Solid State

BUILD YOUR OWN SONAR SYSTEM

By Lou Garner

SONAR — the name alone has an exciting quality, whether you're old enough to remember World War II, young enough just to have read about it in history books, or simply a viewer of the late-late TV movies. You have visions of determined, steely-jawed destroyer skippers searching relentlessly for killer U-boats. You hear the "ping-ping-ping" background sound as a tense and sweating American submarine commander attempts to elude an enemy patrol. Now, with a little skill, a dash of patience, a single IC, and a few accessory components, you can build your own sonar — not a military version, to be sure, but a practical down-to-earth (water?) instrument which can be used as a submerged object detector, depth finder, or fish locator, or, with a few modifications, for underwater data transmission and remote control applications. If you're not a yachtsman (yachtsperson) or fisherman (fisherperson), you can use the same IC to assemble an air ranging version called *sodar* (for SOnic Detection and Ranging) suitable for remote sensing, collision avoidance, and intrusion or burglar alarm systems.

Utilizing a number of novel circuit design techniques, engineers at the National Semiconductor Corporation (2900 Semiconductor Drive, Santa Clara, CA 95051) have developed a monolithic IC which contains all the essential electronic circuitry for a complete sonar system within a chip area of only 80 by 93 mils. Affectionately dubbed *the fishfinder* by the firm's application engineers, the device, type LM1812, was released just recently for general distribution, although it has been in production on a semi-custom basis for over a year. Joining the manufacturer's growing family of special-purpose devices, which includes the LM3909 LED flasher, discussed in last year's July and October columns, and the NSL4944 universal LED, examined in our May issue, the LM1812's unusual circuit contains a 12-watt ultrasonic transmitter and a selective receiver featuring a 10-watt display driver. Despite its high peak power capabilities, the IC, in an 18-pin Epoxy B molded DIP, can be operated without an external heat sink in most applications.

Designed for use on standard 12-volt dc sources, the

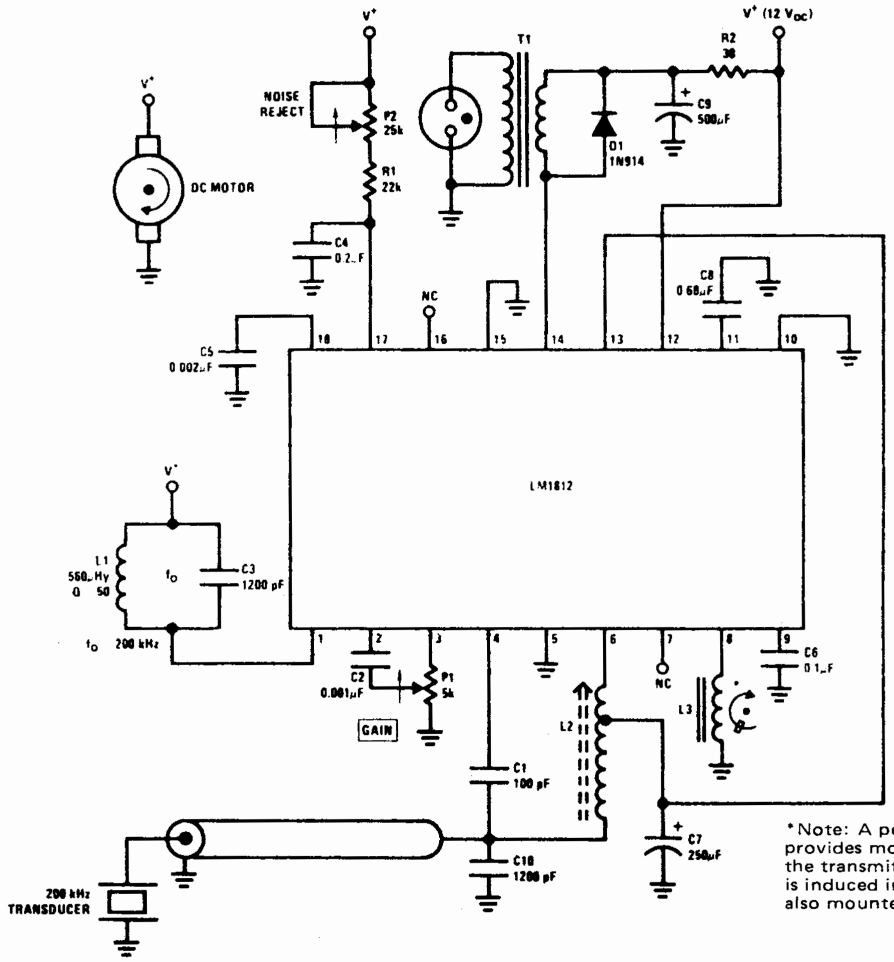


Fig. 1. A typical sonar system circuit. The component values are for operation in water.

*Note: A permanent magnet attached to a rotating wheel provides modulation pulses to pin 8. The time duration for the transmit mode is controlled by the voltage which is induced in a stationary pick-up coil. The neon display is also mounted on this wheel.

LM1812 has a maximum supply voltage rating of 18 volts, coupled with a maximum power dissipation of 600 mW. Its specified operating temperature range is from 0°C to +70°C. Under normal operating conditions, its receiver section has a typical sensitivity of 200 µV p-p, with its display driver supplying a maximum current of 1 A for 1 ms. The unit's transmitter power output stage is capable of delivering a 1-A, 1-µs pulse to a suitably matched load. Although generally used with a neon bulb or LED output display device, the LM1812 can be used in conjunction with a clocked digital readout or a CRT display.

A basic sonar system using the LM1812 is illustrated in Fig. 1. As in most conventional sonar systems, the basic design employs the "echo-ranging" principle—that is, the system transmits short, high-intensity ultrasonic pulses at fixed intervals and detects any resulting echos. In practice, the LM1812 transmits pulses of about 200 kHz for approximately 80µs through its external transducer, which also serves as a pick-up device. Between pulses, the receiver section is activated to detect any returning signals reflected by solid surfaces, such as a lake or river bottom, schools of fish, or submerged objects. These echo signals are detected and amplified, then used to drive the output display. The time differential between the original transmitted pulse and any returning signals is directly proportional to the distance from the object(s) causing the echo, permitting the output display to be calibrated in distance units (feet or meters) rather than time intervals.

A single resonant circuit, *L1-C3,* time-shared by both the receiver and transmitter sections, establishes the system's exact frequency of operation, thus eliminating the need for special alignment procedures and insuring that the two sections track over a relatively wide temperature range. The system's *transmit* mode is activated with the application of an externally generated positive-going timing pulse to the modulator control, pin 8. At this point, the gated oscillator is switched on, developing a controlled sinewave signal across resonant circuit *L1-C3.* Simultaneously, the second r-f stage is gated off, momentarily disabling the receiver section. The sine-wave signal is internally amplified and squared, then applied to a one-shot multivibrator, where each leading edge triggers the generation of a 1-µs pulse. Applied to the power amplifier, each pulse drives the stage into saturation, resulting in high-efficiency class-C operation. The amplified 200-kHz output signal is then coupled to the piezoelectric transducer by means of an impedance matching step-up auto-transformer, *L2.* The final transmitted signal, then, is a narrow burst of 200-kHz sonic energy. At the end of each timing pulse, the transmitter stages are deactivated and the receiving section gated *on.* During this period, and until the next timing pulse is applied, returning (echo) signals picked up by the transducer are applied to the receiver through coupling capacitor *C1.* An external gain control, *P1,* is provided between the first and second r-f amplifiers, coupled to the second stage through dc blocking capacitor *C2.* From here, the amplified signal is applied to a threshold detector which responds only to signals above an established level. Impulse noise is rejected by the combined action of the pulse train detector and integrator stages. The two circuits require a reasonable number of signal cycles for operation. If there is not a continuous train of pulses in the amplified signal (if 2 or 3 are missing, for example), representing a valid echo, the pulse train detector will "dump" the integrator, discharging the integration capacitor to ground. On the other hand, if the signal is valid, the display driver is switched on, activating the display device. An additional protective circuit momentarily disables the receiver if the display driver is kept on for too long a time period; this is accomplished by feeding back a signal from the display predriver stage to integration capacitor *C8* which, in turn, furnishes a control bias to the duty-cycle control transistor.

Although the circuit's basic operation is the same whether it is used for sonar, data communications, or remote control, the external drive and output circuitry must be altered to meet individual system requirements. Generally, much less power is needed for communications and remote control applications than for echo ranging since the latter requires signal transmission over twice the distance (to the target and back). In remote-control systems, the display unit might be replaced by a relay or control device, such as an SCR or power transistor. On the other hand, if the LM1812 is used for communications, a high-impedance detector and audio amplifier should be connected to pin 1 for reception, with another used for modulation. Of course, a single amplifier can be used, if prefer-

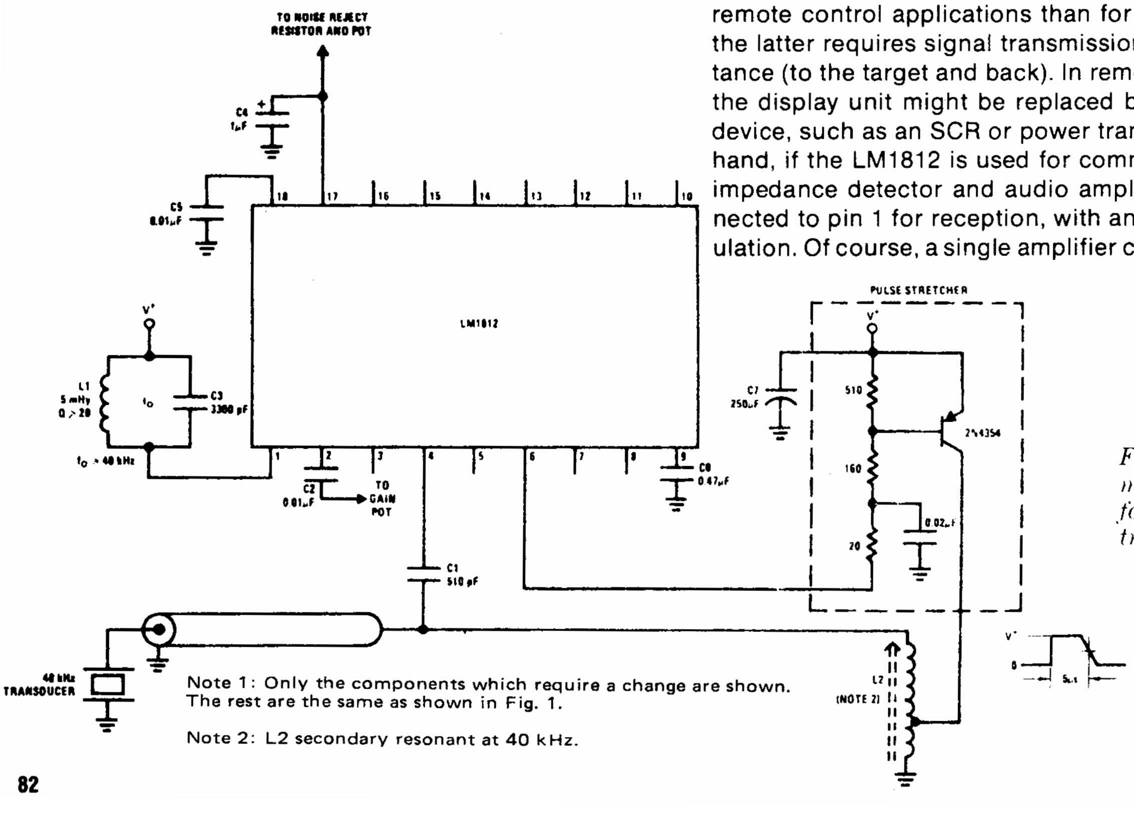


Fig. 2. Circuit modifications needed for a Sodar (air transmission) system.

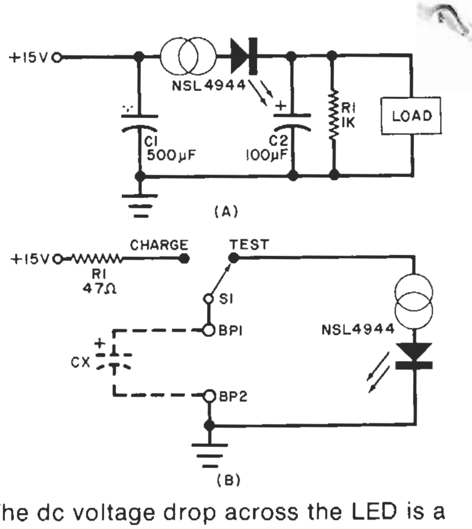
ed, switched back and forth between the modulator and receiver sections for transmission and reception. Variable rate pulse or other modulation techniques may be used for digital data or code communications.

Naturally, some means must be provided for measuring the time interval between the transmitted and echo pulses when the LM1812 is used in a sonar system. Any of several techniques may be used, including digital control and a clocked readout or an oscilloscope display with a calibrated linear sweep, but one popular method is illustrated in Fig. 1. Here, a small permanent magnet and a neon bulb are mounted near the rim of a wheel, with slip rings provided for applying a voltage to the bulb. The wheel is rotated by a constant-speed dc motor. The magnet serves to generate modulation pulses inductively as it passes a fixed pickup coil, *L3*. The neon bulb serves as the display device, driven by the receiver's output stage through transformer *T1*. Shunt diode *D1* is included to suppress switching transients, while a series filter, *R2-C9*, is provided to limit excessive current build up in the transformer's primary under rapid flashing conditions. The transformer must provide a substantial voltage step-up (from 12 to 100 volts or more) to insure flashing the bulb. In operation, the wheel's position at which the initial pulse is transmitted is considered "0," while the arc length traveled by the bulb before it flashes an echo represents the time required for the ultrasonic pulse to travel to the target and back. Since this time period is directly proportional to target distance, a fixed calibrated scale can be positioned around the wheel to indicate distances in feet or meters. Within system sensitivity limits, the sonar's maximum scale range is determined by the repetition rate of the transmitted pulses, for echoes can be received only during the intervening intervals. With a system design similar to the one shown in Fig. 1, then, the scale range is determined by the display wheel's rotational speed (hence motor rpm), for this determines the pulse rate.

Considering the relative attenuation of high-frequency ultrasonic signals in water and in air, a much lower operating frequency is recommended when the LM1812 is to be used in air transmission systems, such as sodar—typically 40 kHz rather than 200 kHz. The basic circuit modifications needed for operation in an air medium are given in Fig. 2. A different transducer is required, of course, together with a matching drive coil, *L2*. In addition, bypass and coupling capacitor values should be increased as indicated and the tuning elements (*L1* and *C3*) changed to achieve 40-kHz resonance, while an external "pulse stretcher" must be added to lengthen the drive pulse from 1 to 5 µs. Driven by the LM1812, the pulse stretcher consists of a simple RC integration network and pnp power driver. Except for these few changes, the circuit arrangement and component values are identical to those of the system shown in Fig. 1.

When using the LM1812 in practical designs, special attention must be given to ground loops and common coupling paths due to the close proximity of transmitter and receiver circuits in the same package. Three ground pins (5, 10, 15) are provided on the device to simplify layout problems, but the ground path(s) still must be adequate to handle peak currents of as much as 2 amperes when the transmitter and display are energized simultaneously. Local sources of high-energy impulse noise, such as lightly loaded motors, if not shielded properly, can cause erroneous display signals or "blips." Ideally, these noise

Fig. 3. Some applications for NSL4944: (A) Decoupling filter; (B) Capacitor tester.



pulses should be filtered at the source, but their effects can be minimized by connecting a small capacitor (about 30 pF) across the first r-f stage (between pins 3 and 4) to reduce amplifier bandwidth. Finally, for optimum overall performance and maximum efficiency, the transducer driver coil (*L2* in Figs. 1 and 2) should be designed to resonate at the proper frequency (200 kHz for water and 40 kHz for air systems) with the sum of all output circuit capacitances, including distributed wiring, that of the coax cable feeding the transducer, and the transducer itself.

Reader's Circuits. Submitted by Peter Lefferts (1640 Decker Ave., San Martin, CA 95046), the two circuits given in Fig. 3 illustrate additional applications for the versatile NSL4944 universal LED. Both designs utilize the LED's unique current regulation characteristic, both are suitable for home projects, both use standard components, and both are noncritical as far as layout and lead dress are concerned. Referring, first, to Fig. 3A, this decoupling network can be used wherever stage isolation is required, as when powering a preamp in an audio amplifier. Essentially a standard pi filter network with a constant current LED used in place of a resistor or inductance, the circuit attenuates power supply ripple by some 60 dB while attenuating back-coupled signals more than 70 dB. The only critical factor is the load current, which must be within the LED's capability, yet, at the same time, large enough to insure LED operation within its constant-current mode — typically about 13 mA. If the load requirements are unusually small, as with some FET preamps, a shunt load resistor (*R1*) is needed to increase the LED's current to within the optimum range. The dc voltage drop across the LED is a little over 2 volts. The second circuit, Fig. 3B, is an extremely simple tester for large electrolytic capacitors. Control switch *S1* is a center-off, spdt toggle, lever, rotary or slide switch; series resistor *R1* is a ½-watt unit, and *BP1* and *BP2* are standard binding posts. In operation, the test capacitor, *Cx*, is connected to terminals *BP1* and *BP2* with correct dc polarity. Switch *S1* is thrown first to the *charge* position, charging the capacitor from the dc source through series limiting resistor *R1*, then to the *test* position. The constant-current LED will discharge the capacitor from 15 volts to 2 volts *linearly*, staying lit during this period. If a typical 13-mA NSL4944 is used, a 1000-μF capacitor will discharge in just one second. Variations in the characteristics of individual LED's can be compensated by adjusting the supply voltage to a value just two volts more than the *actual* LED current in mA (i.e., an 11-mA LED would require a 13-volt supply). By estimating (or measuring) the discharge time, an experienced user can check capacitors with values from about 500 μF to over 100,000 μF (from ½ to 100 seconds). Leakage can be estimated by charging the capacitor a second time, waiting for one discharge period, then testing. With a nominal LED (13 mA), a 10% *decrease* in discharge time would indicate a leakage of 1.3 mA for the test unit. If the LED fails to light when *S1* is thrown to its test position, the capacitor is either shorted or open.

Device/Product News. Currently, microprocessors seem to be dominating the technical news front. Fairchild's Microsystems Division (1725 Technology Drive, San Jose, CA 95110), for example, has introduced a new microprocessor design kit on a fully assembled circuit board which comes complete with a connecting cable for power supply and terminal hookup. The circuit board contains Fairchild's 3850 F8 CPU device, the 3851 program storage unit circuit, the 3853 static memory interface circuit and eight 2102 static RAM's (1 kilobyte of memory). The complete kit is priced at $185.00 in small quantities.

Both Signetics, Inc. and Motorola Semiconductor Products have slashed the prices of their microprocessors. Signetics has reduced the price of its Model 2650 general purpose, 8-bit, 5-volt, TTL compatible n-channel μP from $72.00 to $26.50 in small quantities (1-24). Motorola has reduced the price of its type 6800 8-bit n-channel device from $69.00 to $35.00 in 1-9 units. The firm also has dropped the price of its MC6860 modem from $32.00 to $17.00 in small quantities. ◈