Solid State

By Lou Garner

SIMPLE STOPWATCH SPLITS SECONDS!

ALTHOUGH electronics may be one of your major hobbies, if you're a typical reader, chances are you're interested in a number of other things as well . . . track, perhaps, or wrestling, boxing, swimming, skiing, sailing, horse racing, skating, skeet, target shooting, rally driving, archery, chess, photography or chemistry. In many of these activities, it may be desirable to time an event or series of events with reasonable accuracy and, for this, a stopwatch is a virtual necessity. Fortunately, there's a wide choice of commercial instruments available for nearly all timing applications, from chemical reactions to photographic exposures, from sports matches to the single lap of a race, and from a chess move to the driving (or sailing) coverage of a measured distance. You can choose a conventional mechanical hand-wound type or a sophisticated digital electronic unit at prices ranging from less than fifty to more than two hundred dollars, depending on the accuracy and operational features needed for your application. On the other hand, if you prefer to "roll your own," you can assemble a versatile multi-function digital stopwatch at modest cost and with minimum effort by using an IC introduced late last year by *Intersil, Inc.* (10900 N. Tantau Ave., Cupertino, CA 95014). The resulting instrument features a timing range of up to 59 minutes 59.99 seconds in one-hundredth of a second increments, a low-battery indicator, crystal control, and two operating modes, yet requires, in addition to the IC, only a six-digit LED display, four spst switches, a quartz crystal, a small trimmer capacitor, and three penlight cells, plus a case and customary hardware.

Designated type ICM 7205, Intersil's stopwatch IC is a single chip CMOS device designed to interface directly with a six-digit/seven-segment common-cathode LED readout, and is capable of furnishing a multiplexed drive current of up to 13-mA per segment with a nominal 3.8-volt dc source. It is suitable, however, for use on 2-to 5-volt dc supplies and is fully protected internally against damage from static charges, thus eliminating the need for special handling and wiring precautions. The unit has a maximum power dissipation rating of 0.75 watts and a specified operating temperature range of from −20°C to +70°C. The device contains an integral oscillator, high- and low-frequency dividers, a multiplex generator, control logic, counters, a decoder, digit and segment drivers, and a low-battery sensor/indicator driver. In operation, the circuit divides the 3.2768-MHz signal generated by the crystal controlled oscillator by 2^{15} to obtain 100 Hz, which is then fed to the fractional seconds, seconds and minute counters. An intermediate frequency is used to develop a one-sixth duty cycle 1.07-MHz signal for multiplexing the display drivers. The blanking logic provides leading zero blanking for seconds and minutes independently of the clock.

Described in Intersil's 6-page technical bulletin for the ICM 7205, the stopwatch schematic shown in Fig. 1 is

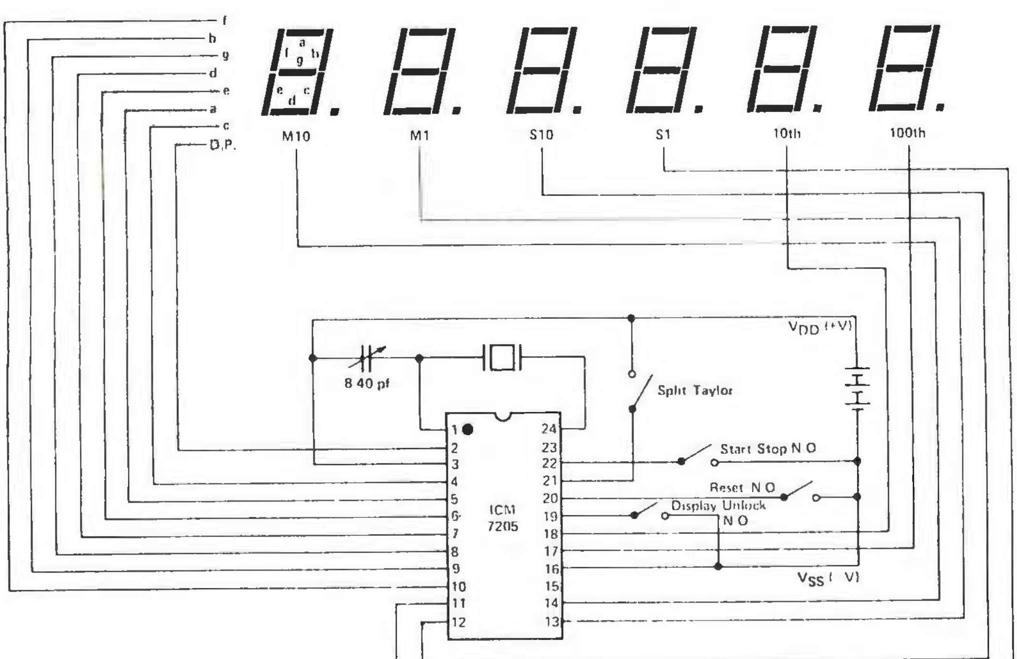


Fig. 1. Circuit for stopwatch using the 7205 chip.

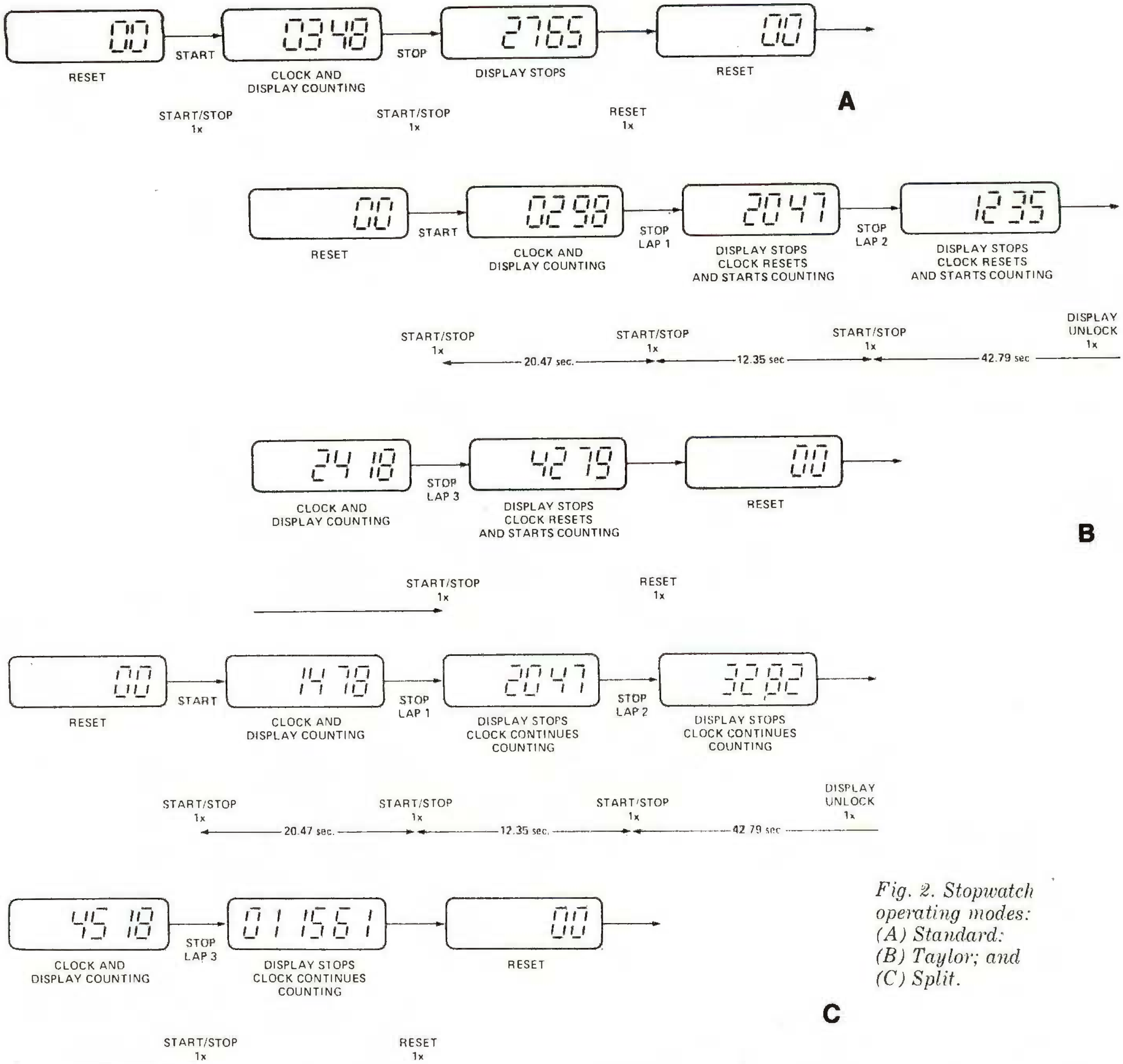


Fig. 2. Stopwatch operating modes: (A) Standard; (B) Taylor; and (C) Split.

complete except for an optional "on-off" power switch. If used, this may be a spst unit connected in series with either power supply lead. The power source consists of three series-connected AA cells or equivalent rechargeable NiCd units. Since standard components are specified, most of these should be readily available through local dealers. However, depending on the individual's location, it may be necessary to order the IC and crystal through one of the larger mail-order distributors. The manufacturer specifies that the quartz crystal used to control the oscillator's frequency should be a 3.2768-MHz unit with an R_S of 50 ohms and a load capacitance of 15 pF. If a different crystal is used, it may be necessary to change the trimmer capacitor's value (shown as 8 to 40 pF) to achieve optimum performance.

With neither parts layout nor lead dress critical, the individual builder may use either PC or perf board construction techniques when duplicating the circuit, as preferred. Good wiring practice should be followed, of course. For best performance, the spst START/STOP switch should be a high-quality, normally open pushbutton type with low "bounce" (less than 15 ms) characteristics. After assembly and checkout, the oscillator trimmer should be adjusted for precise operation, checking the unit against an accurate standard, if available.

In practice, switching the stopwatch "on" will reset the circuits and display "*00*" in the fractional seconds position, with all other digits blanked. This display always indicates that the stopwatch is ready for operation. The instrument may be used in either of two modes in addition to that of a standard stopwatch. All three operational modes are illustrated graphically in Fig. 2. For timing a single event, the START/STOP and RESET switches are used. As shown in Fig. 2(A), depressing the START/STOP switch starts the clock and display counting. At the end of the timed event, depressing the START/STOP switch stops the display, permitting a readout of the time interval. Initially, only fractions of seconds are displayed, with seconds shown after one second and, finally, minutes after the first minute, providing a full display. Since the maximum range is 59 minutes 59.99 seconds, the user must remember the number of hours if the timed event exceeds an hour. Lead-

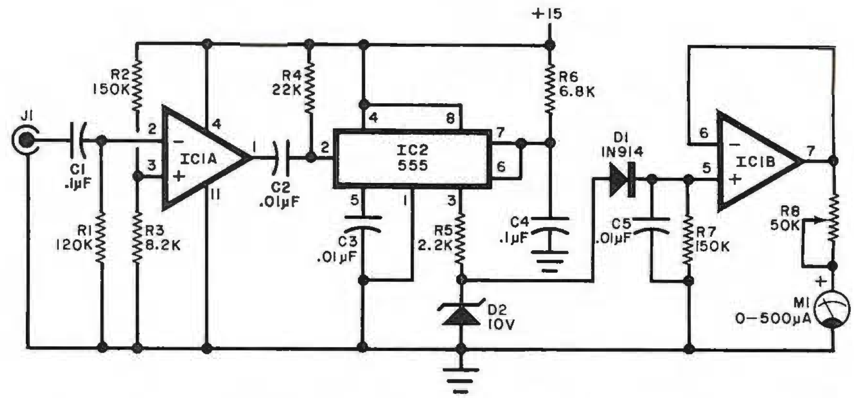


Fig. 3. Ted Reiter's frequency-to-voltage converter circuit.

ing zeros are not blanked after the first hour. Once the event is timed, the instrument can be reset for another measurement by operating the RESET switch. The TAYLOR (or sequential) mode is used when timing a series of rapidly occurring events where the individual time for each event is of immediate interest, rather than the total time. Here, the SPLIT/TAYLOR switch (Fig. 1) is left open and the instrument is controlled using the START/STOP, DISPLAY UNLOCK, and RESET switches. As depicted in Fig. 2(B), depressing the START/STOP switch initially starts both the clock and display counting. At the end of the first event, depressing the START/STOP switch stops the display and resets the clock, which starts counting again. The display remains stationary after the first interval, showing the last previous time, until the START/STOP switch is actuated, which causes the display to show the next interval. Operating the DISPLAY UNLOCK switch will permit the display to show the running clock at any time. Upon completion of the timing tests, the stopwatch is reset by actuating the RESET switch. Finally, for those events where the user is interested in the cumulative time intervals for a series of events, the stopwatch can be operated in the SPLIT mode. Here, the SPLIT/TAYLOR switch is closed. Afterwards, depressing the START/STOP switch starts the clock and display counting, as shown in Fig. 2(C). At the end of the first event, the START/STOP switch stops the display but permits the clock to keep counting. Thereafter, the cumulative time can be read after each succeeding event by operating the START/STOP switch. Whenever desired, the DISPLAY UNLOCK switch may be used to let the display "catch up" with the running clock. At the end of the series of events, the RESET switch reestablishes initial starting conditions but, of course, this control can be used at any time.

The optional on-chip low battery indicator (LBI) is intended for use with a separate LED or with the decimal points of the digital readout. Its output (pin 2) is a p-channel transistor of approximately half the size of one of the segment drivers. The circuit is designed to maintain a voltage difference between the LBI trigger level and the minimum operating voltage. Thus, the lower the LBI trigger voltage, the lower the minimum operating voltage. In practice, this means that the stopwatch will provide at least 15 minutes of accurate timekeeping after the LBI turns on, assuming that the power pack consists of three size AA cells.

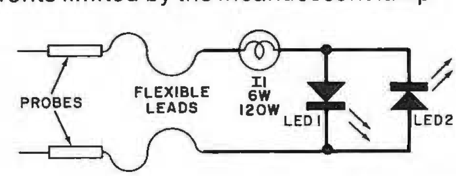
Readers' Circuits. A previous contributor to these pages, Ted Reiter (1442 Brook Drive, Titusville, FL 32780), suggests the circuit illustrated in Fig. 3 as an alternative frequency-to-voltage converter for experimenters who may not have access to Raytheon's new 4151, described in the April column. Ted developed his circuit for use in conjunction with a project involving the measurement of solar intensity levels translated into varying audio tones. Requiring a 3-volt rms input signal, the circuit drives a standard 500-μA meter and is designed for optimum performance between 100 and 500 Hz.

In operation, the input signal is applied through coupling capacitor *C1* to op amp *IC1A,* biased by voltage-divider *R2-R3* for operation as a modified Schmitt trigger. The amplified output signal is applied through a differentiation network, *C2-R4,* to a one-shot, *IC2,* which delivers fixed width output pulses to a peak limiting circuit, *R5-D2.* The pulses are then coupled through detector diode *D1* to a pulse integrator, *C5-R7.* Since the pulses applied to the integrator are of constant width and amplitude, the instantaneous voltage developed across *C5* will be directly proportional to the pulse repetition rate and hence to the frequency of the original signal. This voltage is amplified by a second op amp, *IC1B,* and used to drive the output meter, *M1.* Potentiometer *R5* is used to set the meter's full scale reading at the highest frequency measured (500 Hz).

Ted has specified standard, readily available components in his design. Op amps *IC1A* and *IC1B* are two sections of a type 324 quad op amp (the other two sections are available for other circuit applications), while *IC2* is a familiar 555 timer. Zener diode *D2* is a 10-volt, 400 mW type. All resistors, except for calibration potentiometer *R8,* are ¼- or ½-watt types, and the capacitors are small ceramic, plastic film or paper units. Operating power, nominally 15 volts, is actually furnished by a pair of series-connected 9-volt transistor batteries. Neither component layout nor wiring dress should be overly critical and the builder, therefore, may follow his own inclinations regarding construction methods when duplicating the circuit.

Peter Lefferts (1640 Decker Ave., San Martin, CA 95046), one of our more prolific west coast contributors, has submitted another interesting design . . . a wide range voltage probe. Pete's circuit, given in Fig. 4, requires but three basic components: a 6-watt, 120-volt incandescent lamp, *I1,* and a pair of type NSL 5023 or NSL 5024 light emitting diodes, *LED1* and *LED2.* Despite its simplicity, the probe can indicate the presence of *any voltage from 1.5 to 150 volts ac or dc,* with either the lamp (*I1*) or one (or both) of the LEDs illuminated. The circuit depends, for its operation, on the unique characteristics of the incandescent lamp's filament. At lower voltages, only the LEDs are activated, with their currents limited by the incandescent lamp

Fig. 4. Peter Lefferts's wide-range voltage probe.



serving here as a simple series resistor. At higher voltages, the rapidly increasing resistance of the lamp's filament limits the LEDs' currents to about 50 mA at full line voltage, or about 25 mA average for an ac input. If desired, one of the probes can be "polarized" for dc checks, with the corresponding LED illuminated at correct polarity. For example, if the upper probe (Fig. 4) is considered *positive*, *LED1* is illuminated when correct polarity is applied, with *LED2* indicating reversed polarity. The circuit can be assembled in a small metal chassis box with test jacks, in a plastic case with flexible test leads, or self-contained within a cylindrical tube, at the builder's option.

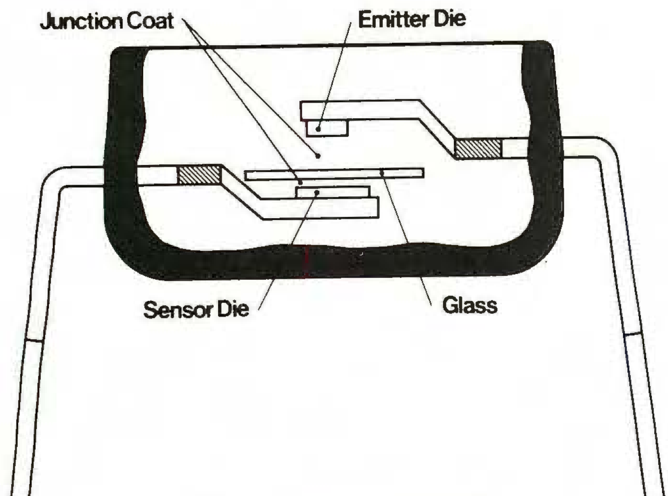


Fig. 5. Cross-section sketch of Fairchild's new optocoupler design.

Data Up-Date. The *National Semiconductor Corporation* (2900 Semiconductor Drive, Santa Clara, CA 95051) has released a number of new handbooks which should be of major interest to serious hobbyists and experimenters. The handbooks, listed below, may be purchased through the firm's franchised distributors or ordered directly from the manufacturer's Marketing Services Department (California residents should add 6% sales tax to the indicated prices):

The *PACE Technical Description* is a 96-page handbook describing the firm's "PACE" single-chip, 16-bit microprocessor. The volume describes both the full-feature CPU and the entire complement of hardware and software items that comprise the "PACE" (Processing And Control Element) system, showing in detail the family of support chips, application cards, software support (including program examples), and microprocessor development systems. Applications as well as operations are described, along with product and instruction summaries. The PACE manual is priced at $3.00/copy.

Interface Integrated Circuits is the title of a 464-page data handbook which gives specifications on the firm's complete line of interface products, including peripheral/power drivers, level translator/buffers, line drivers and receivers, memory and clock drivers, sense amplifiers, display drivers, and optocouplers. The text is supported by graphs, charts and diagrams. Also included is a 72-page section of application notes covering such topics as transmission lines, data transmission in high-noise environments, and driving gas discharge and LED displays, together with product selection guides listing specifications for LED drivers, peripheral drivers and transmission drivers, and two cross reference guides comparing product type numbers of other manufacturers. The Interface handbook carries a price tag of $4.00/copy.

The *TTL Data Handbook* describes National's complete line of bipolar logic devices, giving full specifications and electrical performance characteristics on standard 54/74 TTL, low-power 54L/74L, high-speed 54H/74H, ultrahigh-speed Schottky 54S/74S, low power Schottky 71LS/81LS, Series 9000 TTL, Series 10,000 ECL, and Series 930 DTL. It covers gates, buffers, drivers, flip-flops, latches, registers, counters, selector/multiplexers, multipliers, comparators, decoders, parity generators, and related devices. A Tri-State selection guide, an industry cross reference guide and a functional index also are included, as well as package outlines. The *TTL Data Handbook* may be obtained for $4.00/copy.

The *Memory Data Book* is a 544-page volume covering the manufacturer's memory and memory-related products, including bipolar, MOS, CMOS RAMs, field and mask programmable ROMs (bipolar and MOS), MOS shift registers and PLAs. In addition, the book describes interface/support circuits for memory operation and includes pertinent application notes, cross reference guides and a production status guide on National memories as well as complete specifications, characteristics, diagrams and special features of the products. The price is $3.00/copy.

Finally, the *SC/MP Technical Description* is a 65-page handbook which describes the firm's single-chip 8-bit "SC/MP" (Simple-to-use, Cost-effective, MicroProcessor), a CPU requiring only one memory chip to form a complete, fully-programmable system. Starting with a general introduction to "SC/MP" for non-technical users and following up with complete details for preparation of a preliminary design of "SC/MP"-based applications, the book includes 6 tables and 35 illustrations. The software described includes cross assemblers, loader/debug utilities, and input/output routines. Also outlined is a description of three application modules. The volume is $3.00/copy.

Device/Product News. Both *Fairchild*'s Linear Integrated Circuits Division (464 Ellis St., Mountain View, CA 94042) and Optoelectronics Division (4001 Miranda Ave., Palo Alto, CA 94304) have introduced new devices of potential interest to experimenters and hobbyists, including a line driver and receiver, a series of Darlington arrays, a family of high-voltage opto-couplers, and what is claimed to be the largest single digit LED display available in the industry. The 9636 and 9637 are monolithic circuits intended for applications in data communication and data terminal equipment. Of these, the 9636 is a dual single-ended line driver that provides TTL and CMOS compatible inputs and features an output slew rate that can be controlled with a single external resistor as well as short-circuit protection for all outputs. The 9637 is a Schottky dual differential line receiver providing a TTL compatible output and offering an input threshold accuracy of ±200 mV over a ±7-volt common-mode range. Both the 9636 and 9637 are supplied in 8-pin miniDIPs, making it possible to insert two devices in a single 16-pin DIP socket for use as a quad-input assembly. The new series of Darlington arrays comprises six high-voltage, high-current units intended for interfacing TTL and MOS logic circuits with such devices as solenoids, relays, lamps, small motors and LED displays. The basic devices, types 9665, 9666 and 9667, are rated at 50 volts, with 80-volt units available and identified by an "A" suffix (i.e., 9665A, etc.). All six devices feature seven high-gain Darlington transistor pairs per package, each capable of furnishing output currents of up to 350 mA, with suppression diodes provided for use with inductive loads. Outputs may be paralleled to increase load capabilities. The 9665 is a general purpose array which can be used with DTL, TTL, PMOS or CMOS logic and features input current limiting set by means of external resistors. The 9666 eliminates the need for external resistors and is specifically designed for direct interfacing with PMOS logic to solenoids and relays; it operates at supply voltages from 14 to 25 volts. The 9667 has a series base resistor connected to each Darlington pair for direct operation with TTL or CMOS logic powered by 5-volt sources. The Darlington arrays are available in either plastic or ceramic DIPs. *Fairchild*'s new family of phototransistor couplers offers a minimum isolation voltage of 5,000 volts for all device types. This high rating, more than twice that of standard couplers, is achieved by using glass as an internal insulating spacer between the light source and phototransistor, as shown in Fig. 5. Finally, the firm's Optoelectronic Division is offering a group of 0.8-inch high LED display digits readable at distances of up to 30 feet. The new displays are available in common cathode or common anode versions with either a left or right-hand decimal point. Common-cathode types are the FND800, right-hand decimal, and the FND850, left-hand decimal. Common-anode types are the FND807, right-hand decimal, and the FND847, left-hand decimal. With an average intensity per segment of 0.15 millicandela, the displays require a 1.7-volt source and an average drive current of 5-mA per segment.

If your plans include projects involving telephone dial tone control, you'll want to investigate a new pair of ICs announced recently by the *MOSTEK Corporation* (1215 W. Crosby Road, Carrollton, TX 75006). The new devices, designated types MK 5085 and MK 5086, combine CMOS logic, D to A converters, an operational amplifier, and bipolar transistors on a single chip, and are designed to use an inexpensive 3.58-MHz crystal reference to produce eight distinct audio sinusoidal frequencies, which are mixed together on chip to provide high accuracy tones suitable for dual tone dialing. Both circuits are identical except for keyboard configuration. The MK5085 utilizes a self-scanning technique to interface directly to a class-A or 2-of-8 keyboard, while the MK5086 interfaces to either a 2-of-8 keyboard or other electronic systems. Common key functions such as switching out the transmitter and switching in muting resistance are accomplished electronically. The MK 5085 was designed using CMOS primarily for integration into telephone systems where it is possible to derive the necessary power directly from telephone lines; non-telephone hobbyist applications may use a fixed dc supply such as four AA cells or a single 9-volt battery. In operation, distinct audio frequencies are obtained when keyboard entries select the proper digital dividers to divide the 3.58-MHz crystal signal. These signals are processed by a conventional ladder network, and current-to-voltage transformation is made by an on-chip amplifier. This conventional D/A converter yields sine waves of sufficient purity that they require little or no filtering. The same amplifier accomplishes summing of the low and high group tones to obtain the required dual tone signal. ◈