SINGLE-WIRE COMMUNICATION

Although wireless communication is nothing special these days, it is not a panacea. Below the ground, for instance, radio waves will not get you very far. In such cases, nothing beats copper wire to set up a reliable communication link. The communication system described here is remarkable because it uses only one such wire. Low-cost, and ideal for a camping site intercom, or a cave explorers' talk line.

Design by K. Walraven

MOST frequencies used for wireless communication are so high that only a very small portion of the electromagnetic energy penetrates the soil, not even mentioning solid rock. Although it would just be possible to use very low frequencies in the ELF (extremely long frequency) band for underground communication (similar to submarine calling systems), the relevant antennas and transmitters are of a totally impractical size.

Speleologists (cave explorers) usually employ common-or-garden field telephones linked by a two-wire cable. Bearing in mind that such a cable can have a length of several kilometres, the cost of all this copper can be reduced significantly if a single-wire cable were used. The other 'wire' (return signal) is then formed by the soil (or 'earth', as the word is used in connection with electrical systems). Particularly below the ground, in relatively humid conditions, such an earth connection is a fine alternative to a return wire.

Although excellent for speleologists, the present single-wire communication system is also suitable as low-cost intercom above the ground (where most of you will definitely feel more comfortable).

Design considerations

In fact we are dealing with a normal intercom circuit, with a telephone mouthpiece acting as a combined microphone/loudspeaker. The connection between the (hand-held) extensions is made via one wire and a ground return path. Depending on the dryness of the top soil, the return path can have a resistance of several megaohms (dry soil) down to less than 1 kΩ (wet soil). The input resistance of the circuit and the ground return resistance form a voltage divider which attenuates the desired signal. That is why the circuit is designed to have an input impedance as high as 1 MΩ.

Any number of send/receive units ('telephones') may be connected to the line, since every circuit functions as a receiver by default. The transmitting unit is then heard on all receivers.

Circuit description

The circuit (**Fig. 1**), simple by any standard, is based on the familiar 741 opamp which most of you will be able to dig up from the junkbox. The telephone has two switches: S_2 to switch the unit on and off, and S_1 for the push-to-talk function. The circuit is normally switched to 'receive' mode. Signals transmitted by another unit, and, of course, noise, are received via capacitor C_1. Next, a low-pass filter, R_1-C_2, ensures that frequencies above 5 kHz are attenuated (the roll-of frequency is slightly dependent on the line impedance). The signal is subsequently applied to a high-pass filter consisting of C_3-R_2-R_3, in which the resistors set the receiver impedance to about 1 MΩ. This filter serves to attenuate hum on the signal.

The 'cleaned' signal is applied to the non-inverting input of IC_1. With switch S_1 set to the position shown in the circuit diagram, the opamp functions as a buffer, feeding its output signal to the telephone mouthpiece element via coupling capacitor C_4.

Two things happen when S_1 is pressed. The microphone is connected to the inverting input of the opamp via C_4. The gain is then determined by resistor R_4 and the impedance of the microphone. The mouthpiece used in the prototype has an impedance of about 100 Ω, fixing the opamp gain at about 1,000. Although the microphone impedance should really be of the order of 350 Ω, the 100-Ω type also gave good results. The amplified signal is put on to the communication line via switch contact S_{1b} and coupling capacitor C_1. The transmit level is about 3 V_{pp}. At the same time, switch contact S_{1a} takes junction R_1-D_2-C_2-C_3 to the circuit ground, preventing the non-inverting input of IC_1 from picking up the output signal (which would cause positive feedback). Also, LED D_1 lights, indicating that the unit is in 'transmit' mode, and at the same time assuring the user of sufficient battery energy. If the battery voltage drops below the level determined by the value of zener diode D_2 and the LED voltage (approx. 7 V), the LED will no longer light. In view of the tolerance on the actual zener voltage, it may be necessary to use a different zener diode than indicated. In any case, be sure to use a 400-mW type, since this guarantees a sharper 'knee' voltage than 1-watt types.

That is just about everything there is to say about the operation of the circuit. The final points concern the current consumption. In 'receive' mode,

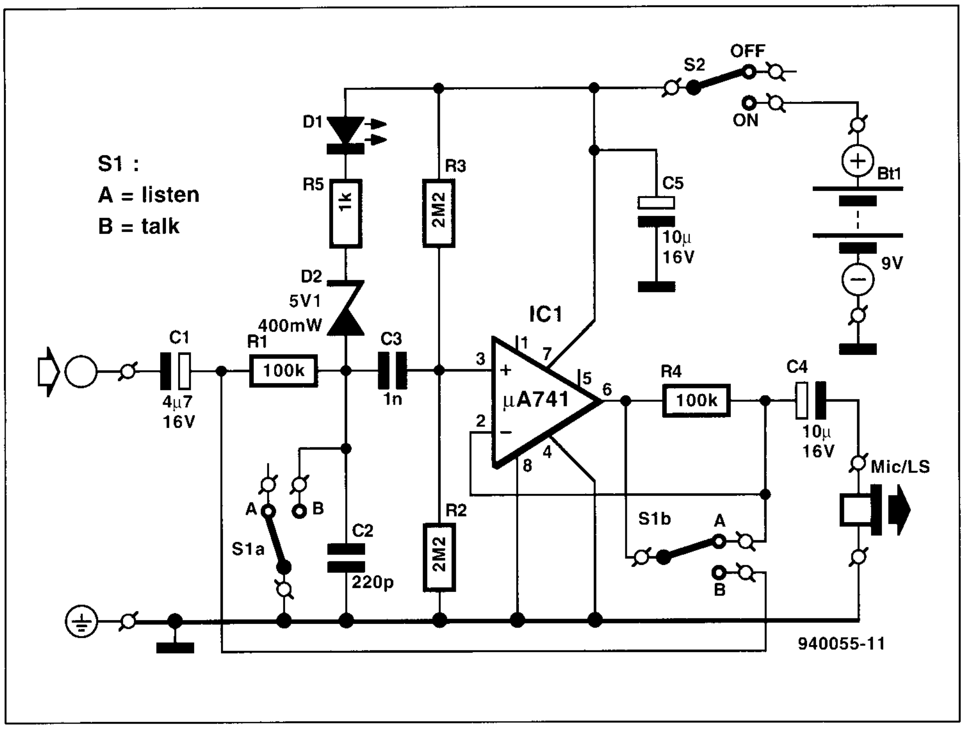


Fig. 1. Circuit diagram of the single-wire communication system. Please welcome an old faithful: the 741 opamp.

the circuit draws about 3.5 mA, which rises to about 5 mA in 'transmit' mode. In both cases, a modest current drain, which guarantees a long battery life.

The 741 may be replaced by a more modern version such as the TLC271, which reduces the current consumption even further, and also results in a slightly higher transmit level (approx. 3.5 V_{pp}). Since pin 8 of IC_1 is tied to the circuit ground, the bias current of the TLC271 is automatically set to 'high' (pin 8 is not connected on the 741).

Rugged construction

Rugged construction is a must particularly if the circuit is to be used for cave expeditions and other activities underground. The printed circuit board designed for the circuit is small (**Fig. 2**), enabling the telephone to be built into a compact, easy to handle, enclosure.

The enclosure must be a metal type (preferably aluminium or die-cast) because the earth return connection is made via the user's hand.

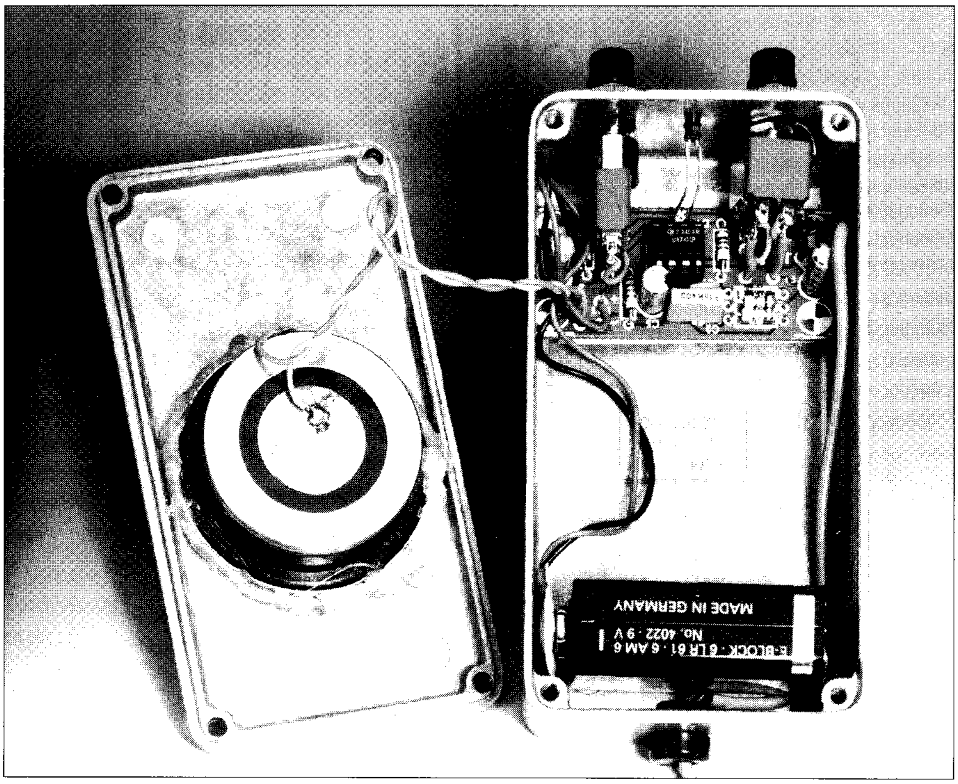
With only a handful of parts to be fitted, populating the printed circuit board is all plain sailing. Less experienced constructors should, however, pay attention to the polarity of the electrolytic capacitors, the LED and the zener diode. The single IC must also be fitted the right way around (have a good look at the symbol printed on the component overlay). Cut the wires at the solder side as short as possible.

Because of the relatively small size of the board, a separate wiring diagram is given **Fig. 3**, showing clearly how the switches, the mouthpiece element and the battery are connected to the board. Although most switches have their mother contact ('pole') in the centre, the ones used to build the prototype (see parts list) happen to have different connections. Therefore always check out the location of the pole and the contacts before connecting a switch. The PCB is designed for switches which have the 'rest' contact nearest to the edge, then come the pole and the 'make' contact. Whatever type of switches you use, make sure they are wired as shown in Fig. 3.

The following method is recommended to build the PCB into the case. Start by securing the switches on to the case, and then connect the board to the switches via a few pieces of solid wire. In this way, the board is held in position by the wires. Stick a few pieces of insulating tape at the inside of the case, below the circuit board, so that short circuits with the solder connections can not occur.

An alternative construction method is to secure the board to the case bottom with sticky rubber feet as used for enclosures. That allows flexible wire to be used for the connections to the controls.

The input ground wire is clamped under the washer of switch S1 to establish the contact with the case (without this connection, the circuit does not work). The telephone mouthpiece (acquired from an electronic surplus outlet) is secured rigidly in the cover of the case, and may be protected with water-resistant foil. Depending on the type of element, one of its terminals may already be connected to the metal body, in which case it is also connected to the cover (check with an ohmmeter). If that is the case, this connection of the element **must** be



wired separately to the output ground terminal on the board.

The unit is connected to the communication wire via a kind of probe, which is a piece of flexible wire about 1 m long. The end of this wire is fitted with a needle or a crocodile clip. To prevent the wire insulation from cracking where it enters the metal case of the telephone, and so causing a short-circuit, a rubber grommet must be used. The switches are types with a protective rubber cover, which makes them reasonably water-resistant. The rest of the unit is made waterproof by using silicon compound. Apply a little compound around the LED, and also fill the strain relief for the 'antenna' wire. Make a packing to seal the joint between the case and the cover. Beforehand, apply a little lubricant, or butter, to the edge of the case, so that the silicone compound will attach to the cover only, and does not crack when the telephone is opened to replace the battery. If the compound is still soft, it is best not to leave the cover on for a while with the screws not fully tightened. In that way, the packing remains a little thicker.

Some practical notes

Some information is given below on the practical use of the single-wire communication system. Use insulated wire for the long cable via which the extensions communicate. Almost any number of extensions may be connected to this cable. The actual connection is made by removing the insulation locally and attaching the croc clip. An alternative method which leaves the cable almost intact is to use a needle or a pin instead of a croc clip. To connect up to the system at a certain location, pierce the cable with the pin or needle to make contact with the copper wire. In this way, the cable is damaged less.

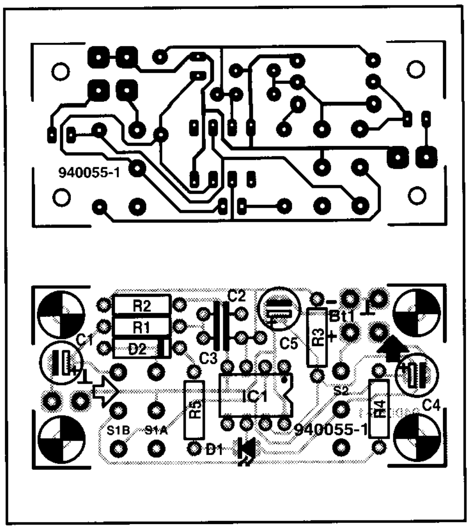


Fig. 2. The printed circuit board designed for the 'earth telephone' is small, and contains only a handful of parts.

COMPONENTS LIST

Resistors:
R_1,R_4 = 100kΩ
R_2,R_3 = 2MΩ2
R_5 = 1kΩ

Capacitors:
C_1 = 4µF7 16V radial
C_2 = 220pF
C_3 = 1nF
C_4,C_5 = 10µF 16V radial

Semiconductors:
D_1 = LED, high efficiency (3 mA)
D_2 = 5.1 V/400 mW zener diode
IC_1 = 741 or TLC 271

Miscellaneous:
S_1 = presskey w. 2 change-over contacts (e.g. APEM 18545).
S_2 = switch w. make contact (e.g. APEM 8636)
2 rubber caps for switches (APEM U-1401).
LSP/MIC_1 = telephone mouthpiece, impedance: 350 Ω.
Metal case, outside dim. 112 x 61 x 32 mm (e.g. Hammond 1590B or Velleman G106).
Printed circuit board, order code 940055-1 (see page 70).

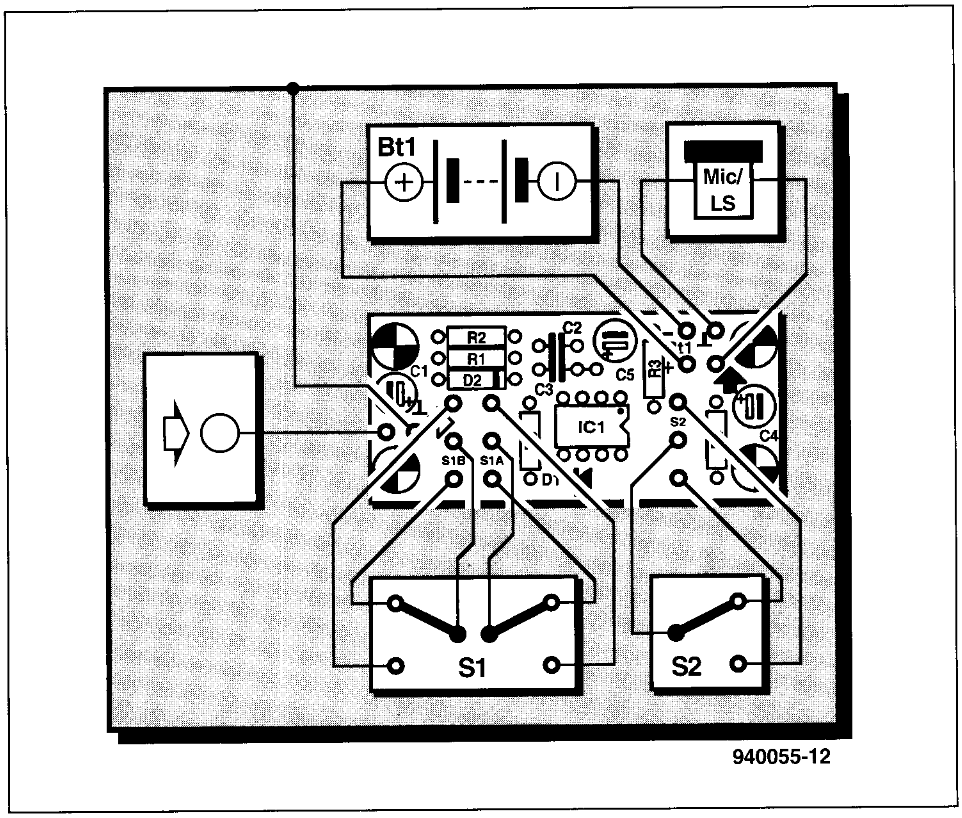


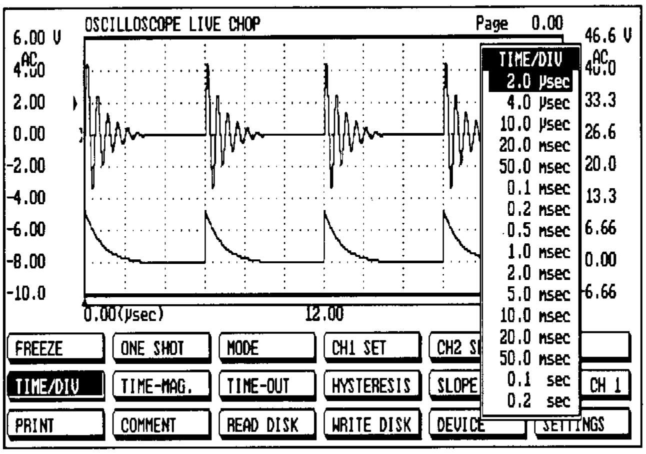
Fig. 3. Connection diagram. The wiring shown is valid for the switch types stated in the parts list.

Like mobile radios, all telephones are normally in 'receive' mode. It is not unusual for the receiver to produce noise, hum, whistling notes and even radio stations. Although difficult to avoid in such a simple communication system, any noise produced by the receiver is also useful because it is a sign that the unit is working! After pressing the 'listen/talk' key, you can start talking into the microphone, and put your message on to the cable for all other units to hear. The quality of the received signal will depend, among others, on the soil humidity, and the resistance between the unit and the ground. A user wearing rubber boots will usually transmit and receive relatively weak signals. In practice, it is recommended to touch the ground, or a wall, while transmitting. That increases the signal level on the cable considerably (both while transmitting and receiving). Obviously, the aim is to make the resistance between the metal case and 'earth' as low as possible.

The battery will last pretty long. An alkaline battery enables a telephone to be used for a couple of days at a stretch, which will be sufficient for most, if not all, applications.

(950055)

DATA ACQUISITION WITH THE PC



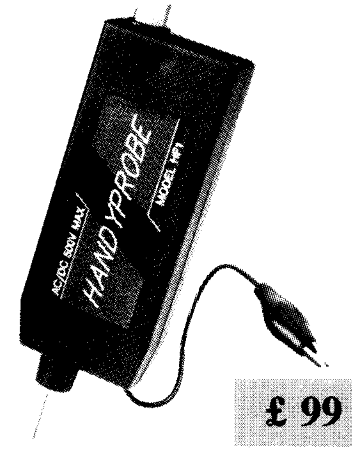
TiePie engineering manufactures a complete range of computer-controlled measuring instruments. Connecting these units to a PC (MS DOS 3.0 or higher) results in a number of comprehensive test instruments:

- oscilloscope;
- voltmeter;
- spectrum analyzer;
- frequency meter;
- transient recorder.

All measured data can be stored on disk or run off for documentation. Because of the many trigger possibilities, a variety of signals can be measured, while the powerful software enables a multitude of measurements to be carried out in a straightforward manner. Application areas include: service; medical research; automatic test systems; research and development; and education.

LOW COST: HANDYPROBE

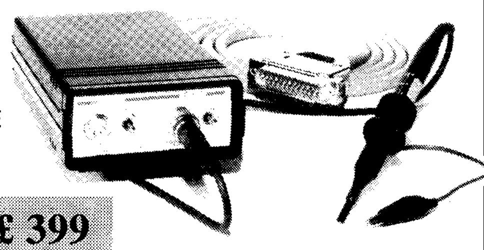
Connect the HANDYPROBE to the parallel printer port of the PC and start the software. Measuring can be carried out at once. The HANDYPROBE does not need an external power supply. Some technical parameters: 0.5-400 V software select input range; one input channel; 8 bits resolution (overall accuracy 2%); A complete software program consisting of a digital storage oscilloscope, spectrum analyzer, voltmeter and a transient recorder is provided. The HANDYPROBE is eminently suitable for servicing and educational purposes.



£ 99

BEST PERFORMANCE: HANDYSCOPE

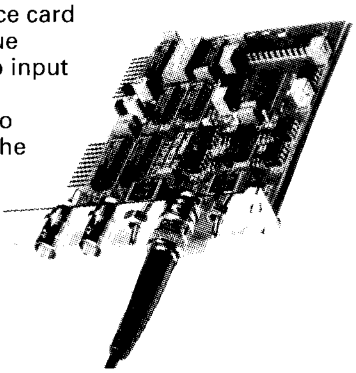
The HANDYSCOPE is connected to the parallel printer port. This makes it possible to carry out measurements with a laptop or notebook PC. Because of its high resolution (12 bits), the HANDYSCOPE is a very accurate instrument. The measuring rate is 100,000 samples/sec. Either of the two channels can be set independently over a range of 0.5-20 V (with a 1:10 probe up to 200 V). The advanced software enables many measurements to be carried out. Two probes (switchable 1:1-1:10) are provided. The HANDYSCOPE is constructed as a small table model with two BNC connectors. The length of the cable linking the PC and the HANDYSCOPE is 1.8 m, which can be extended to 3.8 m.



£ 399

MULTIFUNCTIONAL: TP5008

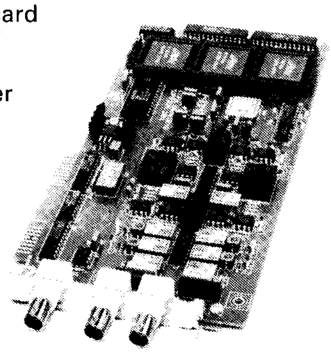
The TP5008 is an interface card that provides an analogue output in addition to two input channels. This output in combination with the two inputs may be used for the setting up of a complete control loop. The output may also be used as a function generator. The TP5008 has a resolution of 8 bits and a sampling rate of 200,000 samples/sec (200 kHz). The input range may be set to 0.5-20 V full-scale deflection. The output range covers 1.25-2.5 V. The TP5008 is fitted with BNC connectors and is delivered complete with a user manual and software. Separately available are 1:1-1:10 probes and 1:100 oscilloscope probes.



£ 197

VERY HIGH SPEED: TP208

The TP208 is an interface card with a measuring speed of 2×20 Megasamples/sec (8 bits). Phenomena shorter than one millionth of a second can still be measured well. The completely digitized triggering ensures very stable triggering with many trigger possibilities. The TP208 has an input range of 5 mV/div to 20 V/div in 12 steps and an auto calibration function. Since both channels may be sampled simultaneously, phase differences can be measured very accurately. Even single phenomena can be measured since each channel has a 32 KByte memory. Comprehensive software is provided.



£ 595

(All prices are exclusive of VAT and P&P)

Interested? Then write or fax for a FREE demo diskette to

INSTRUTEK (UK)

28 Stephenson Road
Industrial Estate
St Ives, Cambs PE17 4WJ
England

Telephone (0480) 460028
Fax (0480) 460340