

## How Lightwaves Are Changing Communications

By Forrest M. Mims III

The wires and cables that connect electronic devices with one another and with their sources of power have always been considered a necessary nuisance. But are they always needed?

Simultaneous advances in low power CMOS circuitry and high-capacity batteries, both disposable and rechargeable, have eliminated power cords from many electronic devices. It's also possible now, with radio waves or beams of light, to replace the wires that traditionally connect between many devices.

### Radio vs. Light

Radio links have been used for decades to open garage doors and to control model airplanes, boats and cars. They are easy to use and omnidirectional, but they require antennas and may be subject to government regulation. For these reasons, photonic systems that transmit information or control signals by means of near-infrared radiation and visible light often offer a viable alternative for short-range links.

Strictly speaking, the term light refers only to the range of wavelengths in the electromagnetic spectrum that is visible to the human eye. It's common practice, however, to classify systems that use visible light and those that employ near-infrared as lightwave links. I'll use that terminology in this column.

Often lightwave signals can be transmitted directly to a suitable receiver in what is usually called a free-space link. When total electronic security is important, or when distance or obstacles preclude a direct optical link, information-carrying beams of light can be injected into highly transparent fibers made of plastic, glass or silica material.

Whether radio or infrared is the best choice for a particular wireless

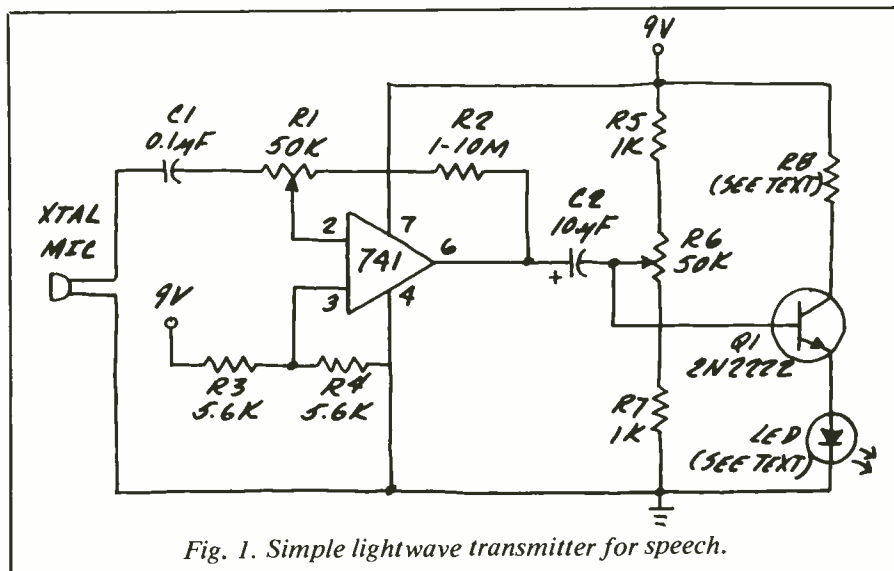


Fig. 1. Simple lightwave transmitter for speech.

application depends upon the circumstances. My personal preference is to use a lightwave link when possible. But I don't hesitate to use radio when transmitting data from model rockets or triggering a camera suspended from a kite or a balloon hundreds of feet in the air. In short, both radio and lightwave links possess relative advantages and disadvantages.

### Lightwave Links

Communications over beams of light were first pioneered in the United States by Alexander Graham Bell and Sumner Tainter in 1880. Up until the 1950's, though, most lightwave communications research was conducted by the military and by individual experimenters. During World War II, Italy, Germany and Japan developed advanced lightwave voice communications gear.

Solid-state light emitters and detectors, as well as the laser, were developed in the United States during the 1960's. Japan and West Germany were among the first to apply these components in lightwave links for consumer products.

German companies were among the first, for example, to develop in-

frared remote control transmitters for television sets, toys and wireless stereo headsets. Japan's Canon further makes a midget infrared RS-232 free-space data-link that allows a handheld computer to communicate with a nearby printer.

Canon's infrared computer-printer link is merely the first of what may become many such wireless links between computers and their peripherals. Indeed, the keyboard of IBM's PCjr personal computer even now transmits keycodes to the system unit over beams of near-infrared generated by a pair of light-emitting diodes.

Telecommunications is by far the biggest application for fiber-coupled lightwave links. If you make a phone call to or from a major metropolitan area in the United States, Japan, Brazil, England, Italy or Canada, chances are your voice will travel at least part of the way as pulsations of near-infrared through silica fibers.

### A Simple Lightwave

A free-space lightwave link capable of transmitting your voice several hundred feet can be assembled from surprisingly low-cost components. I've been building such communica-

tors since 1965 when, as a student at Texas A&M University, I used flashlight bulbs and newly developed GaAs near-infrared-emitting diodes to send voice to receivers, using a silicon solar cell connected to an audio amplifier.

Since then I've designed and built dozens of lightwave communicators. Because of its simplicity and low cost, the transmitter circuit shown in Fig. 1 is one of my favorites.

In operation, the small voltage generated when voice pressure waves are intercepted by a crystal microphone is channeled through C1 into a 741 operational amplifier. The signal is then amplified with a gain determined by R1's setting.

The amplified signal is channeled through C2 to the base of driver transistor Q1. Resistors R5, R6 and R7 form an adjustable voltage divider that permits the bias on Q1's base to be adjusted for an optimum, distortion-free output from the LED.

The collector-emitter junction of Q1 acts like a variable current switch that controls the current flow through the LED. Maximum current flow is limited by R8.

Many different LEDs will work with this circuit. For best results, though, the LED should be an

AlGaAs unit emitting at 880 nanometers. A GaAs:Si unit that emits at 950 nm will also work, but at less than half the power efficiency of an AlGaAs unit.

In any event, it's necessary to limit the quiescent forward current through the LED to a figure ranging from about 10 to 40 milliamperes. Brief high-level audio surges will substantially raise this level.

The easiest way to establish the LED quiescent current is to replace R8 temporarily with a 1000-ohm potentiometer. Then, while monitoring a milliammeter inserted between the LED's anode and Q1's emitter, adjust the pot until the current flow is from 30 to 50 percent of the maximum allowable for the LED you're using. Remove the meter and pot, measure the pot's resistance, and substitute a fixed resistor having a similar value.

The receiver shown in Fig. 2 detects the voice-modulated beam from the transmitter by means of a phototransistor, and this, together with load resistor R1, generates a voltage proportional to the amplitude of the signal. The signal voltage is amplified by a 741 op amp.

An LM386 audio power amplifier provides sufficient boost to drive a

small speaker. R3 controls the signal level that reaches the LM386.

This transmitter and receiver pair will operate over a range of a few feet without external lenses. If you collimate the beam from the transmitter with a lens and place a second lens over the receiver's phototransistor, the range can be greatly increased.

Phototransistors saturate (i.e., turn fully on) in the presence of sunlight. Therefore, the receiver will work much better at night or if you block extraneous light with an infrared filter. Ironically, in total darkness a small amount of d.c. light falling upon the phototransistor will improve its sensitivity. This occurs because the light biases the transistor into conduction.

### *A Low-Cost Communicator*

The transmitter and receiver described above can be linked easily to one another by means of an optical fiber. In fact, I've done so many times over the years.

However, many experimenters who lack experience in building lightwave links have long hoped for an economical kit that would allow them to assemble, with minimum difficulty, a working fiber link.

One answer to their plight is the EDU-LINK Fiber Optic Kit. Available from the Advanced Fiberoptics Corp., 637 S. Hayden Road, Tempe, AZ 85281, for \$19.95 plus \$2 for shipping and handling, this kit consists of a transmitter, receiver and a one-meter length of sheathed plastic fiber. Both the transmitter and receiver circuits can be quickly assembled in under an hour.

The EDU-LINK transmitter is TTL compatible and will convert incoming logic signals into optical pulses. The transmitter also includes a self-contained oscillator that provides a 1-kHz signal for test and demonstration purposes.

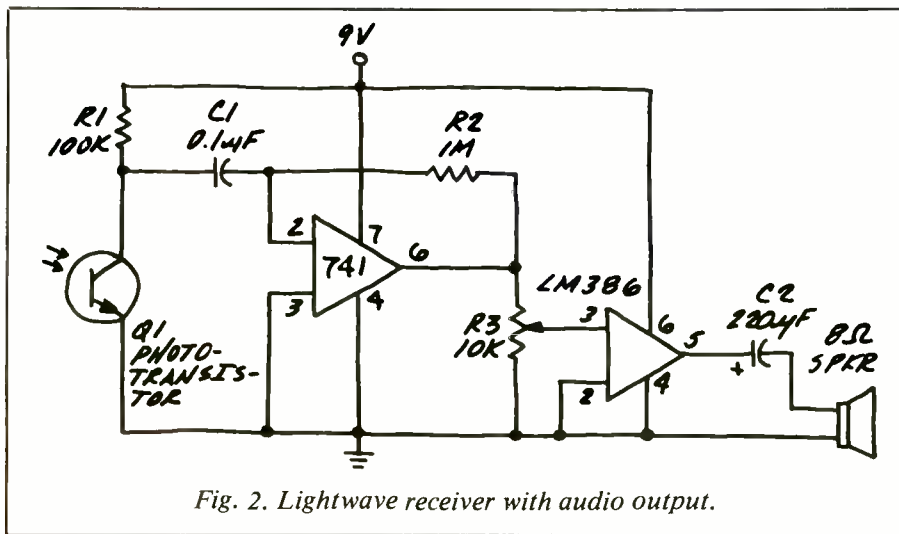


Fig. 2. Lightwave receiver with audio output.

# ELECTRONICS NOTEBOOK ...

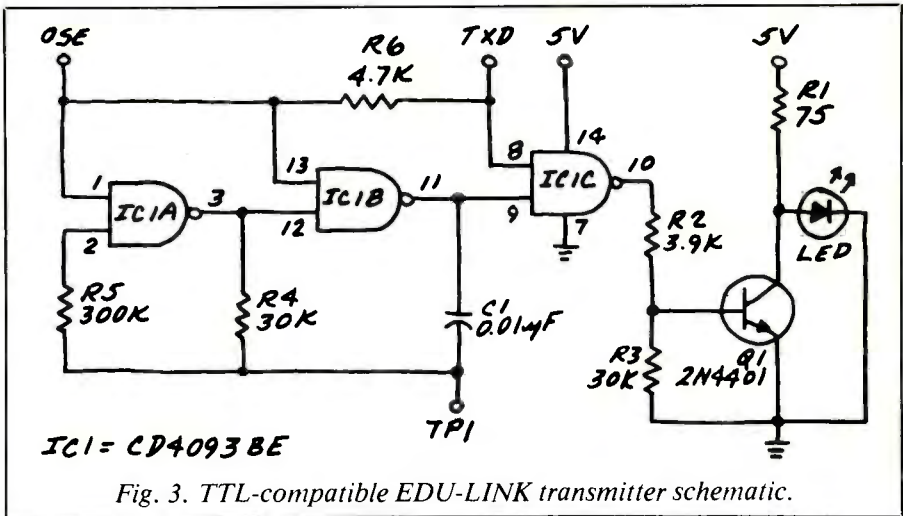


Fig. 3. TTL-compatible EDU-LINK transmitter schematic.

Fig. 3 is the transmitter's circuit diagram. IC1 (CD4093) is a quad of two-input NAND gates, each of which exhibits Schmitt-trigger operation on both inputs. Two of the gates (a and b) are connected as an astable oscillator that's enabled when the OSE (OScillator Enable) and TXD (Transmit Data) inputs are both high (logic level 1).

A third gate (c) steers the signal from the built-in oscillator or an external source to driver transistor Q1. R2 and R3 supply base bias to Q1,

and R1 limits the current through the LED to about 40 mA.

The LED is a Siemens GaAsP visible red (665 nm) emitter. Since the receiver's silicon photodiode is much more sensitive to near infrared at about 800-950 nm, the wavelength range of the powerful near-infrared LEDs I specified for the free-space transmitter in Fig. 1, you may be wondering why the EDU-LINK transmitter uses a less powerful, red-emitting LED.

The principal reason is that plastic

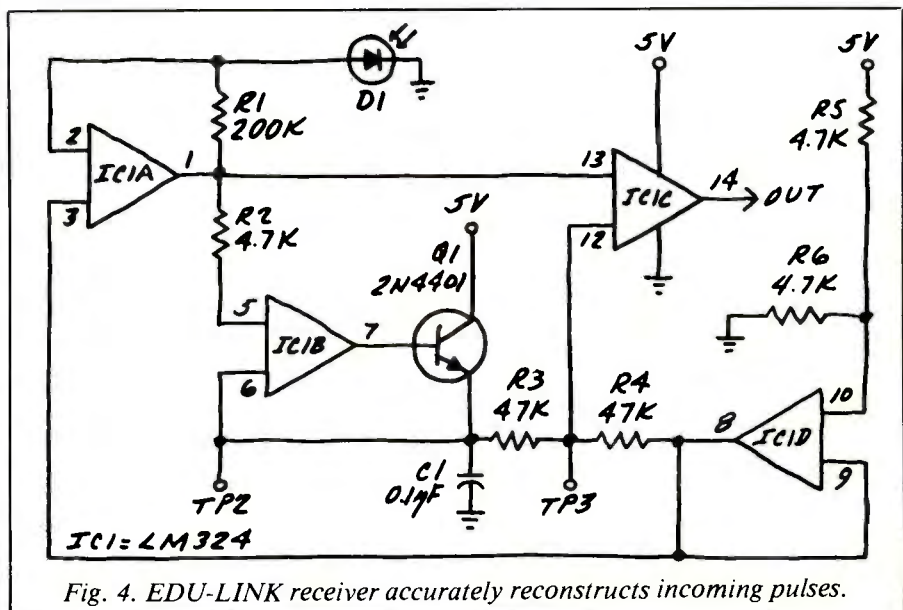


Fig. 4. EDU-LINK receiver accurately reconstructs incoming pulses.

fibers transmit near-infrared radiation very poorly. On the other hand, they transmit visible red wavelengths quite well.

The simple circuit in Fig. 2 will detect signals from the EDU-LINK's transmitter. The EDU-LINK receiver, however, employs a clever design optimized specifically for the amplification and accurate reconstruction of incoming pulses.

The circuit of the EDU-LINK receiver is shown in Fig. 4. IC1 is an LM324N quad op amp, and D1 is a high speed PIN photodiode. In operation, D1 is reverse biased and connected to one of the amplifiers (a) to form a voltage-to-current converter or, as it is commonly known, a transimpedance amplifier. The operation of the remainder of the circuit is more complex than it might at first appear.

Amplifier d is connected as a unity gain follower that provides, at pin 8, a buffered version of the voltage generated by the divider made from R5 and R6. Amplifier b, together with Q1 and C1, forms a peak detector that stores the amplitude of the incoming pulses. According to the EDU-LINK instructions, "This stored reference signal allows one to sample the incoming signal at its point of minimum distortion, thereby reducing pulse width distortion."

The output from the peak detector is halved, relative to the reference voltage, by the divider formed from R3 and R4. This signal, along with the amplified signal from the photodiode, is then applied to the output comparator (c).

The neatest features of the EDU-LINK kit are the plastic connectors into which the LED and photodiode are installed. Each of these connectors is attached to its respective circuit board by a pair of mounting screws.

Only a few minutes are required to terminate the plastic optical fiber supplied with the kit. After a quarter-

inch of sheathing is removed from each end, the ends of the fiber are inserted into plastic ferrules. The exposed fiber emerging from the end of each ferrule is then cut with a hobby knife. The link between transmitter and receiver is completed when the plastic ferrules at each end of the fiber are snapped into the LED and photodiode connectors.

All that's necessary to test the link is a 5-volt power supply and an audio amplifier or oscilloscope. I powered the unit I assembled with a pair of 6-volt batteries. (I dropped the voltage from the transmitter battery to about 5.4 volts by connecting a 1N914 diode between the positive battery terminal and the circuit.)

You can hear the test tone by connecting the output from the receiver to a small audio amplifier. Or you

can monitor the signal with an oscilloscope as described in the instructions supplied with the kit.

### Going Further

If you would like to learn more about lightwave communications, you may want to read my book, *A Practical Introduction to Lightwave Communications* (Howard W. Sams, 1982). For a variety of both amplitude and pulse-modulated circuits, see *The Forrest Mims Circuit Scrapbook* (McGraw-Hill, 1983).

In the meantime, be sure to stay tuned. Along with many other topics to be covered in "Electronics Notebook," I'll include additional tips on free-space and optical fiber lightwave communication circuits in future columns. **ME**

Quick charge cordless soldering iron. Up to 125 electronics joints per charge. Total recharge in less than 4 hours. Isolated tip design. One of more than 2 dozen ISO-TIP and ORYX irons available. Write for free catalog and name of nearest distributor

**A Hot Tip on Cordless Soldering**

**ISO TIP ORYX**

No. 7700 QUICK CHARGE Cordless Soldering Iron

WAHL CLIPPER CORPORATION  
Sterling, Illinois 61081 • (815) 625-6525

CIRCLE 25 ON FREE INFORMATION CARD

October 1984 / MODERN ELECTRONICS / 89