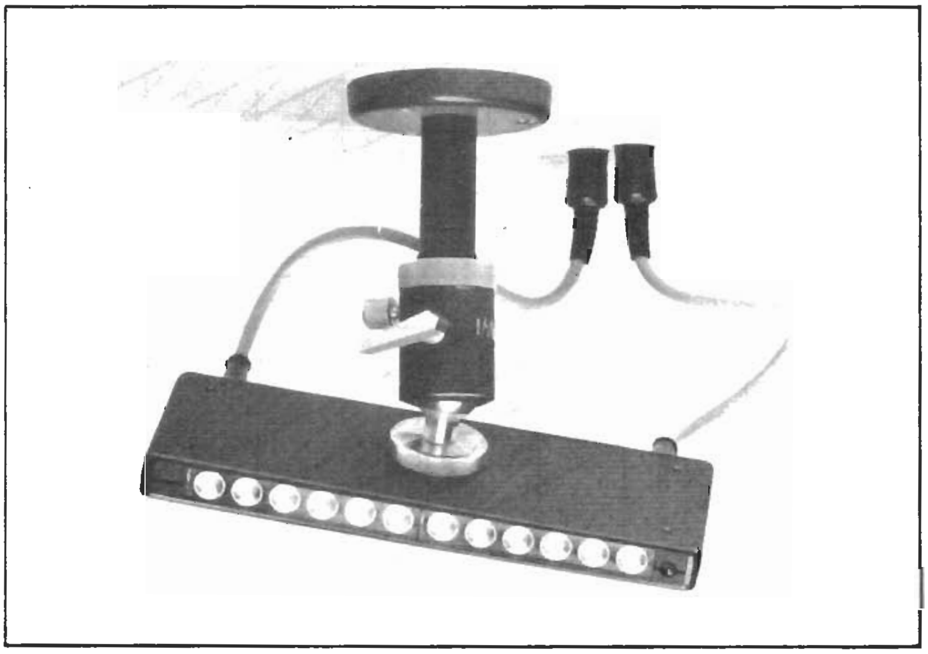
Infrared Systems for Wireless Stereo



Siemens infrared radiator for ceiling mounting.

IR technology and how receivers and transmitters are used in audio.

BY ARTHUR MAKOSINSKI

UNTIL a couple of years ago, infrared communication devices were almost unheard of in high-fidelity electronics. Then, the availability of relatively inexpensive IR light-emitting diodes that could be conveniently and easily amplitude, frequency, or pulse modulated started manfacturers on a whole new line of audio products for hi-fi. With the introduction of the first IR products, a heretofore untapped area of electronics technology began to create a revolution in hi-fi listening.

In this article, we will briefly discuss the history of IR communication and the devices that made it possible. Then we will detail some of the audio IR products that have been developed and marketed during the past two years.

A Brief History. Experiments in data transmission and communication using light beams can be traced back to 1880 and Alexander Graham Bell. But modern work in this area has been concentrated mostly on the use of infrared radiators in line-of-sight communication systems. Early experimental infrared data transmission and voice communication suffered from complexity and high cost insensitive IR detectors and inefficient radiators that often had to be liquid-helium cooled.

The new era dawned with the development of an infrared laser but only as far as the scientific community was concerned. What was perhaps an even greater step forward was the development of inexpensive light-emitting diodes. Here at last was a relatively inexpensive source of stable infrared radiation that could be powered even by a D cell. Even more important is the fact that a LED can be conveniently amplitude, frequency, or pulse modulated.

With the appearance of the IR LED in 1963, sophisticated infrared line-of-sight communicators soon became available. Then, starting in about 1975, commercial IR communication devices that are not restricted to line-of-sight communication became available. These devices use modulated and diffused IR radiation fields as information carriers. As a result, these nondirectional communicators created an alternative to the use of radio frequencies for short-range communication and control systems. They also made possible the new concepts being applied to hi-fi products.

IR LED Radiators & Detectors. Almost any type of IR LED can be used as a radiator for communication purposes. Two important factors about IR LED's that should be borne in mind are the radiant output power, which is the radiated output at a given fixed dc power level, and efficiency. The Texas Instruments TIL32 IR LED, for example, has a 1.2-mW radiant output power and a 5% efficiency. This LED, therefore, requires 24 mW of input power.

Like most other IR LED's, the TIL32 can be switched at rates approaching 1 MHz and radiates at a wavelength of 940 nanometers (nm). Many other IR LED's available today are capable of much greater radiated output power, a few of which exceed the 200-mW mark. If greater powers are desired, single-diode laser LED's that can be pulsed at powers approaching 100 watts are available. The drawback here, however, is that the duty cycle is 0.1% or less, making the average radiated output power quite low. Furthermore, if a laser LED is to be used in a diffused IR system, some optical means for spreading the light must be used for the system to work properly.

Over the years, as the applications of IR widened, many different types of detectors for the radiation were developed. They range from simple thermocouples to exotic gold-doped germanium detectors that must be operated at cryogenic temperatures.

The two most practical and accessible detectors for communication purposes are the reverse-biased silicon solar cell and the PIN photodiode. Reverse-biasing a silicon solar cell minimizes the effect of large junction capacitance. By maintaining the input impedance of the detector circuit at a low value, a bandwidth of 1 MHz can be achieved for a cell with an area of 1 cm^2.

The PIN photodiode is a far more sensitive detector than the solar cell. It is also capable of much wider bandwidths. One such photodiode is the Siemens BPW34, which has an effective area of 9 mm^2, less than 40 pF of capacitance when reverse biased, and a cost of approximately $4.00. Its sensitivity peaks at 850 nm, which is conveniently within the radiation spectrum of modern infrared LED's.

Since its introduction in early 1975, the BPW34 photodiode has sparked a great deal of interest in the European electronics industry and has been responsible for the introduction of several new consumer products. Late last year, Siemens introduced the BP104, which is specially made for IR communication applications and features lower capacitance to facilitate higher receiver frequencies that are necessary for stereo reception. It also has its own built-in infrared color filter.

New Applications. As early as May 1975, Zenith Radio Corp. published information on a projected infrared wireless speaker system for its new 4-channel hi-fi system. Though the two front speakers in this system were to be connected to the amplifier by the usual wires, the two rear speakers were to be completely independent, consisting of separate IR receivers, power amplifiers, and speakers. Super-wide-band transmission of IR radiation served as the communication link.

In the Zenith system, a single IR LED on the transmitter generated a beam that was focused by a lensing system on a solar cell 30' (9 m) away. The solar cell was connected to a simple pulsecounting receiver on the rear of the speakers. A signal-to-noise ratio (S/N) of greater than 85 dB and a distortion of less than 1% were achieved with this simple but high-quality communication system.

In the latter part of 1975, Sennheiser introduced to the European market its Model MDI 416 wireless infrared headphones. Not much larger than a stethoscope, the headphones house an IR FM receiver with built-in sensor, volume control, NiCd cell and charger. It sold for less than $100. The companion Model S1406 IR transmitter could be driven by any audio source. Sennheiser has also focused its sales of IR devices on wireless TV sound devices. Both the headphones and TV-sound systems were introduced in the U.S. in 1976.

As the infrared technology was gathering momentum, European manufacturers like Grundig, Philips, Normende, Lowe-Opta, and Telefunken, began installing permanent IR radiators in their TV receivers. This offers the buyer a private wireless sound option.

Beyer's Model IE 76 is a compact IR receiver that can be hung from the user's neck and connected to existing headphones. The small Model 1S76 IR transmitter can accommodate any audio source. The system is rated to provide a low 1.5% distortion figure.

The Model DT444 Infraphone is another Beyer IR product. It contains the entire IR receiver, plus batteries, in a pair of headphones. AKG has a similar receiver housed in a modified version of its Model K140 headphones. Its Model G-20 wL companion transmitter can also be connected to line or speaker outputs and provides 100 mW of radiated power and a 30-to-12,500-Hz bandwidth.

Recently, a number of sophisticated FM infrared TV remote control systems and coded garage-door openers have shown up on the European market.

IR Transmitters and Receivers. Low frequencies are used as carriers for diffused-field FM transmissions in the IR medium. This is because of the capacitance limitations of the broad-area PIN

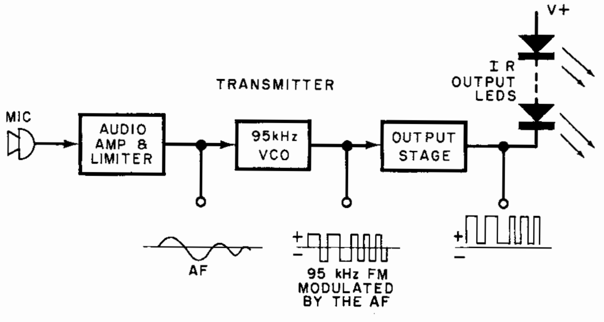


Fig. 1. Typical IR transmitter uses multiple output LED's.

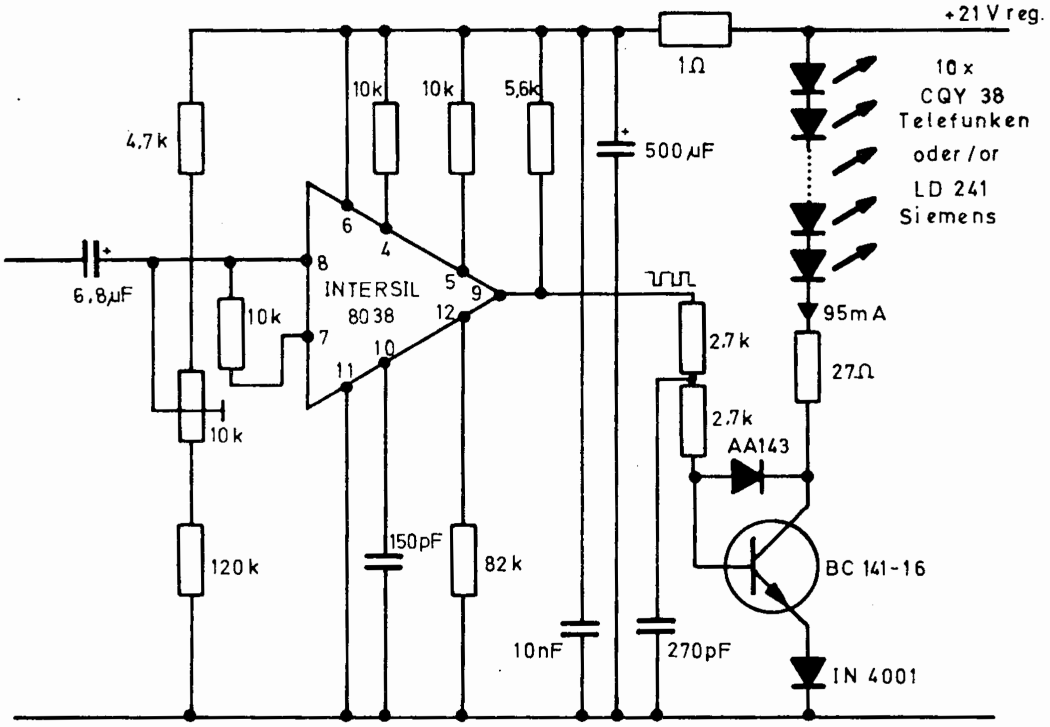


Fig. 2. Schematic diagram of the infrared FM transmitter modulator recommeded by Sennheiser.

photodiode, switching limitations of most LED emitters, and practical circuit considerations. Very wide frequency deviation is used to maximize the S/N at the audio end.

There are several approaches to designing IR transmitters. Basically, however, all IR transmitters consist of an audio preamplifier, a voltage-controlled oscillator that operates at the center frequency of the transmitter (95 kHz for mono), and a power-output stage that drives the IR LED's (Fig. 1). The output transistor is a class-D amplifier stage. For maximum efficiency, several LED's are connected in a series. Usually, as many LED's as are required are used to maintain a particular average drive current. The pulse duty cycle in most commercial transmitters is 50%, although a narrower pulse can be used to save power. The circuit shown in Fig. 2 has a continuous pulse-width potentiometer control for experimental applications.

The radiation angle of the transmitter LED's is critical in the range of the transmitter shown schematically in Fig. 2. Commercial transmitters using such standard LED's as the TIL32, CQY38, or LD242 utilize the relatively wide radiation angles of the diodes, which may vary between 30° and 60°. Sometimes, however, additional metallic reflectors are used to focus the beam of IR energy.

Recently, Siemens announced production of the Q62902-B137, a combined reflector/heat sink for use with its new LD242 IR LED that was specially designed for IR communication.

For particularly long distance communication, standard lenses or parabolic reflectors can be used to prefocus an IR beam for line-of-sight communication over distances of up to several miles. In diffused-radiation transmission, where sound quality rather than long distance is of utmost importance, a number of IR LED's are used to broaden the energy diffusion angle and improve the S/N at the receiver.

A practical IR transmitter might have eight to 12 standard LED's in series, 0.5 watt of input power, and 25 mW of IR output power. This low output power can carry a high-quality audio signal across a room up to 20 meters long, depending on the reception angle.

Construction of an FM receiver for IR communication applications is greatly simplified, thanks to the many IC FM demodulation circuits on the market today. A block diagram of the typical IR receiver is shown in Fig. 3. It consists of a preamplifier, wideband FM discriminator, and low-pass filter. The last section may or may not contain a deemphasis network, depending on whether or not preemphasis is used in the transmitter.

An example of the design approach used in FM IR receivers is shown in Fig. 4. The circuit employs the Siemens BPW34 photodiode as the pickup.

An inductor in series with the photodiode minimizes the saturation effect under bright ambient lighting conditions. Without the inductor, the self-capacitance of the diode would be greatly increased, causing attenuation of the FM carrier signal. Care and some experimentation are required in selecting the FM limiter/amplifier/detector that will operate at 100 kHz, since most such circuits are designed to operate at 455 kHz or 10.7 MHz.

The S/N in infrared systems can be increased by the simple expedient of preemphasizing the modulating signal in the transmitter and deemphasizing the received signal. Some commercial IR systems, for example, operate with a 50-µs emphasis/deemphasis figure.

IR Stereo. In April of last year, a European standardization committee made recommendations for IR devices. Following these recommendations, Sennheiser, AKG (Telefunken), and Beyer introduced stereo IR systems to the European consumer market. At least one of

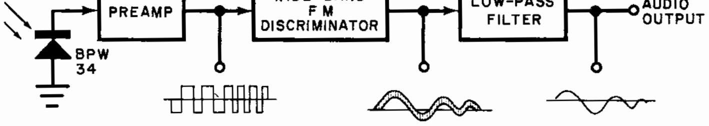


Fig. 3. Block diagram of a typical infrared FM receiver. Preemphasis and deemphasis may be used in transmitter and receiver.

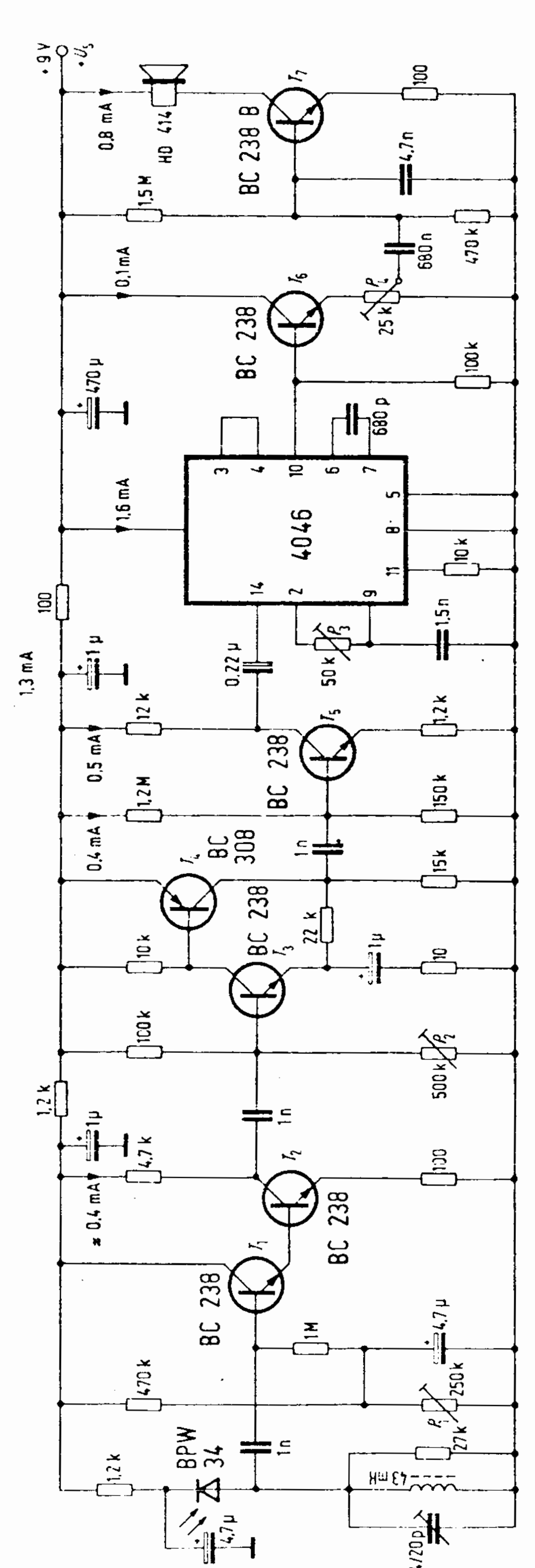


Fig. 4. The Siemens FM infrared receiver uses a 4046 integrated circuit as a wide-band FM demodulator.

these systems has made it to the U.S. market.

All commercial IR stereo systems intended for the stereo enthusiast are relatively inexpensive. They also conform to the recommended standard—95-kHz and 250-kHz carrier frequencies for the left and right channels, each of which can be deviated by ±50 kHz. (Mono systems use a 95-kHz carrier and ±50-kHz deviation.) Each system uses a stationary IR transmitter that connects to the line output jacks of a stereo system and a portable receiver that can be carried around by the user.

The IR stereo transmitters are, in fact, two transmitters in a single case. One operates at 95 kHz and carries the left-channel signal, while the other operates at 250 kHz and carries the right-channel signal. The LED radiators that are driven by the transmitters are housed in the same case that houses the transmitter.

The receiver in the case of Beyer's Model DT444 and Sennheiser's Model HDI434 IR stereo phones is built right into the phones themselves. A small lens on one of the earcups focuses the IR energy intercepted onto a BPW34 photodiode that serves as a common receptor for both channels. Circuitry within the headphones themselves demodulates the signal to separate out the two channels. Then the left and right channel signals are amplified to drive the phones.

The headphones also have built into them rechargeable nickel-cadmium cells that power the receiver circuitry. Even with the built-in circuitry and power sources, the IR stereo headphones are about the same size and weight of conventional headphones.

Testing the Sennheiser Model AD416 IR stereophones at a distance of 4 meters from a 60-mW radiated IR transmitter in a room 5 × 4 × 3 meters with light colored walls and a flat ceiling, we obtained a 58-dB S/N in daylight (200 Lux). Under worst-case conditions, with the receiver's pickup facing away from the transmitter's IR radiators, the S/N degraded to 40 dB. Needless to say, IR stereo headphones offer an attractive and practical alternative to conventional phones. They typically have good S/N characteristics and wide frequency response. (Beyer, for example, rates its IR phones at 20-to-20,000 Hz frequency response).

Closing Comment. Infrared radiation radiated by LED's in an IR audio system scatters and is reflected and diffused by the room's walls and ceiling. Some materials in a listening room reflect IR energy better than do other materials. Hence, the mixture of materials found in a typical home environment may cause signal dropouts when the receiving element of the IR receiver is facing away from the transmitter.

One drawback for the IR system is that the receiver's sensitivity to the transmitted signal is reduced in the presence of an additional high-level IR source, such as a tungsten lamp or the sun. Strong incandescent lamps, too, can add noise, obscuring the signal. Even so, the advantages to using IR phones are so great that they far outweigh the disadvantages of conventional phones with their trailing cords. ◇