ELECTRONICS NOTEBOOK

A Multi-Function Two-Transistor Oscillator

By Forrest M. Mims III

Some integrated circuits, particularly the 741 operational amplifier and the 555 timer, have for many years been considered standard devices by engineers and experimenters alike. Because these and other ICs are so exceptionally versatile, it's easy to overlook simple circuits made from discrete components that are equally versatile and sometimes simpler.

One of the best examples of a highly versatile non-integrated circuit is the two-transistor oscillator shown in Fig. 1. This circuit is designed to function as a code-practice oscillator when connected to a telegraph key, speaker and battery. However, it has numerous other applications, some of which have greatly influenced my career as an electronics experimenter. While this circuit may not affect anyone else's career, perhaps it will lead experimenters to reconsider the value of discrete transistors in their circuits.

Back to Basics

For some 20 years, Radio Shack stores have sold an assembled version of the code-practice oscillator circuit in Fig. 1 for a few dollars (catalog number 20-1155). During my senior year at Texas A&M University in 1966, I used one of those circuits to supply pulses to some of the first commercially available infrared-emitting diodes. I used those pulsed infrared emitters as optical sources for miniature travel aids for the blind and in lightwave communications experiments.

Later in 1966, I used the basic circuit in Fig. 1 to drive a silicon solar cell. The cell emitted pulses of infrared which were detected by a second, identical solar cell nearby. I also used a miniaturized version of the circuit to drive an infrared-emitting telemetry transmitter which I launched in small rockets. A light-sensitive cadmium-sulfide photocell varied the pulse rate of the infrared transmitter, thus providing an indication of the rocket's roll rate. In 1968, I modified the circuit slightly so that it would cause a small incandescent lamp to emit brilliant flashes of light. I

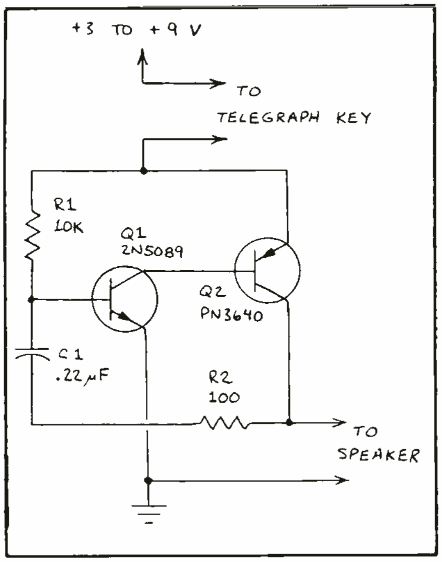

Fig. 1. Schematic diagram of a CPO Radio Shack has sold for 20 years.

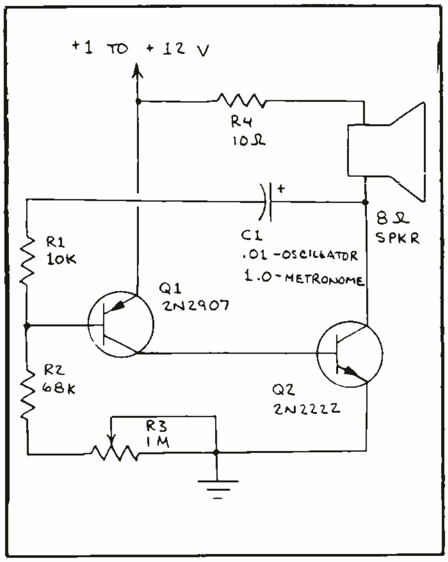

Fig. 2. Shown here is the schematic of a simple oscillator/metronome.

built a series of miniature flashers to assist in the recovery of dozens of night-launched model rockets that carried an experimental guidance system.

These experiments with the basic circuit in Fig. 1 had consequences more far ranging than I could ever have imagined. The rocket light flasher became the subject of my first magazine article and led directly to my decision to become an electronics writer. Ed Roberts helped with some of those night launchings. In 1969, Ed and I joined with two friends to form MITS, Inc. Though our first product was a model rocket light flasher, MITS is best remembered for the Altair 8800, the first personal computer.

Designing travel aids for the blind, a project which still occupies a good deal of my time, led to a series of articles and books about light-emitting diodes and lasers. The experiments in transmitting infrared pulses between two identical solar cells led to similar work with LEDs. In 1973, after I used a pair of identical LEDs to transmit audio in both directions through both the air and an optical fiber, I submitted an invention disclosure to Bell Labs. After agreeing to pay for the suggestion if they used it, Bell Labs rejected it as being impractical. Five years later, however, Bell Labs announced it had developed an optical telephone that incorporated the core of my suggestion. Since *Business Week* said the new phone would "dramatically alter the basic nature of the phone network" (December 4, 1978), I spent several months asking Bell Labs to pay for the use of the suggestion. They refused, I sued, and they eventually settled out of court.

Recently I learned that after more than 20 years Radio Shack plans to discontinue the code practice oscillator circuit in Fig. 1. For sentimental reasons, I'm sorry to see the end of that product. On the other hand, the basic circuit can be assembled in a minute or so on a plastic breadboard. Recently I've experimented with an assortment of applications for the circuit and many of them are covered below. First, let's review the circuit's operation. Referring to Fig. 1, when the key is closed *C1* begins to charge through *R1*, *R2* and the speaker. Both *Q1* and *Q2* are initially off. Eventually, the charge on *C1* becomes high enough to switch *Q1* on, which then switches *Q2* on.

When *Q2* is on, the speaker is connected directly across the power supply through *Q2*'s emitter-collector junction. Meanwhile, *C1* discharges to ground through the base-emitter junction of *Q1*. When the charge on *C1* falls below that necessary to keep *Q1* switched on, *Q1* switches off; *Q2* then switches off, and current is no longer supplied to the speaker. The charge-discharge cycle repeats, resulting in audible pulsations from the speaker. If the charging time is made brief by making *C1* small, the speaker will emit a high-pitched tone.

Introducing the Circuits

Note that *Q2* in Fig. 1 is a pnp transistor. For applications like light flashers, where low-switching impedance is desired (for maximum current), it's best to use an npn transistor switch, since its on resistance is less than that of a pnp transistor. The basic circuit can be modified for this purpose by rearranging it to be a mirror image of the circuit in Fig. 1. This version of the basic circuit is used in each of the circuits that follow. It can produce fast rising and falling current pulses having a peak amplitude greater than 1 ampere. And it will oscillate when the power supply voltage is only about 0.7 volt.

Each circuit given below specifies a 2N2907 for the pnp transistor and a 2N2222 for the npn transistor. However, many different pnp and npn transistors can be substituted for these. For best results, use silicon transistors designated for switching applications. You may wish to use a power transistor for the npn unit in applications that switch lots of current (e.g. driving incandescent lamps).

To monitor the operation of the circuits, break the connection between *Q2*'s emitter and ground and insert a small resistor in the gap. Connect an oscilloscope across this resistor to monitor the pulsed output from the circuit. If this monitoring resistor has a value of 1 ohm, it will have very little influence on the circuit's operation. If a circuit fails to operate, disconnect the power while looking for the problem. Otherwise, *Q2* may stay turned on and both it and any device with which it is in series may be damaged or destroyed by the excess heat generated.

Incidentally, the very fast rise and fall times of the basic circuit can produce in-

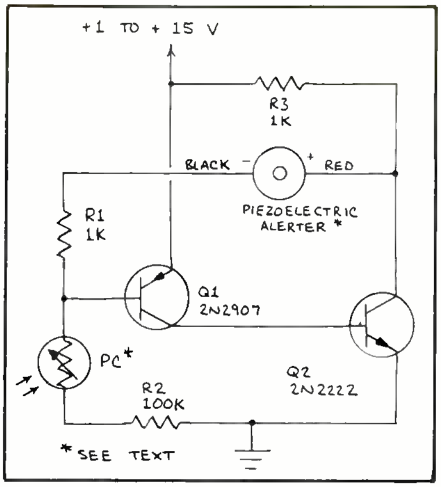

Fig. 3. This light-dependent oscillator uses a piezoelectric alerter.

terference on a nearby radio. Be sure to keep this in mind while testing the circuit.

Audio Oscillator Circuits

Figure 2 shows a mirror image of the circuit in Fig. 1 configured as an audio oscillator. Potentiometer *R3* controls the circuit's oscillation frequency. When *C1* is 0.01 microfarad, the circuit generates a tone. The tone slows to a series of distinct clicks or pocks when *C1* is increased to 1 microfarad. Resistor *R4* limits current through the speaker and thereby reduces the volume of the sound from the speaker. The volume can be increased by increasing power supply voltage. Resistor *R1* controls the time *Q2* remains on during each cycle. When the pulse duration is brief (*R1*'s value is reduced), speaker volume is reduced.

Figure 3 is an audio oscillator whose frequency is determined by the intensity of light that strikes a cadmium-sulfide photocell (Radio Shack 276-116 or similar). When the light level is increased, resistance of the photocell falls, thus increasing the frequency of oscillation.

A unique feature of the Fig. 3 circuit is the substitution of a piezoelectric alerter (Radio Shack 273-064 or similar) for *C1* in Fig. 2. The inherent capacitance of the alerter permits the circuit to oscillate. At the same time, the alerter emits an audio

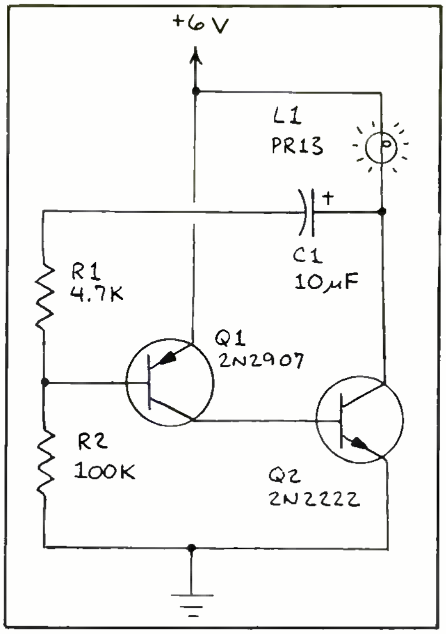

Fig. 4. An incandescent-lamp flasher.

tone, thereby eliminating the need for a separate speaker as in Fig. 2.

Lamp and LED Flashers

Figure 4 is the circuit for an incandescent lamp flasher similar to one I have often used to track and recover night-launched model rockets. This circuit generates from one to two flashes per second. The rate can be altered by changing the value of *C1* or *R2*. Use care when first operating the circuit or when altering its flash rate. If the lamp stays on continually without flashing, the heat generated by the heavy current flow will quickly overheat and possibly damage or destroy *Q2*. If *Q2* becomes warm, substitute a suitable heat-sinked npn power transistor.

Figure 5 is an LED flasher circuit. With the values shown and when the power supply provides 9 volts, the circuit delivers a 1-millisecond pulse twice each second. The pulse has an amplitude of 600 milliamperes. I have used this circuit to drive an ultra-bright Stanley H2K red LED. The resulting flashes are too bright to observe at close range. (See the April "Electronics Notebook" for more information about the remarkable H2K.)

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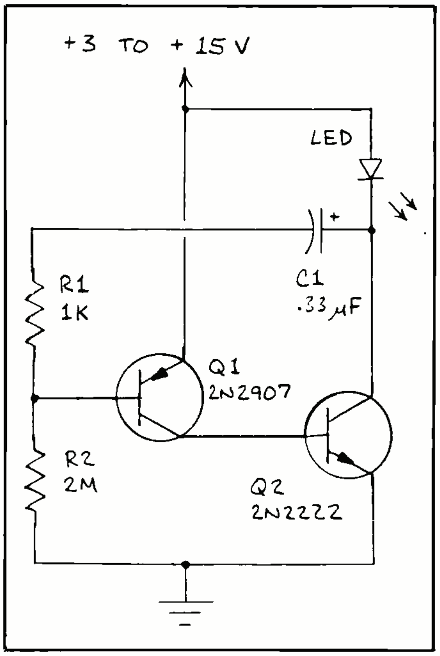


Fig. 5. A simple LED flasher circuit.

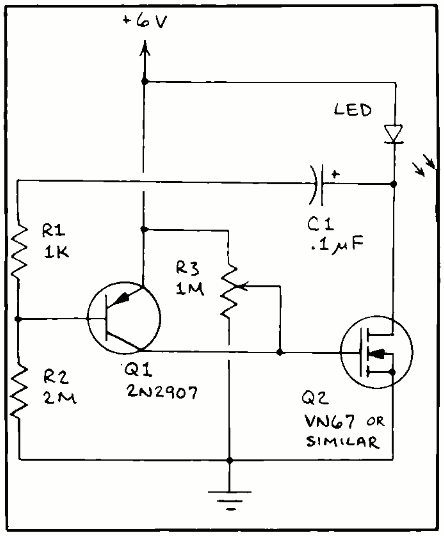


Fig. 6. A power-MOSFET flasher.

Figure 6 is a variation of the circuit in Fig. 5 in which the *Q2* npn transistor has been replaced by a power MOSFET. Though I used a VN67, any n-channel MOSFET should work. With the values shown, the circuit delivers a 1 millisecond pulse to the LED every 80 milliseconds (a flash rate of about 12.5 Hz). Peak current through the LED is 500 milliamperes, and the pulses are very square.

For the circuit in Fig. 6 to oscillate, potentiometer *R3* must be properly adjusted. After the desired operating mode is achieved, the resistance between the rotor and the two stationary terminals can be measured and a pair of fixed resistors substituted for the pot.

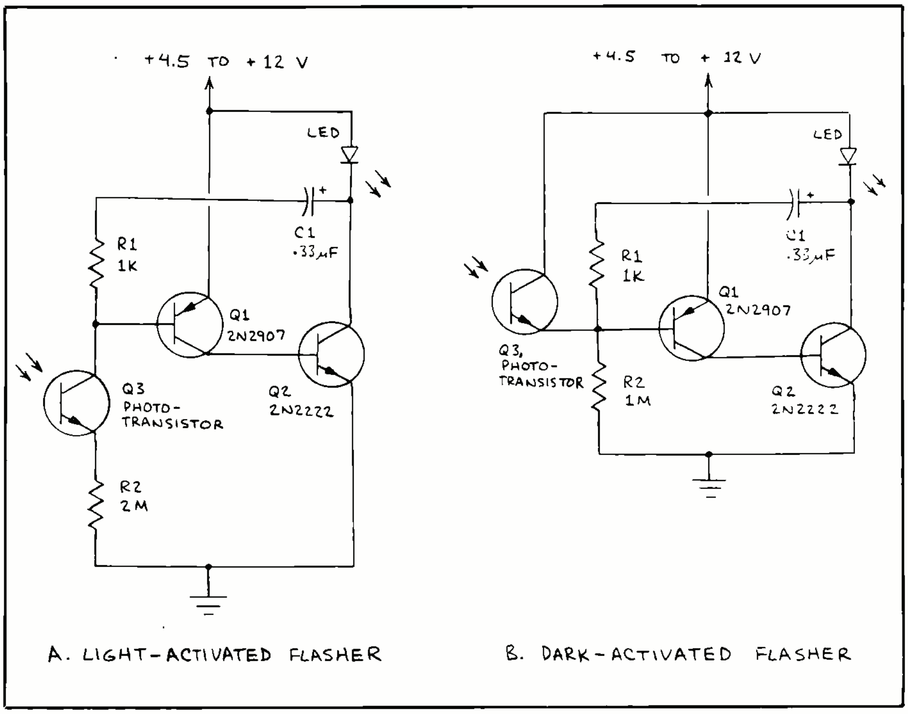
I have used the circuit in Fig. 6 to drive both near-infrared and red LEDs. For very high pulse current through the LED, use a low on-resistance MOSFET (under 1 ohm). If you can't find a low on-resistance MOSFET, two or more standard power MOSFETs can be connected in parallel to reduce the resistance of the current path through the LED. Be sure to avoid driving the LED above the current level for which it is rated; otherwise, it will be degraded or even destroyed.

Figure 7 shows a pair of two-flash-per-second flasher circuits that are activated by the presence or absence of light at phototransistor *Q3*. In Fig. 7A, the flasher circuit is disabled when *Q3* is dark. Light at the active surface of *Q3* switches on this transistor and permits the flasher circuit to function.

The circuit in Fig. 7B can be used as a warning flasher that operates only at night. The circuit is disabled when light switches *Q3* on, thereby clamping *Q2*'s base to the positive supply. When *Q1* is dark, the flasher operates normally. The circuit consumes only about 1 microampere when *Q3* is illuminated and the supply provides 5 volts. When the supply provides 12 volts, standby current drain increases to about 4 microamperes.

Incidentally, the dark-activated function can be accomplished by means of a cadmium-sulfide (CdS) photocell instead of a phototransistor. One way is to remove *Q3* and connect a cadmium-sulfide photocell between the positive supply and *Q1*'s base. Alternatively, connect the CdS photocell across *C1*. There is no reason why the light/dark activation methods described here cannot be used with any of the other circuits in this column. For in-

Fig. 7. Light-activated (A) and dark-activated (B) flasher circuits.



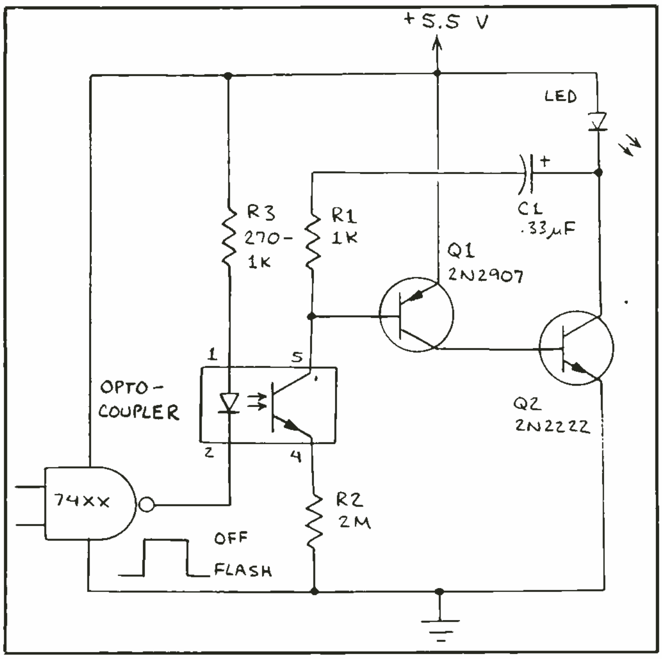


Fig. 8. Schematic diagram of a TTL gated LED flasher.

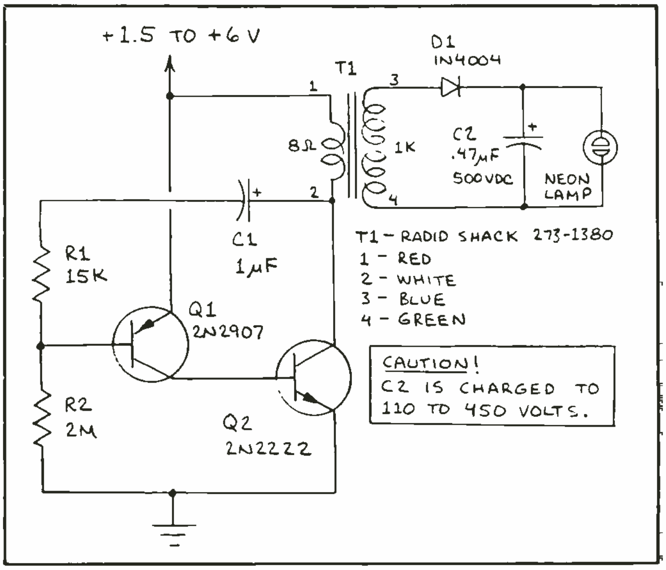


Fig. 9. Schematic diagram of a dc-to-dc-converter.

stance, a phototransistor or photocell can be used to make a light- or dark-activated tone generator.

Figure 8 shows one way to control the basic flasher circuit by means of an external logic signal. The LED in an optocoupler is connected to the output of a TTL logic gate. When gate output is low, the LED receives current and illuminates the phototransistor in the optoisolator. This permits the flasher circuit to function. When the output of the logic gate is high, the LED is extinguished, the phototransistor is dark, and the flasher circuit does not operate. The basic technique shown here can be applied to the other circuits in this column.

Dc-to-Dc Upconverter

A dc-to-dc upconverter can be made by replacing the LED of the previous circuits with the 8-ohm winding of an 8:1000-ohm miniature output transformer. For each current pulse through the winding, a high-voltage pulse is induced in the secondary winding. This voltage can be rectified and stored in a capacitor or used to drive low-impedance loads, such as a piezoelectric bimorph tactile stimulator.

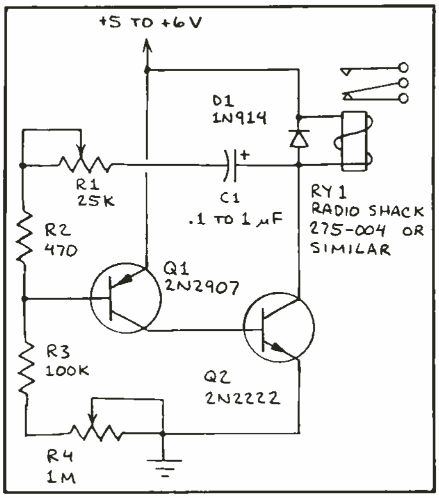


Fig. 10. Two transistors make an ultra-simple relay controller circuit.

Figure 9 shows how this kind of circuit can flash a neon lamp. Though I used a Radio Shack No. 273-1380 output transformer, other transformers with a similar turns ratio should also work. Diode *D1* rectifies the high-voltage pulses from *T1* and *C2* accumulates the voltage. Capacitor *C2* discharges through the neon lamp when the charge stored in it reaches the lamp's firing voltage. The charge/discharge cycle then repeats.

The circuit in Fig. 9 can produce surprisingly high output voltages at relatively low current drains. Here are the results I measured for the prototype circuit:

Supply Voltage	Current Drain (mA)	Output Voltage
1.5	0.6	110
3.0	1.6	320
4.5	2.2	450
6.0	2.6	450

Note how the output from the circuit saturates when the supply voltage exceeds 4.5 volts. Be sure *C2* is rated for the expected voltage level.

Relay Controller

Adding a relay permits the basic oscillator circuit to supply a continuous stream of current pulses to a high-power device. Figure 10 shows an experimental circuit that does just that. Note that the supply should range from 5 to 6 volts for consistent results. Potentiometer *R1* and capacitor *C1* control both the time interval the relay is closed per pulse and the rate at which the pulses are applied. Potentiometer *R2* controls only the pulse rate. Switching cycles of a few seconds can be achieved by careful adjustment of the various components.

Pulse Generator

Since the oscillator circuit produces fast rising and falling pulses, it is well-suited as a pulse generator. Figure 11 shows how a pulse generator can be implemented by inserting a 50-ohm resistor between *Q2*'s emitter and ground. Here is a summary of the operation of the circuit with the values shown in Fig. 11 when the supply was 12.5 volts:

C1 Value (μF)	Pulse Duration (μs)	Maximum Rate
0.001	5	1500
0.010	22	225
0.100	200	23

The amplitude of the output pulse ranges from 10 volts ($C1 = 0.001$ μF) to 11 volts ($C1 = 0.1$ μF). The rise time for all values of *C1* is a very fast 10 nanoseconds (measured at 10% to 90% points).

Going Further

The circuits shown here merely illustrate the wide range of applications for the basic two-transistor oscillator shown in Fig. 1. Here are some other applications you might want to explore:

- Continuity tester
- Burglar alarm
- Low-power radio-frequency transmitter
- Pulse-amplitude modulator
- Pulse-duration modulator
- Monostable multivibrator
- Sound-effects generator
- Infrared tone transmitter/beacon

Finally, though to my knowledge the basic oscillator circuit isn't available in integrated form, you can easily assemble

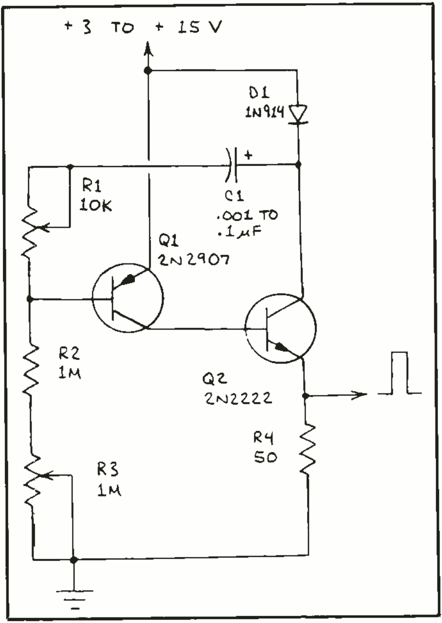


Fig. 11. Adjustable pulse generator.

its components on a 14-pin dual in-line header. Some of the companies that advertise in this magazine sell such headers, along with plastic covers. **ME**