Solid State

By Lou Garner

Designing With Ingenuity

INGENUITY—that happy blend of imagination, knowledge, intelligence and skill—can be the most valuable talent which an experimenter, hobbyist or project builder can possess. Properly applied, it can change the routine to the rare, the commonplace to the curious, the mundane to the marvelous, accident to advantage, and problems to progress.

One person may look at an amplifier circuit and see just that—an amplifier. An ingenious person, on the other hand, may look at the same circuit and envision a whole spectrum of exciting projects: controls, alarm systems, musical instruments, test equipment, intercoms, paging systems, or electronic games and toys.

There are many who feel that a project *has* to be complex to be useful. Some, experienced engineers included, will even lift their noses in disdain at simple circuits, considering any design requiring less than, say, a half-dozen IC's beneath their talent and dignity.

In the final analysis, however, it's really no trick to find complex solutions to complex problems or, for that matter, even to simple problems. All that is required is technical knowledge, routine design procedures, and hard work. The real trick is to find simple solutions to complex problems . . . to find the simplest circuit or design that will solve the problem or accomplish the desired result. And that's where ingenuity can play a role.

A good example is the pnp Darlington amplifier illustrated in Fig. 1A. Two direct-coupled transistors in this configuration are equivalent in performance to a single very-high-gain transistor and, in practice, may be used as such. Although the circuit can be assembled from discrete devices, several semiconductor manufacturers offer fabricated Darlington transistor assemblies in low, medium and high power versions in both pnp and npn types. Typical commercial units are Motorola's low power HEP types S9100 (npn) and S9120 (pnp) and high power types S9140 (npn) and S9141 (pnp). Where npn devices are used, circuit dc polarities are reversed.

As in a conventional single-transistor, common-emitter amplifier, dc is supplied by power source *B1*, with base bias applied through current limiting resistor *Rb*. The input signal is applied between the base (B) terminal and either circuit ground or the emitter (E). Any of a variety of input arrangements and output loads may be used, depending on the circuit's application.

Now let's add a bit of ingenuity and consider a *few* of the many possible applications for this one simple circuit.

METER AMPLIFIER. Use a low-power Darlington and a D'Arsonval meter as the collector load, applying the dc input signal between the base (B) and emitter (E) terminals. Resistor *Rb* is not used. This arrangement can increase the meter's effective sensitivity by factors ranging from 100 to 1000 or more, depending on the components used.

SENSITIVE RELAY. Use a low-to-medium-power Darlington and an electromagnetic relay as the collector load, applying the input dc control signal between the base and emitter electrodes. Resistor *Rb* is not used, but a current limiting resistor in series

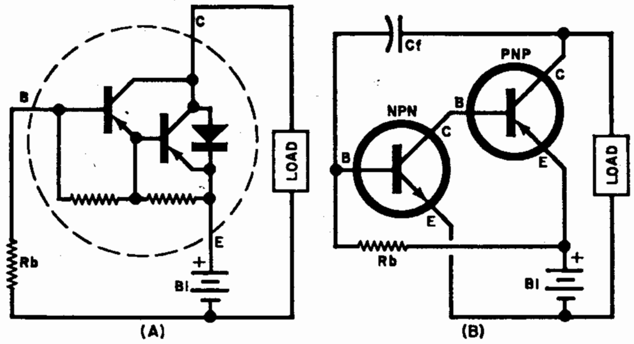


Fig. 1. The Darlington amplifier (A) and complementary relaxation oscillator (B) are simple circuits; but, with ingenuity, can be used in many diverse types of applications.

with the base is advisable. Would you believe a *10 microampere* relay?

PHOTOMETER. Use a low-power Darlington and a D'Arsonval meter as the collector load. Connect a photovoltaic or photoresistive cell in series with *Rb*, adjusting its value accordingly.

PHOTORELAY. Replace the meter in the previous circuit with a suitable electromagnetic relay. This arrangement can be used for burglar alarms, doorway annunciators, slave photoflash, and equipment control applications.

TEMPERATURE CONTROL. Use a low-to-medium-power Darlington and a relay as the collector load. Replace *Rb* with a thermistor bridge circuit. Use the relay contacts to switch external heating or cooling equipment.

ELECTRONIC THERMOMETER. Replace the relay in the previous circuit with a D'Arsonval meter. Calibrate the meter's scale in degrees C or F.

BURGLAR ALARM. Use a low-power Darlington with a relay as the collector load and connect window foil and closed-circuit door switches *in series* with *Rb*. The relay contacts are used to switch an external alarm bell or horn. The value of *Rb* is adjusted so that the relay is closed. Opening the base circuit at any point, as by breaking a foil protected window or opening a door, will cause the relay to drop out, sounding the alarm.

BOOSTER AMPLIFIER. Use a medium-power Darlington with an output transformer driving a PM loudspeaker as the collector load. The input signal is applied to the base (B) through a dc blocking capacitor and may be obtained, say, from the earphone jack of a small transistor radio or similar source.

POWER MEGAPHONE. Replace the PM loudspeaker in the previous circuit with a horn-type paging speaker and connect a carbon microphone in series with *Rb*, readjusting the value if necessary.

AUDIO SIGNAL TRACER. Use a low-power Darlington and an earphone as the collector load. Add a potentiometer gain control ahead of the base, coupling to the base through a dc blocking capacitor. Assemble in a probe body with self-contained battery.

R-F SIGNAL TRACER. Add a simple diode detector and r-f bypass capacitor ahead of the gain control in the previous circuit. In both, a suitable dc blocking capacitor should be connected in series with the input lead or probe terminal.

Another simple but, with a touch of ingenuity, extremely versatile circuit is illustrated in Fig. 1B. Here, npn and pnp transistors are direct-coupled as a complementary relaxation oscillator powered by *B1*. The two devices may be interchanged if dc polarities are reversed. Feedback is provided by *Cf*.

In operation, the circuit develops a pulse-like harmonic-rich signal at a repetition rate determined by the *Cf-Rb* time constant, by the transistors' characteristics, and by the supply voltage. Depending on one's choice of components, the circuit can be operated at rates from less than 1 Hz to the upper kHz or lower MHz values. It can be used with small-signal or medium-power devices, or even with a combination of a small-signal transistor driving a power type. A number of different load devices can be used in the design.

To some, this would be "just an oscillator." To the ingenious, however, this circuit could become one of these:

POCKET METRONOME. A potentiometer is connected in series with *Rb*, a moderately large value is used for *Cf*, and an earphone is used as an output load.

STANDARD METRONOME. The previous circuit is modified by using a power transistor for the output stage and replacing the earphone with a PM loudspeaker.

CODE PRACTICE OSCILLATOR. The value of *Cf* is reduced in the previous circuit and a handkey is connected in series with *B1*.

TOY ELECTRONIC ORGAN. A number of different capacitors are used for *Cf*, selected by separate momentary contact key or pushbutton switches to provide different frequencies (tones).

SIGNAL INJECTOR. Small signal transistors are used with an inductive load (such as a small iron-core choke) and the instrument is packaged in a probe body.

AUDIO PHOTOMETER. A photovoltaic or photoresistive cell is connected in series with *Rb* in the CPO circuit. Here, the circuit's output frequency will vary with the light falling on the photocell.

LIGHT FLASHER. An incandescent lamp or LED load is used and a moderately large value is chosen for *Cf*.

CYCLIC PULSE TIMER. An electromagnetic relay is used as the output load.

ELECTRONIC CRICKET. A thermistor is substituted for the photocell in the photometer circuit.

Reader Circuits. Reader John Lord (16 N 4th Ave., Clayton, NM 88415), who works for a cable system firm, wanted to switch moderately low-level audio and r-f (4.5 MHz) signals without using electromechanical relays. He decided to use diodes as switching elements and devised the circuits shown in Figs. 2A and 2B.

Both circuits utilize an externally applied 12-volt dc signal to achieve switching action. Depending on the control voltage polarity, the switching diodes are biased in either a forward (conducting) or reverse (high-resistance) direction. In both circuits, a positive control voltage transfers input signal 1 to the common output terminal, while a negative voltage switches input 2 to the output.

John used standard components in his designs. The input and output terminals are conventional coaxial connectors. All diodes are type 1N914 silicon devices and the resistors are half-watt types. Capacitor *C1*, Fig. 2B, is a disc ceramic capacitor.

Suggesting that other readers may find applications for his electronic switching circuits, John writes that his models have given excellent service for over a year without problems.

Device/Product News. Recognizing that a constant motor speed is essential for optimum performance in tape recorders, cartridge players, phonographs, and similar types of equipment, the SGS-ATES Semiconductor Corporation (435 Newtonville Ave., Newtonville, MA 02160) is offering a pair of linear IC dc motor speed-control regulators, types TCA 900 and TCA 910. Both devices are housed in standard TO-126 three-lead packages, with the TCA 900 designed primarily for use in battery-operated portable equipment, while the TCA 910 is intended for applications at the higher voltages found in automotive and line operated equipment. The maximum source

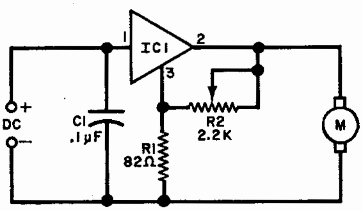
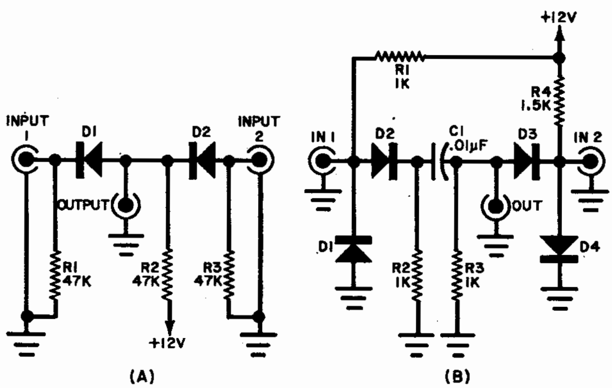


Fig. 3. The SGS-ATES circuit for motor regulation uses one IC.

Fig. 2. Two different circuits for switching moderately low-level audio and r-f signals, without using standard relays.



voltage ratings are 14 volts for the TCA 900, 20 volts for the TCA 910.

Requiring only two external components for operation, as illustrated in Fig. 3, the new SGS-ATES devices are designed to maintain a virtually constant motor speed despite variations in supply voltage, ambient temperature, or load.

The National Semiconductor Corporation (2900 Semiconductor Drive, Santa Clara, CA 95051) has introduced several new devices of potential interest to serious hobbyists, including two digital alarm clock IC's, a two-wire transmitter, and what is termed a "second generation" phase-locked loop (PLL) FM stereo demodulator.

Intended for use with seven-segment gas discharge displays, National's new digital alarm clock circuits are low-threshold p-channel MOS devices containing all of the logic needed to build several types of clocks and timers. Identified as types MM5370 (for 60-Hz operation) and MM5371 (for 50-Hz applications), the two IC's can provide three displays modes: time, alarm set, and sleep time. The display format may be either 12 hours with leading-zero blanking and a.m./p.m. indication, or 24 hours. Operating over a wide power supply range of from 8 to 29 volts, and with an integral power failure indicator, the MM5370 and MM5371 are available in either 28-pin Epoxy-B or ceramic DIP's.

Suitable for use with various sensors, including thermocouples, strain gauges, and thermistors, National's two-wire transmitter, type LH0045, is designed to convert a voltage signal from the sensor into a current and to transmit the current down a simple twisted-pair line to a receiver. The same twisted pair can serve to supply the device with its dc operating voltage, permitting the IC's use in remote sensing applications. Comprising a sensitive input amplifier, an output current source, and a reference designed to power the sensor bridge, the LH0045 is offered in both 12-pin TO-8 and 8-pin TO-3 packages.

Designated type LM1800, National's new PLL FM stereo demodulator features automatic stereo/monaural switching, a built-in stereo indicator lamp driver, an improved output decoder circuit, an on-chip voltage regulator, and a wide operating supply range of from 10 to 24 volts. Its design permits the use of a single, inexpensive potentiometer, rather than a coil, for all tuning functions. With a typical channel separation of 45 dB, the LM1800 is supplied in a 16-pin Epoxy-B DIP.

Both Motorola Semiconductor Products, Inc. (P. O. Box 20924, Phoenix, AZ 85036) and RCA's Solid State Division (Box 3200, Somerville, NJ 08876) have introduced new devices which should be of interest to hams, advanced experimenters, or students working with uhf and microwave circuits.

Motorola's 3N209 and 3N210 dual-gate MOSFETs are diode protected n-channel silicon-nitride passivated devices developed for use through the 500-MHz band. Featuring designed-in agc capability, low feedback capacitance, and very low intermodulation distortion, they offer a common-source power gain of 13 dB at 500 MHz, with a 4.5-dB noise figure.

Assembled in tiny ceramic "pills," Motorola's new vhf/microwave diodes are identified as types MV205 and MV206 hyper-abrupt tuning diodes, MBD103 silicon hot-carrier mixer (Schottky) diode, and the MPN3601 PIN microwave switching diode.

Supplied in HF-46 style flanged ceramic-metal packages, RCA's new microwave power transistors are designated types RCA2001 and RCA2310. Of these, the RCA2001 is intended for applications in the 500-MHz to 2-GHz range and, used with a 28-volt supply, can yield 1 watt output power with 7 dB gain at 2 GHz. The RCA2310 is rated to supply 10 watts CW at 2.3 GHz with a 24-volt dc source and is designed especially for telemetry service.

With a maximum turn-off time of 8 μs, RCA's first SCR family consists of 10-amp devices, types S5210B, S5210D and S5210M, rated at 200, 400 and 600 volts, respectively. The second family includes 35-amp devices with a maximum turn-off time of 10 μs, types 2N3654, 2N3655, 2N3656, 2N3657, 2N3658 and S7432M, with voltage ratings from 50 volts for the 2N3654 to 600 volts for the S7432M. Both SCR families are suited to a broad range of applications.

Consisting of a gallium-arsenide infrared emitting diode and a silicon npn phototransistor supplied in a modified hermetically-sealed TO-5 package, RCA's new optically-coupled isolator type C30111, can be used for data processing, control, alarm, instrumentation, and power-supply regulation applications. The device features a maximum isolation voltage rating of ±1000 volts and a minimum dc current transfer ratio of 20 percent. ◆