Experimenter's Corner

By Forest M. Mims

Optical Fiber Communications (Part 2)

IN this second of a two-part primer on optical fiber communications, we'll experiment with several transmitter and receiver circuits suitable for communicating through optical fibers and free space. If this fascinating form of communications appeals to you, be sure to review Part 1 before designing your own optical link. You might also refer to last month's Project of the Month, because the simple amplitude-modulated light-wave transmitter and receiver presented there are ideal for fiber links. You'll then be well prepared to try the circuits shown in this column.

I have built and tested all these circuits. Nevertheless, I suggest that you assemble versions on solderless breadboards before making permanent units. This will allow you to make gain and modulation adjustments and to perform preliminary operating tests to determine whether or not a particular circuit is suitable for your application.

Selecting Emitters and Detectors. Double-heterostructure injection lasers generate higher power levels over greater bandwidths than light-emitting diodes, but their high cost rules out their use for all but the most affluent experimenters. Fortunately for the rest of us, LEDs provide enough power for fiber links of a kilometer or more. GaAs: Si LEDs are very powerful, but the 940-nm wavelength they radiate is readily absorbed by most fibers. Therefore, GaAs (900 nm), GaAlS (780 to 900 nm) and even common GaAsP (650 nm) red LEDs are better choices.

Among the devices that are suitable detectors are phototransistors, solar cells, photodiodes, PIN photodiodes and even LEDs. Phototransistors are excellent for low-bandwidth links, but they must be shielded from ambient light. PIN photodiodes are the best choice for high-bandwidth applications. For 2-way communications over a single fiber, use a LED as a dual-function emitter/detector.

Operating Tips. Some of the circuits we'll be using employ operational amplifiers with large feedback resistances to provide very high gain. These circuits will probably oscillate violently (at least mine did) unless you take the following precautions. Connect a 0.1-μF disc ceramic capacitor directly across the power-supply pins of the op amp. The capacitor should have short leads. Avoid long component leads and interconnection wires. Use miniature shielded cable (Radio Shack 278-752 or similar) to connect components such as detectors and microphones to the input of an op amp if the distance involved is more than a few centimeters. *Never* use an earphone to monitor the output of an untested receiver! If the circuit oscillates, the resulting sound pressure level can quite easily exceed the threshold of pain.

PFM Transmitter. Transmitting voice and other analog information as a stream of light pulses rather than an amplitude- (intensity-) modulated continuous light carrier offers several important advantages. Perhaps the most important is noise immunity. Unlike the signal transmitted by an AM light-wave system, all bursts of light in a pulsed system have the same amplitude. This means a threshold circuit can be connected to the receiver to automatically block noise pulses having an amplitude smaller than that of the information-carrying pulses.

Another important advantage is the fact that most LEDs and certain types of injection lasers emit far more power when driven by brief current pulses than when operated more or less continuously as in an AM system. Other advantages of pulse communications include increased bandwidth, reduced (continous) operating power and interesting data encryption and multiplexing possibilities.

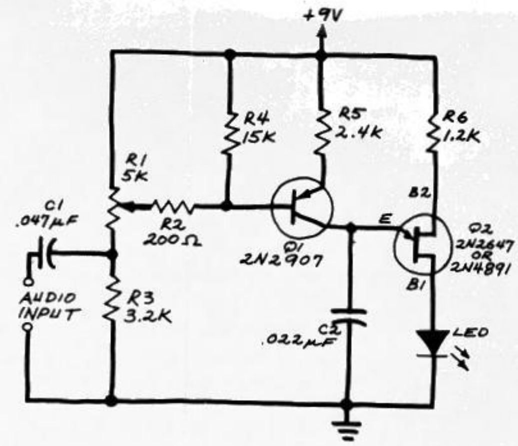

Fig. 1. Simple unijunction transistor PFM transmitter.

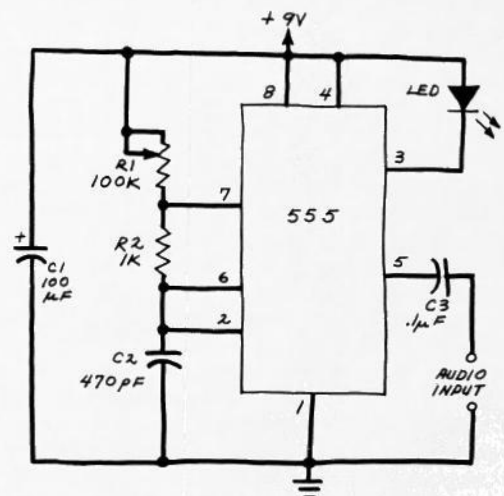

Fig. 2. A light-wave transmitter designed around a 555.

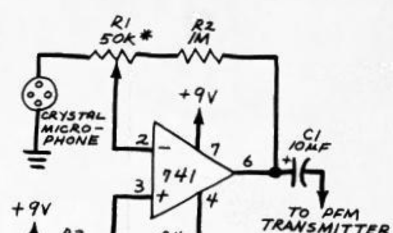

Fig. 3. Microphone preamplifier for PFM transmitter.

A pulse frequency-modulated (PFM) transmitter is fairly simple. In quiescent operation, the circuit produces a continuous stream of pulses at a specified center frequency, usually above the audio range. Audio signals applied to the input of the modulator cause the center frequency to vary in direct proportion to both the amplitude and frequency of the input signal.

Figure 1 is the schematic diagram of a simple unijunction-transistor PFM transmitter I first described in this column in May 1976. (Back issues of POPULAR ELECTRONICS are available at many libraries.) Although this circuit works very well, the pulses delivered to the LED do not have enough duration and amplitude for maximum optical power generation.

Figure 2 is an even simpler circuit designed around a 555 timer IC. This modulator delivers more current to the LED. When powered by an 8-volt rechargeable battery, the peak current as measured across a 1-ohm resistor in series with the LED is 320 milliam-

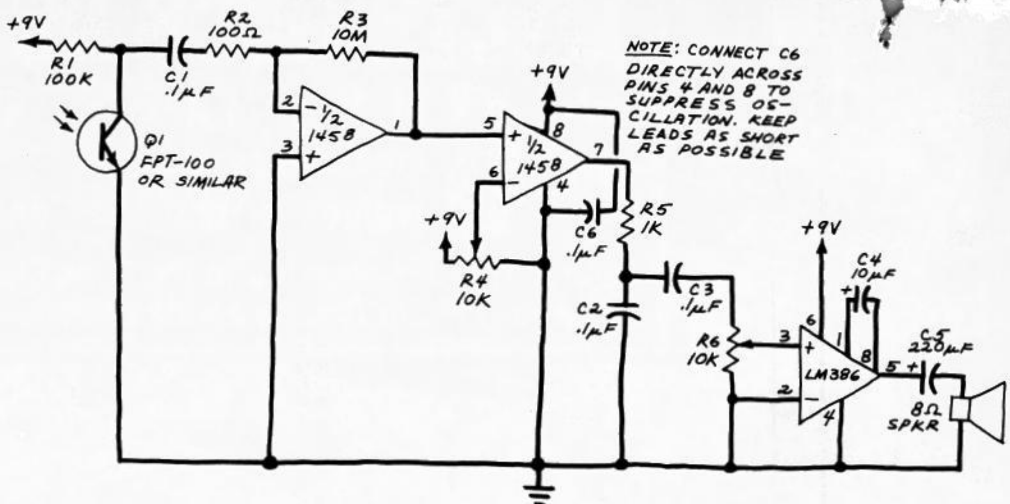

Fig. 4. A PFM receiver with a threshold detector and demodulator added.

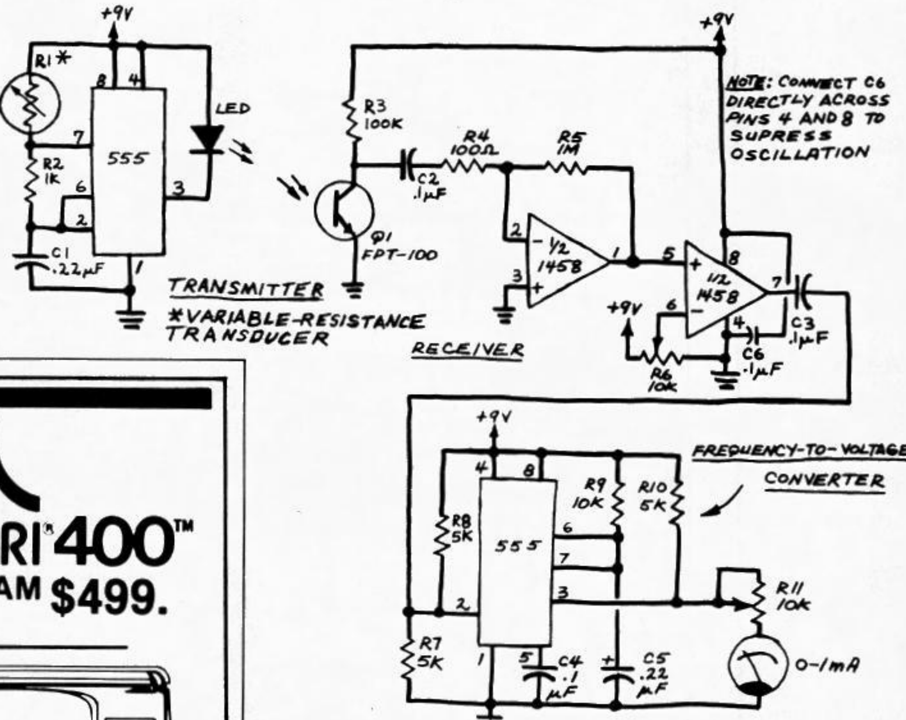

Fig. 5. An analog light-wave transmission system using a 555 astable oscillator transmitter with a receiver similar to that shown in Fig. 4.

peres. This is from three to six times the maximum allowable LED current in an amplitude-modulated continuous-carrier light-wave system.

The pulse duration is a brief 400 nanoseconds. This keeps both the duty cycle of the LED and average power consumption of the circuit very low, but reduces the effectiveness of a phototransistor detector because its response time is slower than that of a PIN photodiode.

For best results, *R1* should be adjusted to give a center frequency between 20 and 30 kHz. You don't need a frequency counter to make this adjustment. You can monitor a suitable light-wave receiver (see below) while adjusting *R1* for optimum sound quality.

Initial tests and adjustments are simplified if you connect the o- put of a transistor radio (via its earphone jack) to the input of modulator. The modulator works best when the amplitude of t- input is 2 to 4 volts peak-to-peak. For voice operation, connect any standard audio amplifier to the modulator's input. Figure 3 is the schematic of a microphone preamplifier that I like to use.

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PFM Receiver. You can receive signals from a PFM transmitter with any light-wave receiver if the center frequency of the transmitter is higher than approximately 15 kHz. For best results, however, a threshold detector and demodulator should be added as shown in Fig. 4.

Note how this circuit uses one half of an MC1458 (other dual op amps can also be used) as a preamplifier and the second half as a comparator or threshold detector. Demodulation (actually, integration) of the transmitted intelligence is provided by *R5* and *C2*. The recovered audio is then amplified by the LM386 power amplifier. Potentiometer *R6* controls the signal level at the input of the LM386 and is therefore used as a gain control.

Potentiometer *R4* permits adjustment of the comparator. Standard dual op amps such as the MC1458, however, may have insufficient bandwidth for the threshold circuit to work properly. In such cases, the narrow incoming pulses from the transmitter are stretched by the preamp and detector stages until they merge to form an amplitude- rather than pulse-modulated signal. You can obtain true threshold detection by using selected 1458's or using the LF353 or another of the better-quality dual op amps. For optimum results, you might prefer to use individual op amps rather than a dual IC to prevent inadvertent triggering of the comparator at very high preamp-gain levels.

Once the receiver is working, you can reduce the gain of the preamp by increasing the value of *R2*. And you can change the values of *R5* and *C2* to alter the tone response.

Use care when tinkering with the receiver, because inadvertently touching a lead might produce an ear-splitting squeal from the speaker. To protect your ears, you can insert a few hundred ohms of series resistance between *C5* and the speaker, at least until the receiver is ready to be buttoned up and there is no chance of inadvertently touching off a spasm of shrieks and whoops.

Analog Data Transmission System. In the October and November 1979 installments of this column, we experimented with voltage-to-frequency converters and an analog light-wave data-transmission system designed around a pair of 9400 V/F chips. The LM331 V/F converter can also be used in this application. Since those columns appeared, V/F chips have become more widely available. Nevertheless, I have long wanted to design an analog light-wave transmission system around the even more widely available 555 timer chip. Figure 5 is the realization of that desire.

The transmitter is a basic astable oscillator that supplies current pulses to a LED. Resistance *R1*, which controls the pulse rate, can be a cadmium-sulfide photoresistor (for light sensing), a thermistor (for temperature sensing), a strain gauge (for pressure sensing) or some other variable-resistance transducer. It can even be a FET if remote monitoring of a voltage is desired.

The front end of the receiver is essentially identical to the preamp and threshold detector stages shown in Fig. 4. The 555 and its associated components form a frequency-to-voltage converter. Output monitoring is provided by a 0-to-1-mA meter movement.

This circuit works best over a 0-to-360-Hz frequency range (1 mA = 360 Hz), but this can be extended by altering the values of *R9* and *C5*. The threshold potentiometer (*R6*) requires careful adjustment, particularly if slow op amps are used. Potentiometer *R11* permits calibration of the output meter.

The receiver's front-end phototransistor must not be exposed to ambient light if the system is to operate properly. LEDs and PIN photodiodes, which can also be used as detectors, are less susceptible to the deleterious effects of ambient light.

Going Further. For more information about optical-fiber communications, see W.S. Boyle's excellent article "Light-Wave Communications" in the August 1977 issue of *Scientific American*. A good general introductory book is *Light-Beam Communications* (F. Mims, Howard W. Sams, 1975), and a more technical text is *Fundamentals of Optical Fiber Communications* (edited by M.K. Barnoski, Academic Press, 1976). You can keep abreast of the latest developments in this field and get the names and addresses of fiber manufacturers by reading such trade magazines as *Laser Focus* and *Electro-Optical Systems Design*. All these and many other publications on light-wave communications are available at well-stocked libraries. ◇