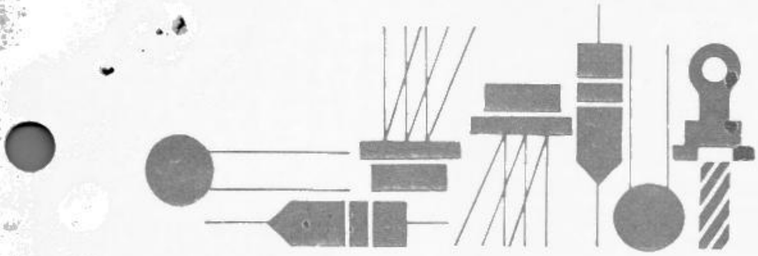

Solid State

By Lou Garner

DOWN NOSTALGIA LANE

LOOKING back over the past quarter-century, one soon realizes that POPULAR ELECTRONICS and the solid-state industry have grown to maturity together. When the first issue of the magazine appeared in October 1954, the transistor itself was a mere infant scarcely over six years old, having been introduced publicly by the *Bell Telephone Laboratories* in June 1948. This was the early—and now obsolete—point-contact transistor. The junction transistor, still a viable type, was even younger, for it was not introduced by *Bell* until July 1951. It was less than two years earlier, late 1952, that transistors had made their first appearance in consumer products—expensive hearing aids.

In those days, the vacuum tube was the king, and that first issue, Volume 1, Number 1, featured but a single "solid-state" construction project—an AM Broadcast Band crystal receiver using the ubiquitous 1N34 germanium diode. There were, however, descriptions of several solid-state products, including a battery-eliminator charger kit using selenium rectifiers and a transistor experimenter's kit. In addition—shades of the current energy crunch—there was a feature story on solar batteries! The next two issues, November and December 1954, featured no further solid-state projects since the devices were not yet modestly priced.

There was GOOD NEWS for the experimenter in late 1954, however, for the *Raytheon Manufacturing Company* had cut the price of its fan-ic experimenter's transistor, the CK722, to a mere $3.50, bringing well within the reach of virtually every hobbyist. Introduced in early 1953, the CK722 was actually a selected "fall out" from the firm's premium-priced hearing-aid transistor line. A low-voltage, moderate-gain, low-power, audio-range, germanium pnp junction transistor assembled in a plastic case, the unit originally was priced at $7.60 each—not a bad price at the time, considering that other available transistors were $50.00 each and up! And those were "middle 50's" dollars, which had a lot more purchasing power than today's inflated dollars. POPULAR ELECTRONICS carried a newsstand price of only twenty-five cents, and a 12-ounce *Pepsi-Cola*® cost only a nickle, as did candy bars, packs of chewing gum, and two-ounce packages of potato chips. You can bet that experimenters and hobbyists were very, *very* careful with how they handled their transistors then!

Although the vacuum tube continued its dominance, transistor prices began to drop slowly with each passing month. More semiconductor manufacturers entered the field, increasing competition. New devices were introduced. Solid-state electronic projects appeared a little more often in these pages and experimenter interest waxed hotter and hotter. Before long, the editors decided that the young upstart, the transistor, needed special treatment. Consequently, they started a regular column entitled "Transistor Topics." A Contributing Editor since the magazine's first issue, I was asked to take over that column soon after it first appeared. By the time my first column was published in June 1956, the transistor was starting to come into its own as a viable experimenter's device. Raytheon was offering an *r-f transistor*, the CK768, at a mere $1.50, while the CK722 had broken the dollar barrier and was selling for only 99 cents.

Despite dropping prices, however, transistors were still considerably more expensive than vacuum tubes by mid-1956 so most construction projects used only one or, at a maximum, four transistors. A four-transistor broadcast-band receiver was featured in the May issue, a couple of single-transistor Geiger counters in June, and a single-transistor power megaphone in July. The latter was one of the first hobbyist projects to use a multiwatt power transistor, the 2N68.

From this point, Time and Progress marched forward arm in arm. Prices continued to drop. Hundreds of new transistor types were introduced. Interesting new semiconductor devices made the scene—the silicon controlled rectifier (SCR), the unijunction transistor, the tunnel diode, the 4-layer silicon switch, the Gunn diode, the phototransistor, the triac, the Diac, the field-effect transistor (FET), charge-coupled devices (CCDs), the Darlington transistor, VMOS devices, integrated circuits, light emitting diodes (LEDs), and that fabulous "computer on a pinhead," the microprocessor. The trickle of semiconductor devices became a flood and, all the while, POPULAR ELECTRONICS and its readers kept pace. The vacuum tube was driven from its throne by the semiconductor legions, and "Transistor Topics" became "Solid State."

You've Come A Long Way, Baby! From the very beginning, POPULAR ELECTRONICS readers have been more sophisticated than most other electronics enthusiasts, enjoying advanced as well as elementary projects. Over the years, they have assembled not only a wide variety of conventional audio amplifiers and radio receivers and transmitters, but laser systems, electronic musical instruments, ultrasonic gear, test equipment, household and automotive alarms, light-beam communicators, calculators, electronic games, and minicomputers and peripherals.

"Reader's Circuits" was introduced originally as part of my first "Transistor Topics" column and later became a regular feature, continuing when the name was changed to "Solid State." Through this section, readers are able to share their pet designs with other experimenters and hobbyists. Early contributions tended to be relatively simple one- to three-device designs, and this trend has continued to the present. But while the specified devices in the early designs generally were single transistors and diodes, later designs often include one or more IC's (integrated circuits), each of which may contain the equivalent of from a half dozen to a hundred or more transistors.

Two early Reader's Circuits, from the June and July 1956 column, are shown in Fig. 1A and 1B. In those days, there was still some question regarding the proper reference symbol for a transistor, so you'll note a "V" (for *valve*) reference designation in one circuit, and a "TR" in the other. Today, of course, "Q" is the standard letter symbol for a transistor.

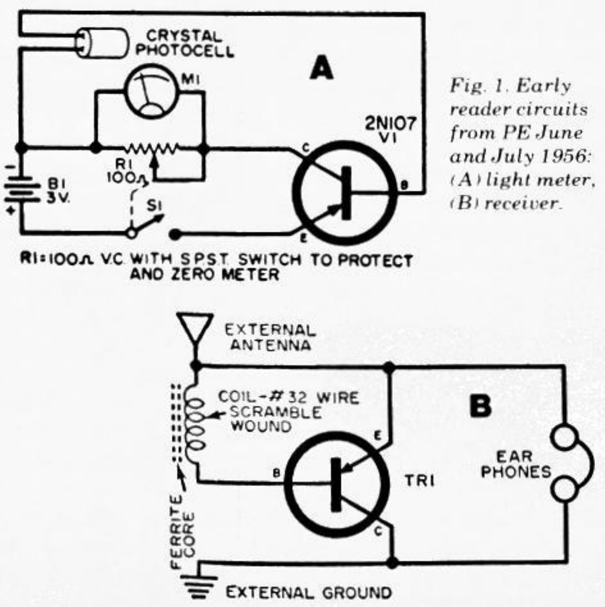

Fig. 1. Early reader circuits from PE June and July 1956: (A) light meter, (B) receiver.

Fig 2. Circuit for a general-purpose alarm. Many applications are possible, depending on the sensor used.

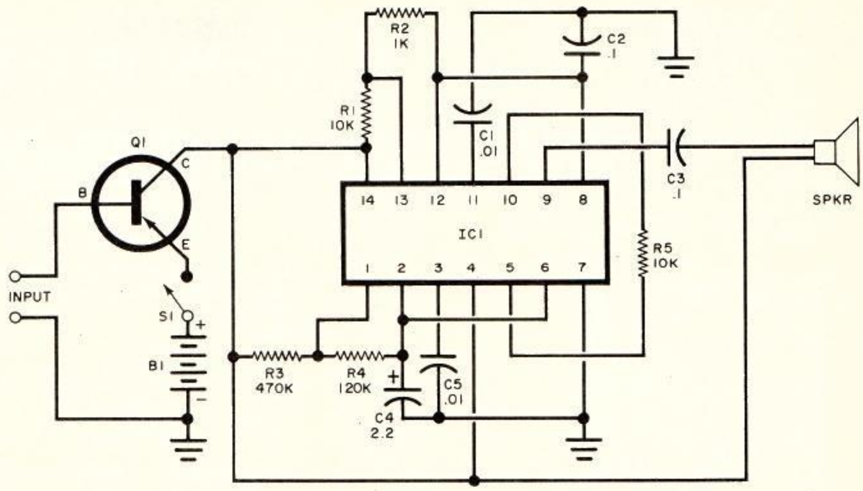

Figure 1A was submitted by Joe Gabus and features a Clairex type CL-1 cadmium-sulphide photocell direct-coupled to a GE type 2N107 pnp transistor, serving as a common-emitter dc amplifier. A 500-microampere meter, *M1*, is used as an output indicator, shunted by a 100-ohm potentiometer, *R1*, for calibration adjustment and meter protection.

The extremely simple receiver circuit contributed by Matthew Mandl, can use virtually any type of pnp or npn transistor. Designed for single-station reception, it uses a hand-wound coil on a ferrite core. The number of turns is determined experimentally (by guess and by golly) for best reception of the strongest local station. Unless the user lives near a broadcast station, an external antenna and ground system are mandatory.

The Past Is Prologue. Many years ago, in the 1800's, an important official suggested that the Patent Office be abolished, for "there was nothing left to invent." But look at what's happened not only since then, but just in the last quarter century: pocket calculators, electronic watches, electronic language translators, home computers, and on and on!

Predicting future developments is a fun game and one which I, a science-fiction aficionado, really enjoy. Here, then, are my predictions for the next quarter century:

In energy:

- Development of low-cost photovoltaic cells, making solar-generated electric power competitive with conventional sources.
- Development of economical fuel cells for vehicular use, making the electric car feasible for long as well as short trips.
- Development of small-scale nuclear power plants suitable for individual buildings and larger vehicular (trucks/buses) applications.

In computers:

- Development of begabit memories (i.e., a *billion bits* per module).
- Development of full aural interactive computer systems which not only respond to voice commands but which can answer questions.
- Similarly, development of microcomputer controlled test instruments and systems which react to voice commands and provide an audible response.
- Development of full-capacity computer systems with flat-screen displays and hard-copy printouts no larger than a standard attache case.

In general electronics:

- Continued development of specialized large-scale integrated circuits, leading to equipment and instrument design using systems engineering techniques.
- Continued development of more advanced discrete devices despite the increasing use of IC's.
- Breakthrough in solid-state or liquid-crystal imaging devices, leading to flat, large-size TV screens and displays.
- Comparable breakthrough in solid-state transducers, including sound generators (i.e., loudspeakers), sensors, and prime movers.
- Full integration of solid-state and microwave technologies, leading to lower priced instruments and equipment.
- Similar integration of solid-state and fiber-optic technologies, with fiber-optic light-beam communications and data transmission systems becoming as common as today's hard-wired networks.

Reader's Circuit. With literally dozens of potential practical applications, the general-purpose control/alarm circuit in Fig. 2 was submitted by high school student, Edwin Goei (111 Tophill, San Antonio, TX 78209). Depending on the type of sensor switch used, the circuit may serve as a water-level, freezer-failure, fire, intrusion, theft, or power-failure alarm. It requires no standby power, assuring long battery life and, once activated, emits an attention-getting "beeping" sound. Easily assembled in one or two evenings and requiring no special construction skills, the design uses standard components.

Two sections of a 556 dual timer, *IC1*, are used as interlocked low- and high-frequency multivibrators to generate the required "beep" signal, which drives a loudspeaker directly through dc blocking capacitor *C3*. To achieve control and minimize the need for standby power, pnp transistor *Q1* is used to switch the dc power source, *B1*. With switch *S1* closed, the circuit is inactive as long as the input terminals are open, for *Q1* is operating without base bias and thus behaves as a

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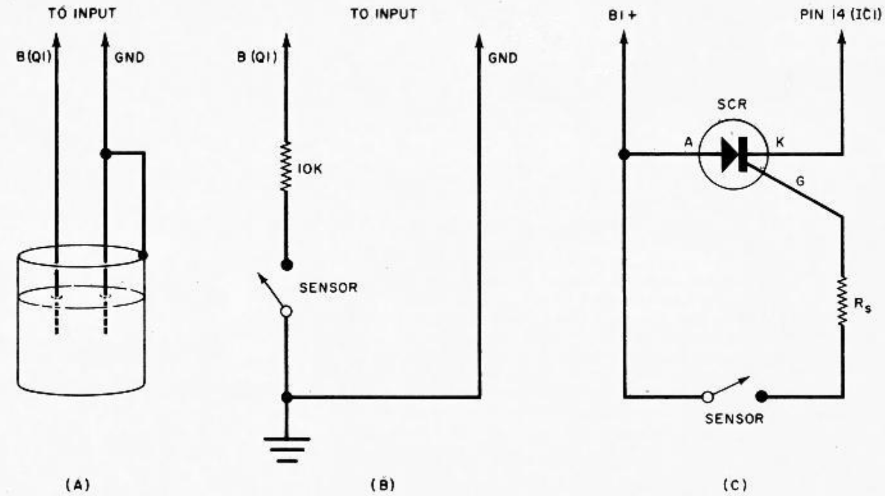

Fig. 3. Techniques for using reader's alarm circuit: (A) as water-level alarm; (B) with sensor and thermostatic switches; (C) in "latch-on" alarms.

high impedance or "open" circuit. If the input terminals are connected through a moderate resistance, base bias is applied to *Q1*, which shifts to a low-impedance state, thus supplying power to *IC1* and activating the alarm.

Neither parts layout nor lead dress is critical and the circuit can be assembled using any construction technique. The power source, *B1*, is a standard 9-volt transistor battery, but six series-connected penlight or flashlight cells can be used instead. Switch *S1* is a spst toggle, slide, rotary or pushbutton type, *Q1* is a general-purpose pnp transistor, and *IC1*, of course, is a type 556, although a pair of 555s can be used by making the necessary changes in pin connections. The resistors are all one-quarter or one-half watt types and the capacitors are conventional low voltage units.

Several techniques for using the basic design in different applications are suggested in Fig. 3. For a water tank or sump level alarm, simply mount two metal probes, such as heavy bus wire, rods, or tubes, so that they are contacted by the water at the level at which an alarm is to be sounded (Fig. 3A). The probes should be close together, but insulated from each other, with an exposed lower surface to make contact with the water. The probes are connected *directly* to the alarm's input terminals.

For applications using a simple switch sensor, such as a "Micro-switch" or bimetallic thermostatic switch, as in a freezer door or fire alarm, a 10,000-ohm, half-watt resistor should be connected in series with the "hot" input lead to limit the transistor's base current (Fig. 3B).

Finally, for burglar, theft, intrusion or similar applications requiring a continuously sounding alarm once tripped (until deliberately reset, of course), transistor *Q1* should be replaced with a low-voltage sensitive-gate SCR, as shown in Fig. 3C. Depending on the installation, the sensor switch might be a normally open magnetic door switch, a pressure sensitive mat switch, a "Microswitch," or some similar device. The value of the series gate resistor, *Rs*, will depend on characteristics of the SCR used in the circuit. In operation, the alarm will sound continuously once the sensor switch is closed, even momentarily, until the system is "reset" by opening and closing the main power switch (S1, Fig. 2).

Device/Product News. Back when POPULAR ELECTRONICS—and the solid-state industry—were still infants, the word *hybrid* was used to describe electronic equipment, principally audio amplifiers and radio receivers, which used both transistors and vacuum tubes. A hybrid receiver generally used vacuum tubes in the r-f and i-f stages and transistors in the audio section. In hybrid audio amplifiers, transistors were used in the low-level voltage amplifier stages and vacuum tubes as power output amplifiers.

Today, hybrid is used to describe integrated solid-state circuits manufactured by assembling what are essentially discrete components, including resistors and capacitors, on a single substrate. The MWA Series of wideband r-f amplifiers are good examples of modern hybrid circuit design. Introduced recently by Motorola Semiconductor Products, Inc. (Box 20912, Phoenix, AZ 85036), these are single-stage amplifiers suitable for applications in r-f, i-f, agc, and isolation circuits as well as in-line drivers. With 50-ohm input and output impedances, the devices offer typical gains up to 14 dB and, depending on type, frequency responses from 100 kHz to 1 GHz. Thin-film hybrid construction on an alumina substrate is used with gold metallization and laser-trimmed nichrome resistors.The units are supplied in metal TO-39 hermetically sealed packages.

In addition to the wideband r-f amplifiers, Motorola has introduced a number of new discrete devices with potential applications in hobbyist projects, including a line of fast-switching npn power transistors and a family of plastic packaged high-power triacs. Designated the MJ8500 Series, the new power transistors offer maximum $V_{CEO(sus)}$ ratings of 800 V and IC ratings as high as 10 A, depending on type. Suitable for use in switching-mode power supplies, inverters, converters, and similar applications, the new devices are packaged in special metal TO-3 cases. Comprising sixteen different types, the new triac family features a 25-A current rating, with a 250-A surge capability. Identified as the MAC223/223A Series, they are offered with voltage ratings from 100 V to 800 V, depending on type. The highest voltage types are capable of handling loads in excess of 10 kW. Designed for lighting, heating, and motor control applications, the units are supplied in special TO-220 plastic packages.

The International Rectifier Corporation (233 Kansas St., El Segundo, CA 90245) is marketing a line of high-power MOSFET's. With high input impedances, high gain, and switching speeds to over 200 kHz, the new devices are offered with V_{DS} ratings from 60 to 400 V at continuous I_D ratings from 4 to 16 A, depending on type. The devices, therefore, can handle power levels in excess of 1 kW. Potential applications include audio amplifiers, switching power supplies, motor controls, induction heating, and ultrasonic systems. ◇