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Constructional Project

HEADSET COMMUNICATOR

TERRY de VAUX-BALBIRNIE

Portable three-channel communication system

THIS communication system was originally designed to help in the production of short commercial videos. With it, the "director" is able to hold a two-way conversation with any one of up to three camera operators. It is also possible to speak to all the operators simultaneously.

No doubt, such a system could find many other uses, such as in amateur stage work, concerts and sports events etc.

WIRED FOR SOUND

In the prototype arrangement, the director sits at a small desk console and the remote operators wear units clipped on to their belts. Cables, which may be of any reasonable length, link the remote stations to the main unit.

The director ("Master") and remote ("Slave") operators wear headsets which are plugged into their units. These headsets consist of a pair of headphones (or a single headphone) having a small boom microphone attached (see photograph).

FREE SPEECH

For the target applications, headsets are more convenient than loudspeakers. They provide "hands free" operation and allow the remote operators to move around freely (within the limits set by the interconnecting cables). Incoming speech cannot enter any microphone used to pick up the sound of the performance and cannot be heard by the audience.

Headsets (while worn) are free from acoustic feedback (the howling noise which is produced when the sound from a loudspeaker re-enters a microphone and builds up in a loop). The close proximity of the microphone to the speaker's mouth provides very clear communication even when there is a lot of extraneous sound or when he or she only whispers.

Power is supplied using four AA size alkaline cells housed inside each unit. The current requirement is 25mA approximately (40mA for the master unit) and the specified batteries should provide at least 50 hours of operation. *For safety reasons, the system MUST NOT be operated using a mains-derived supply such as a plug-in adaptor.*

The Headset Communicator system units showing (left to right) the master unit, three slave units and a headphone with "boom" mic.

MASTER UNIT

The Master unit is built in a sloping front instrument case (see photograph). The headset is plugged into a pair of sockets on the front and sockets on the rear panel connect the cables leading to the slave units.

On the top, there is an on-off switch and associated l.e.d. (light-emitting diode) "On" indicator. There is also a three-position Slave Select rotary switch (S2) which selects which slave (A, B or C) is to be placed "on line", a momentary-action pushbutton switch which provides the "Talk to All" function and a Volume control.

Rotary switch S2 has three associated l.e.d.s (Red, Yellow and Green) which confirm the slave unit selected. These will be found useful when the unit is being used under dim conditions. Note that while the "talk to all" switch (S3) is being operated, only the remote station set by the S2 can be heard.

SLAVE UNIT

Each slave unit is built in a small plastic box having a belt clip attached (see photograph). As well as sockets for the headset

and the cable leading to the master unit, there is an on-off switch, l.e.d. "on" indicator and volume control.

One particular feature of this circuit is that the operator's voice is heard in his or her own headphones. This practice is used in telephony and helps the speaker to regulate his or her voice level. It also allows the user to hear someone speaking direct without the muffling effect of the headphones. The amount of voice feedback may be adjusted for each station at the setting-up stage. It may even be reduced to zero if required.

HOW IT WORKS

The basic circuit for the Headset Communicator is shown in Fig.1 and this is the same for both Master and Slave units. Each unit may be considered as having one input and one output – the Listen (L) and Talk (T) lines respectively – plus a common "Earth".

By linking the talk line of one unit to the listen line of another and the listen line of the first to the talk of the other and also making the common earth connection, two-way communication would be established. Of course, additional switching is

Rear panel shows the three XLR type sockets for connecting up the Slave units.

Completed Slave unit with belt clip attached to the lid.
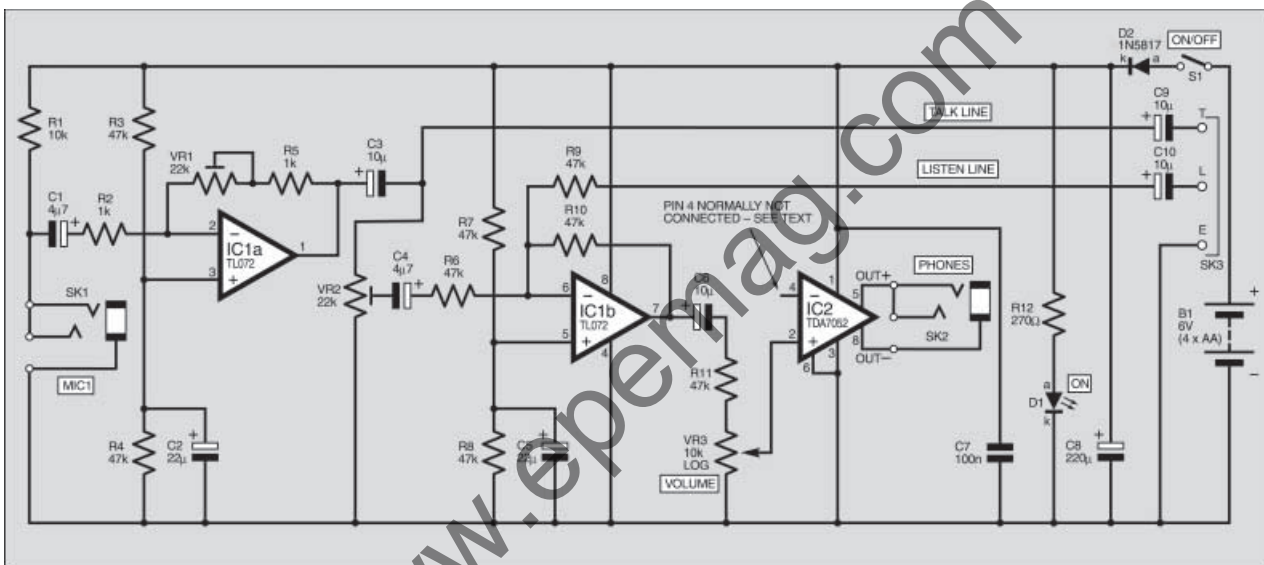

Fig.1. Circuit diagram for the Headset Communicator. This is the same for both the Master and each Slave unit.

needed in the Master unit to select the slave unit to be communicated with. This aspect of operation is looked at later.

Six-volt battery B1, supplies current through On/Off switch S1 and diode D2. The diode provides reverse-polarity protection. Thus, if the supply were to be connected in the wrong sense, D1 would fail to conduct and no current would flow, thus preventing damage to semiconductor devices.

Note that a *Schottky* diode is specified for D2. This introduces a smaller forward voltage drop than a conventional diode.

Capacitor C8 provides a reserve of energy and allows peaks of power to be delivered especially when the battery is nearing the end of its useful life. Light-emitting diode, D1 is the *on* indicator and operates through current-limiting resistor R12.

The microphone section of the headset, MIC1, is connected to the circuit via socket SK1. This microphone is of the electret type and so requires a power supply for its internal preamplifier. This is derived from the nominal 6V supply through resistor R1.

The speech signal is applied, via capacitor C1 and input resistor R2, to the

inverting input (pin 2) of operational amplifier (op.amp) IC1a. This is one half of a dual unit. The function of the other section, IC1b will be looked at presently.

COMPLETELY BIASED

The non-inverting input of IC1 (pin 3) is connected to a nominal 3V reference derived from the potential divider comprising fixed resistors R3 and R4 working in conjunction with capacitor C2. Since the op.amp is powered from single supply rails (+6V and 0V), this procedure allows for a "false zero" to be set allowing both the positive and negative half-cycles of the input waveform to be amplified.

Fixed resistor R5 and preset VR1 connected in series apply negative feedback between IC1 output (pin 1) and the inverting input (pin 2). The value of the feedback resistance divided by that of input resistor R2, determines the gain.

With preset VR1 at minimum adjustment this will be unity and when at maximum 23. In fact, these values are *negative* but this has no practical consequence here. Preset VR1 will be adjusted

at the end of construction to provide a suitable gain for the particular microphone used. If tests prove the gain to be too small, the value of resistor R2 could be decreased.

TALK TO ME

The output signal from IC1a flows, via capacitors C3 and C9, to the Talk (T) pin of input/output socket SK3. In addition, some of this signal flows through preset potentiometer VR2. The sliding contact selects a fraction of this and passes it, via capacitor C4 and resistor R6, to the inverting input (pin 6) of IC1b. The non-inverting input (pin 5) biasing arrangements are the same as for IC1a, using fixed resistors R7 and R8 in conjunction with capacitor C5.

A further signal arrives at IC1b inverting input from the Listen (L) pin of socket SK3 through capacitor C10 and resistor R9. This has been derived from the "talk" output of the remote unit.

Op.amp section IC1b may be regarded as a mixer for the local and distant signals and since feedback resistor R10 is equal in value to input resistors R6 and R9, the gain

is unity (actually –1). The level of the local (own voice) signal may be adjusted using preset VR2.

VOLUME CONTROL

The output of IC1b (pin 7) is applied, via capacitor C6, to the top end of the potential divider comprising fixed resistor R11 connected in series with panel-mounted potentiometer VR3. A fraction of the signal is obtained from the sliding contact and applied to the input (pin 2) of power amplifier IC2.

This device has been designed to allow an 8-ohm loudspeaker to be connected between its outputs (pin 5 and pin 8) to develop one watt approximately. Here headphones are used and, since these have a higher impedance than a loudspeaker (30 ohms approximately), the available power is reduced.

However, only a small amount of power is needed to drive the headphones at full volume so this method works well. The headset volume may be adjusted using VR3.

The specified power amplifier (type TDA7052 – having no suffix) does not require a connection to pin 4. However, there are variants of this device having a suffix and which have a "d.c. volume control". If one of these must be used, then pin 4 will be used to control its gain.

To match the characteristics of the specified unit, it would be necessary to impose a voltage greater than 1·5V on pin 4 which sets it to maximum. This could be done using a potential divider and more will be said about this later.

MASTER SECTION

How the Master console is connected to the slaves is shown in Fig.2. The master Listen and Talk lines are directed to one of sockets A, B or C using switch S2. This switch is a 4-pole 3-position type.

The talk and listen lines are connected via switch S2a and S2b respectively while the l.e.d. corresponding to the chosen socket receives current via S2c and current-limiting resistor, R13. Pole d is not used.

The "All Talk" function (enabling the Master to speak to all slave units simultaneously) is provided by connecting the master talk line to all three sockets. This is

Fig.2. How the Master console unit is connected to the three Slave units.
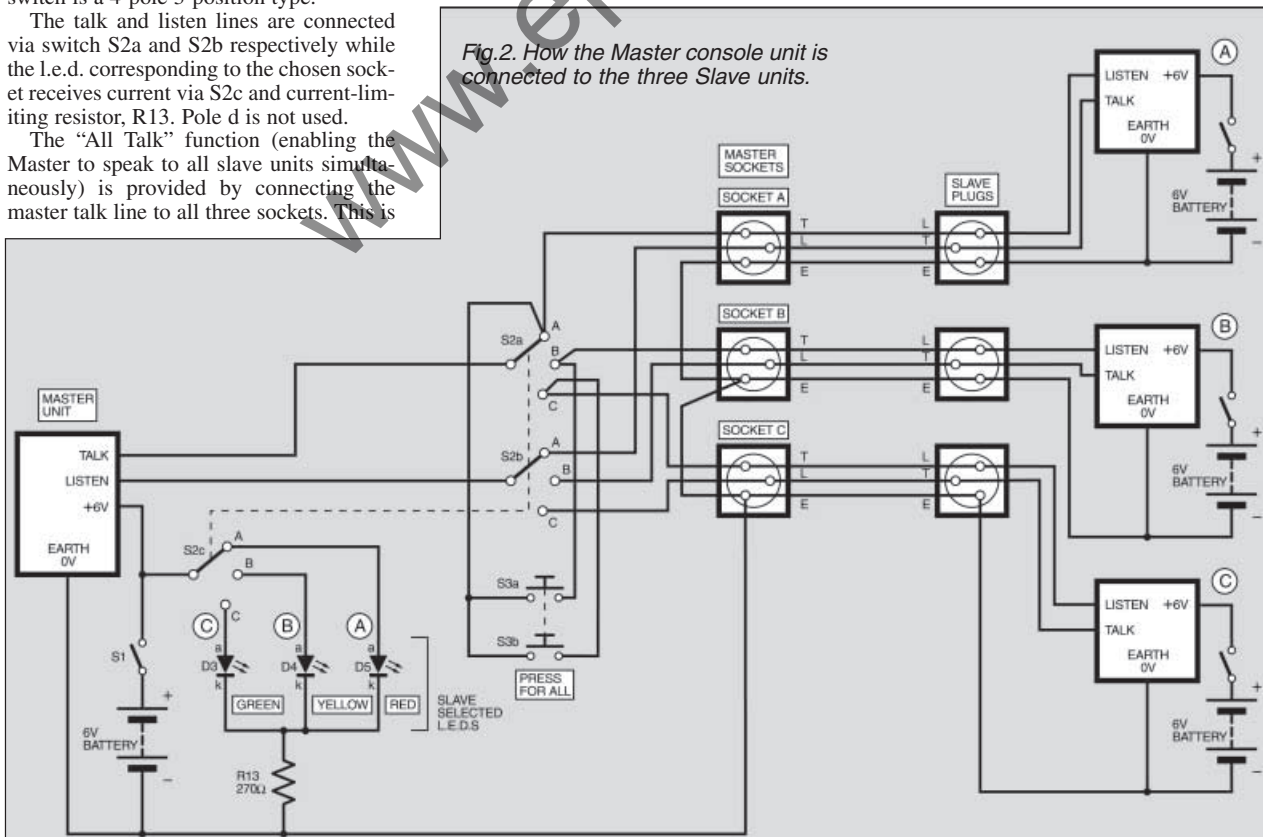
Fig.3. Printed circuit board component layout and full-size copper foil master.

carried out using a double-pole momentary action switch S3.

TAKING THE LEAD

In the prototype system, the interconnecting leads were of the commercial variety fitted with a 3-pin XLR line plug on one end and a matching line socket on the other. These connectors are widely used in the industry and are normally used for balanced audio applications. Before purchasing XLR leads, check that they are of the standard pattern.

Some cheap cables intended for unbalanced microphones, have only one inner conductor with the screening connected to two of the pins. For this circuit, you need two available inner conductors plus the screening. You could, of course, use homemade leads constructed using two-core screened wire and stereo-type jack (or XLR) connectors.

CONSTRUCTION

Construction of the Headset Communicator is based on four identical single-sided printed circuit boards (p.c.b.s). This, of course, assumes that three slaves are required. These boards are available from the *EPE PCB Service*, code 369.

The p.c.b. topside component layout and full-size underside copper foil master pattern are shown in Fig.3. Begin construction of each p.c.b. by drilling the two fixing holes as indicated.

Next, solder the i.c. sockets in position, also the link wire connecting IC2 pin 2 with Volume control VR3 sliding contact, all resistors (including the presets) and the capacitors. Apart from C7, the capacitors are all electrolytics so take care with their orientation. Note that there are four holes which will have been left empty – see later.

Now solder pieces of stranded connecting wire to the talk (T), listen (L) and earth (E) points on the completed p.c.b. Connect similar pieces of wire to the MIC1 and VR3 positions. Use different colours to avoid errors later. Adjust presets VR1 and VR2 to approximately mid-track position.

TESTING

It is advisable to check the operation of *each* circuit board at this stage because it is then much easier to correct

minor problems. Solder the battery connectors to the +6V and 0V p.c.b. pads, taking care over the polarity (red wire for +6V).

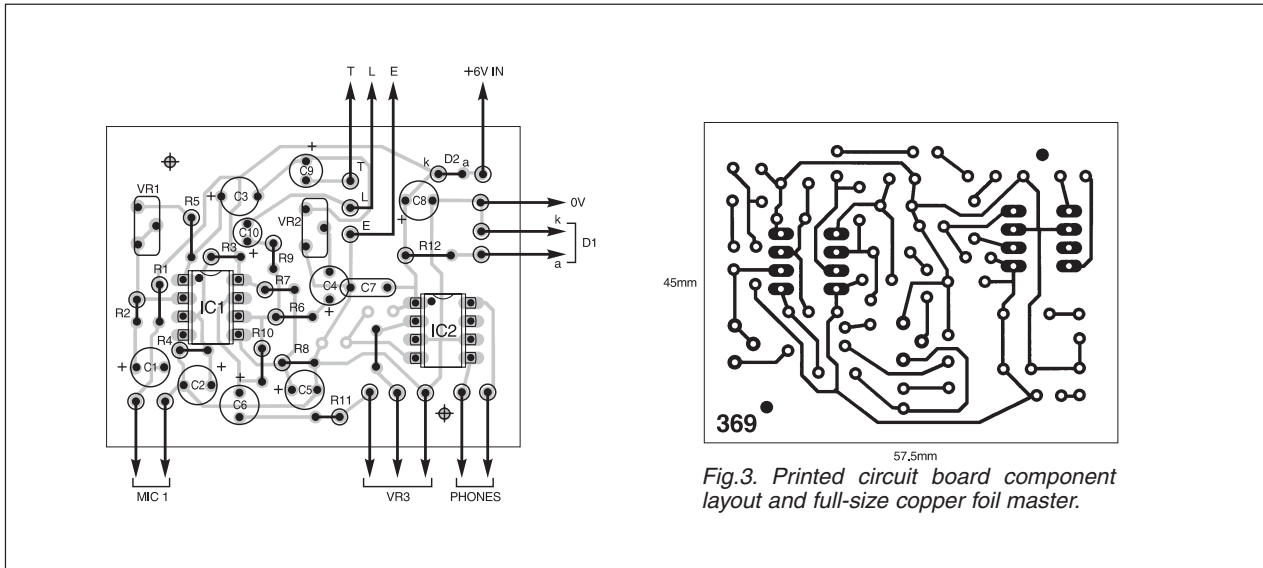Solder jack sockets (or the required type to match the headset) to the MIC1 and Phones wires. Note that the *sleeve* of the microphone plug *must* connect to *right-hand* MIC1 wire on the p.c.b. – that is, the one connected to the 0V line. In the prototype unit, the microphone plug was a 3·5mm *stereo* jack type but either "tip" connection could be used because they were connected together internally.

The prototype headphones were also wired to a 3·5mm stereo jack plug. In this case, each tip connection was responsible for one unit while the "sleeve" was common to both. This enables the headphones to be used individually for stereo applications.

Here, both tips need to be connected together so that the units appear in parallel and provide mono operation. The common tips connect to one wire and the sleeve to the other. This procedure may need to be modified depending on the plugs fitted to the headsets.

Referring to Fig.5, the Slave unit wiring, solder potentiometer VR3 tags to its wires in the sense shown. Adjust it to approximately mid-track position.

Insert the i.c.s into their sockets. Since these are CMOS devices, they could be damaged by static charge which may have accumulated on the body. *To avoid possible problems, touch something which is earthed (such as a metal water tap), before unpacking them and handling the pins*. Do not throw away the packaging because it will be needed again later.

IT'S WORKING

Do not put the headset on initially in case of sudden loud clicks and other noises. Satisfy yourself on this point before putting it on.

Connect the battery and note that the On l.e.d. operates. If acoustic feedback is evident (which should not occur when the headphones are worn) adjust Volume control VR3.

Listen to the headphones and speak into the microphone. If you can hear your voice clearly, the circuit is working. If it is obvious that the microphone gain is too small (quiet sound even with VR1/VR2/VR3 set to maximum) reduce the value of resistor R2 to 560 ohms (after switching off and removing the i.c.s).

Repeat all this with the other circuit boards then, observing the anti-static precautions mentioned earlier, remove the i.c.s from their sockets and replace them in their anti-static packaging. De-solder the jack sockets, potentiometer and positive battery connector lead. Connect a piece of stranded wire to the +6V p.c.b. point instead.
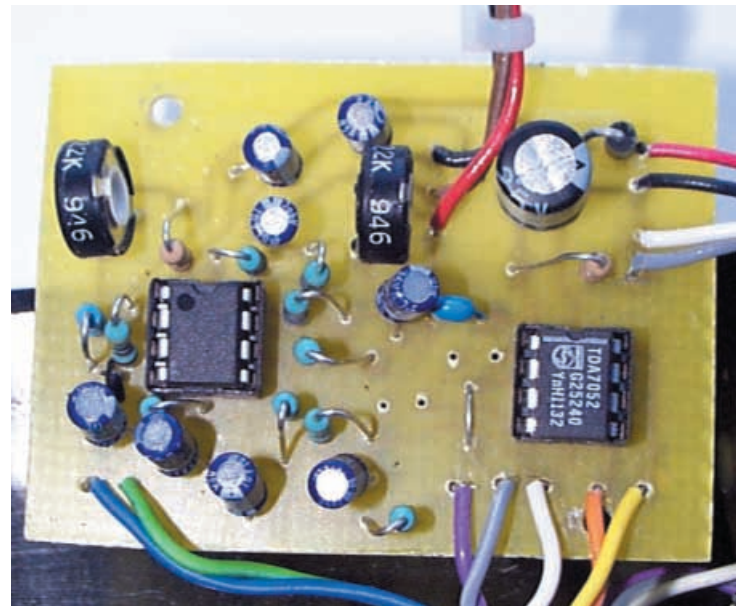
Completed prototype circuit board.

MASTER BOX

The sloping front aluminium instrument case used for the prototype Master unit gives a professional appearance, see photographs. There is an advantage in using a box that is of part plastic construction. This is because a case made entirely of metal will need additional insulation on the Phones output socket.

Find the best positions for the switches, panel potentiometer, l.e.d. indicators and sockets. The headset socket should be located on a *plastic* part if possible.

Decide whether commercial XLR leads are to be used or whether leads are going to be made up so that the appropriate connectors may be chosen. In the prototype, XLR sockets were used in the master with a matching plug on each slave unit. Drill holes for all these parts.

Mark out and drill the holes for mounting the p.c.b., battery holder and any remaining parts, including one for the solder tag (in a metal part). Drill small holes to correspond with the anti-rotation tabs on the rotary switch and potentiometer. This prevents their bodies possibly turning in service and breaking off soldered connections.

INTERWIRING

Attach all internal components and, referring to Fig.4, complete the interwiring to off-board components. Note how resistor R13 is connected. Apply some sleeving to the joints at the l.e.d. leads and any bare wires to prevent short circuits. Using a multitester, check that the solder tag makes good contact with the metal part of the case. The wires connected to it should be twisted together and hooked through the hole before soldering.

Note that neither Phones socket connection may make contact with 0V (earth) – that is, any metal part of the case. If, as in the prototype unit, the socket is mounted on a *plastic* part, there will be no problem.

If the socket must be mounted on metal, the best approach would be to use a *fully-insulated* jack socket. Unfortunately, most types make automatic connection of the sleeve to the case.

If necessary, you will need to make an insulating sleeve (or a shouldered plastic bush) and use plastic washers to isolate it from the metalwork. Use a multitester to check that the sleeve does not make electrical contact with "earth" before proceeding.

Take care to wire up the Listen/Talk selector and the Talk to All switches correctly. The pole lettering and contact tag numbering (see inset dia.) is as shown on most switches of this type.

If using XLR connectors, pin 1 should be connected to Earth (0V) along with the solder tag which connects to the metal body. In the prototype, pin 2 and pin 3 are used for the Talk and Listen connections respectively.

All the wires connected to these sockets will need strain relief. In the prototype, this was done by means of a cable tie passed through slots in the bottom of the case. This will help in preventing the wires from breaking free in service.

MICROPHONE WIRING

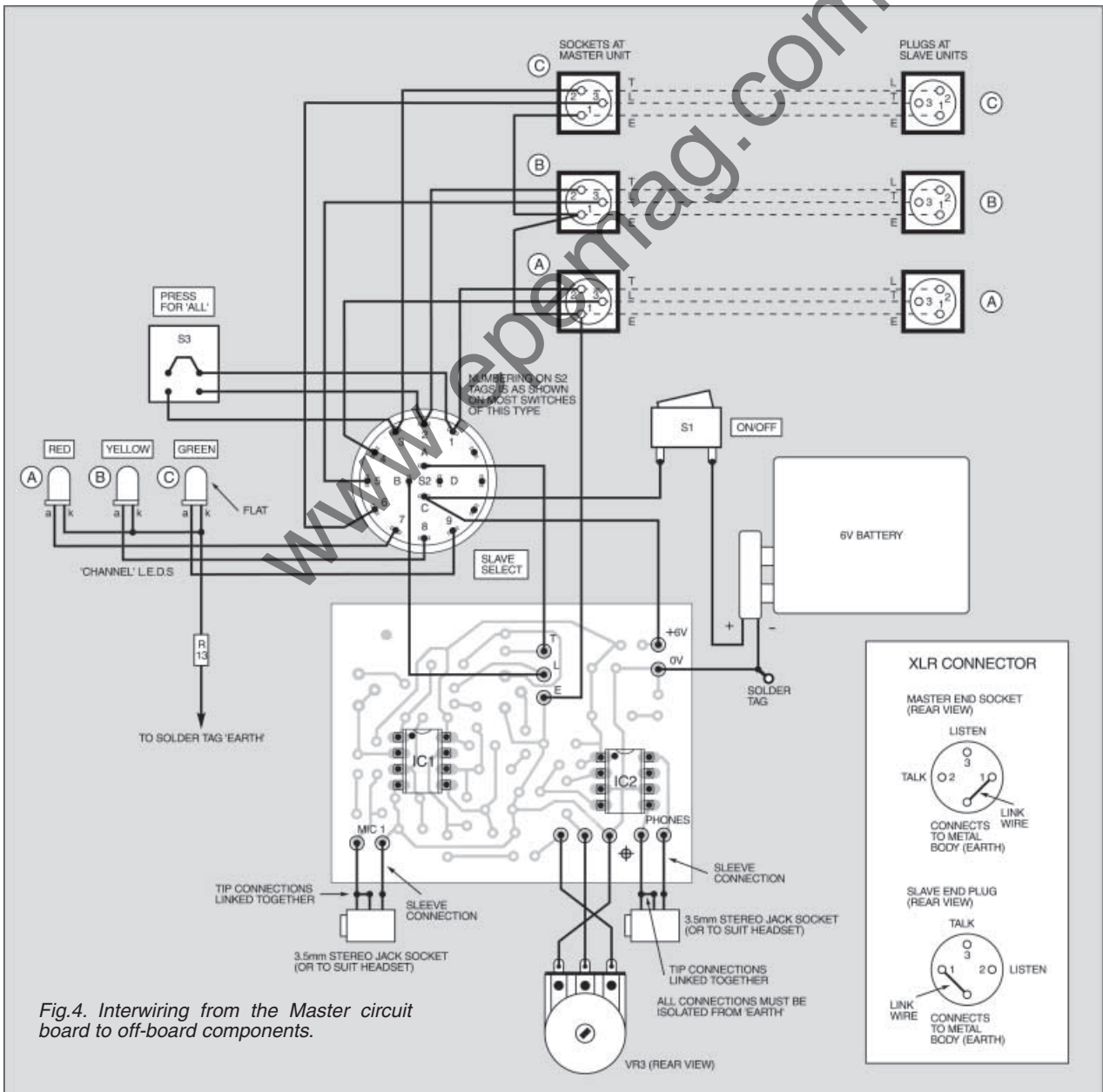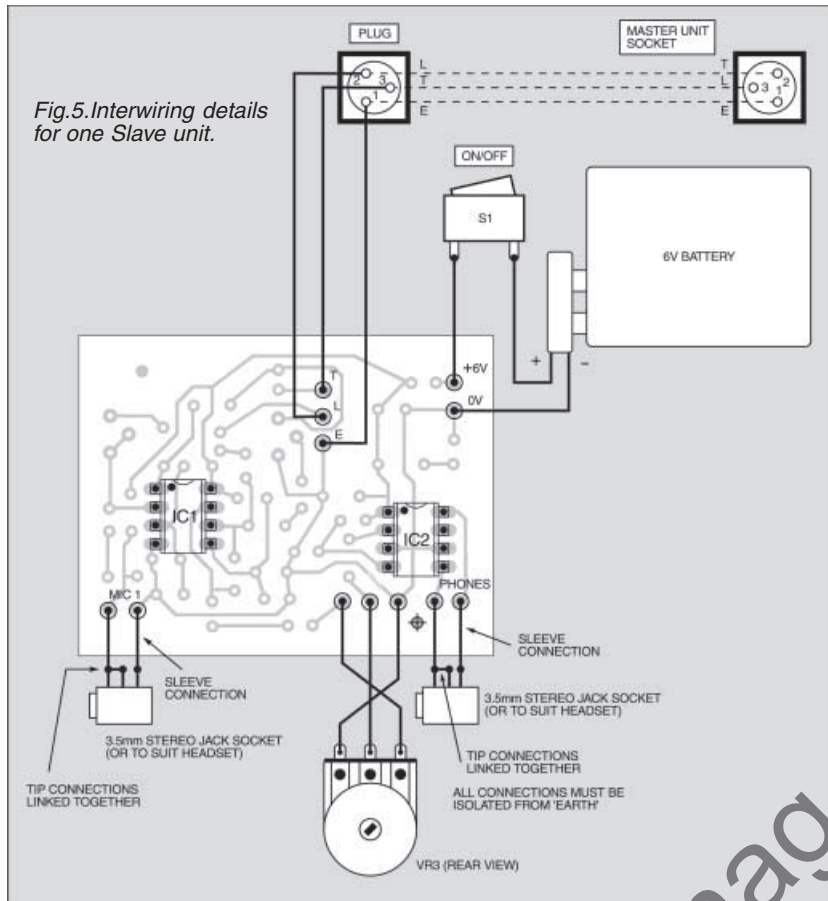The microphone input socket may be mounted on a metal part because its sleeve

Fig.4. Interwiring from the Master circuit board to off-board components.

Fig.5. Interwiring details for one Slave unit.

Packing the components into the Slave unit.

General layout of components on the Master unit metal front panel.

must be connected to earth (0V). However, it will probably be mounted next to the phones socket for cosmetic reasons. If it is on plastic, you will need to hard wire its sleeve connection to the solder tag.

Note the sense of the wiring to the Volume control (VR3) potentiometer tags. This gives conventional operation – clockwise rotation increasing the volume.

Note also that only one current-limiting resistor, R13, is needed for the slave indicator l.e.d.s. This is because only one l.e.d. can be illuminated at a time.

SLAVE UNITS

Choose plastic boxes of appropriate size for the Slave units and fit the belt clips if required. Check the layout of internal parts and drill holes for them. Do not forget the small hole needed for the Volume control potentiometer anti-rotation tab.

Attach all slave parts and, referring to Fig. 5, complete the internal wiring leaving plenty of slack in the wires. Note that certain connections will be close together so make sure they do not touch and cause a short-circuit. Use additional insulation as necessary.

Check that the connections to the plug pins allow the interconnecting lead to make the appropriate connections (Talk to distant Listen and Listen to distant Talk). In the prototype, pin 2 was used for listen and pin 3 for the talk. Connect pin 1 to the solder tag on the plug that connects to the metal body. Take care over the sense of the connections to the potentiometer tags.

Attach the control knobs to the spindles of the switches and potentiometers in all units. Leave the lids removed from the cases for the moment to allow presets VR1 to be adjusted. Observing the usual anti-static precautions, insert all the i.c.s into their sockets taking care over the orientation.

FINAL CHECKS

Begin final checking with all the units switched off. Fit the batteries then plug in the interconnecting leads and headsets, with integral microphone "booms". Turn all the Volume controls to minimum and switch the units on.

The l.e.d. On indicators should operate. The headphones should be listened to with caution in case the Volume controls have been wired in the wrong sense and a sudden loud noise develops.

Test the operation between the Master and each Slave unit. Preset VR1 should be adjusted in each unit so that the maximum volume set by VR3 is not too great and that there are no signs of instability. Adjust preset VR2 in each unit for the preferred degree of voice feedback. Check the "talk to all" function.

When satisfied, attach the lids of the cases and label the controls. You will know when the batteries need to be replaced because the sound will become weak or distorted and the l.e.d.s will glow less brightly.

In use, always start with the volume turned down to minimum and switch on all units before wearing the headsets. This will avoid any loud clicks.

ALTERNATIVE POWER AMPLIFIER

If it is impossible to obtain the specified power amplifier (i.e. a TDA7052 *without* a suffix letter) and you must use one having a "d.c. volume control", its gain will need to be configured to maximum to match the characteristics of the specified unit. This may be done by soldering resistors Rx and Ry in the unused positions on the p.c.b. Resistor Rx will be in the upper position which connects to IC2 pin 1 and Ry to the lower position which connects to IC2 pin 4.

Resistor Ry may need a 1µF capacitor connected in parallel with it. This could be placed on the underside of the p.c.b. Note that this set-up has not been tested and some experimentation may be needed to obtain correct operation. □
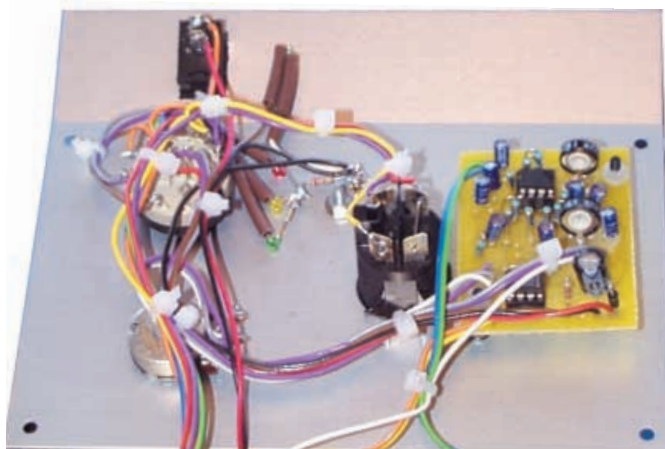
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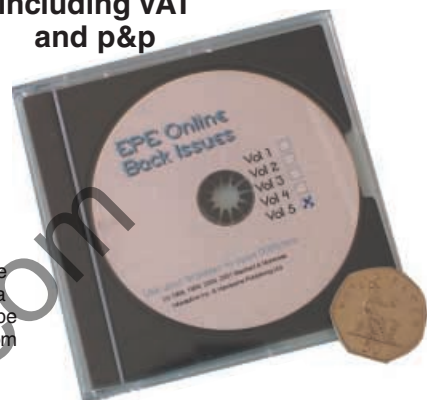
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M10/02

LOGIC GATE INVERTER OSCILLATORS

GEORGE HYLTON

Part Two

A compendium of practical oscillator circuits for the creative experimenter, all based on inverting logic gates.

LAST month we examined the basic principles which allow CMOS inverters to be used as oscillators, concluding with an example of a Colpitts oscillator. We conclude this two-part series by first examining a ccrystal oscillator circuit.

CRYSTAL OSCILLATOR

The high frequency crystals used to set the clock frequency in computers can replace L in the Colpitts circuit of Fig.10. The circuit is then sometimes called a Pierce oscillator (Fig.11), although this nomenclature is dubious.

Since a crystal blocks d.c., a resistance (R1) must be added to allow d.c. negative feedback to set the working point. This resistance should be high enough not to impair the oscillation.

Crystal manufacturers specify the value of shunt capacitance needed to trim the frequency to its nominal value. In the pi-network, the two capacitances are effectively in series so each should be twice the quoted shunt capacitance. The frequency can be fine tuned by adjusting one or both of them.

It is possible that oscillation may be too violent. A feedback control (VR1) may also be used as with the Colpitts oscillator. Crystal manufacturers may specify a safe operating voltage and VR1 can be set to

Fig.11. Pierce crystal oscillator. Here the crystal replaces L in the Colpitts circuit.

ensure that it is not exceeded. Generally speaking, it is sufficient to set VR1 so that reliable oscillation (in the face of falling supply voltage, etc.) is just feasible.

For crystals designed to generate frequencies below about 1MHz, or above about 10MHz, special circuit arrangements may be needed. Consult the manufacturer's data sheet.

TWO-TERMINAL LC

The need for transformers or twin capacitors can be avoided by using a so-called two-terminal oscillator circuit. This means that the frequency-determining LC circuit can be connected by just two leads, those marked X in Fig.12.
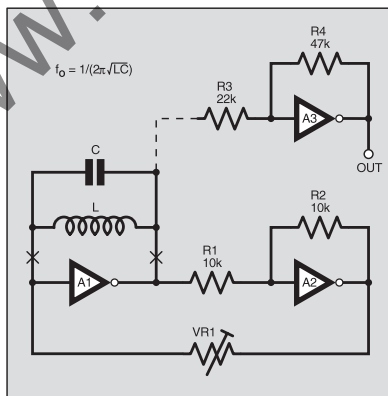

Fig.12. Two-terminal LC oscillator. A2 provides the required phase inversion. A3 can be added as a output buffer.

With R1 = R2, A2 has a gain close to one, so it is just a voltage inverter. Then A1 must provide the gain needed for oscillation. The critical condition is that VR1 should be just less than the effective resistance of the LC circuit at its resonant frequency f_o.

The effective resistance is called the dynamic resistance and is Q times the reactance of L or C at f_o. For a usable coil the Q "quality factor" is unlikely to be less than five, and may be several hundred.
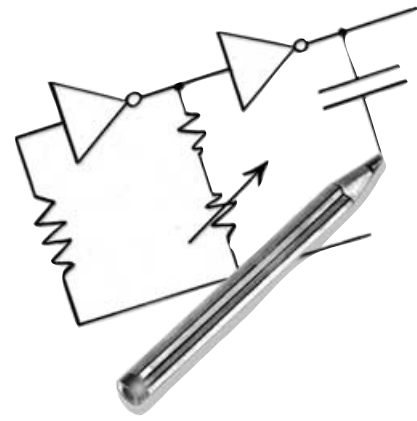
Good sine waves are obtainable at the LC circuit when VR1 is considerably less than the critical value, but to get a pure waveform at A2 output, VR1 must be set so that the circuit just oscillates. It may be simpler to pick off a sine wave output at A1 and extract it via buffer A3. This has a gain of R4/R3. The circuit may be used up to about 1MHz.

If VR1 is calibrated it can be used to obtain a reasonably accurate indication of the dynamic resistance of the LC circuit. Simply adjust VR1 to the maximum value for oscillation. Then VR1 is the dynamic resistance. From this the Q can be calculated:

Q = dynamic resistance / reactance of L or C at f_o

This circuit has overall d.c. positive feedback. It would latch up if the d.c. gain of A1 exceeded one. Fortunately, the low d.c. resistance of L keeps gain well below one, so it is d.c. stable.

Resistors R1 and R2 set the gain of A2 to unity (−1). Driving A2 directly would cause over-violent oscillation, The ratio R2/R1 could be increased to up the loop gain but this is not necessary with typical LC values.

In A3, R3 and R4 set the gain and working point and R3 also provides some buffering. With VR1 set correctly there is no protection-diode conduction. This implies a VR1 of slightly less than the dynamic resistance $2\pi f$LQ or Q/($2\pi f$C). However, VR1 can be less than optimum without seriously impairing the sine wave at the LC.

WIEN BRIDGE SINE WAVE OSCILLATOR

The reactive (RC) arms of a Wien bridge (Fig.13) can be used to set the frequency of a sine wave oscillator formed around an op.amp (Fig.14). In a Wien bridge, when R1 = R2, C1 = C2 (the usual case) balance (zero output) is obtained when V2 = V3, in which case C then has a reactance equal to R.

This occurs when the input frequency f_{in} is 1/(2πCR), usually called f_o. Tuning is conveniently effected by using a two-gang potentiometer for the two controlling resistors (R1 and R2) so that they are always equal. In this way balance is maintained as these resistors are adjusted.
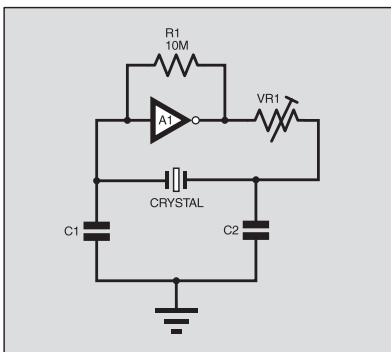
Fig.13. Wien bridge.

$C1 = C2 = C$ $f_o = 1/(2\pi CR)$
$R1 = R2 = R$ $R3 = 2R4$
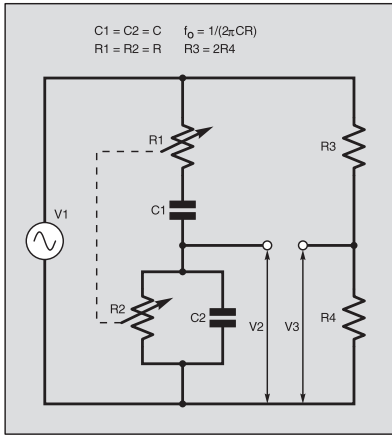
In oscillators, use is made of the fact that RC arms of the bridge form a frequency-selective voltage divider whose output is greatest at f_o. At frequencies away from f_o, output falls. When this network is used as a positive-feedback path in an amplifier (Fig.14) and the gain is just sufficient for oscillation, a sine wave at f_o is generated.

Unfortunately, the Wien network is only very weakly frequency-selective. It does a poor job of discriminating against harmonics produced by the amplifier overloading. The waveform is distorted.

A solution used in commercial Wien oscillators for audio work is to provide a distortionless means of automatically restricting gain to be just sufficient for oscillation. Very pure sine waves can then be obtained. A common method is to use a negative temperature coefficient (n.t.c.) thermistor for the R3 resistance. As oscillation builds up the signal warms the thermistor whose resistance falls. This increases the negative feedback to the inverting input terminal, damping down the oscillation.

The standard circuit (Fig.14) does not translate into inverter-oscillator form because an inverter has only one input terminal. It can, however, be adapted to a 2-inverter circuit, as illustrated in Fig.15.

Inverters A1 and A2 are used in their "linear" mode and the parallel-RC arm now creates negative feedback to A1 while the series RC arm conveys positive feedback from A2 to A1. The circuit oscillates at f_o when the gain of A2 (adjusted by VR2) slightly exceeds two. An extra preset
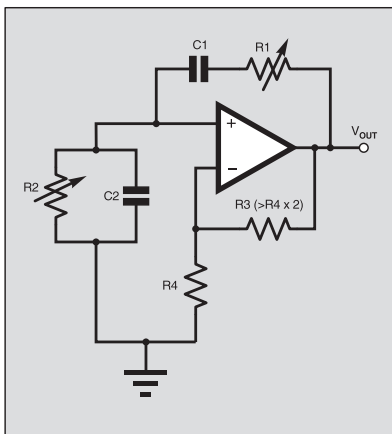

Fig.14. Wien bridge oscillator using an operational amplifier.

resistance, VR1, has been added. Without it the circuit would cease to oscillate as R is reduced towards zero. The oscillation frequency is:

$$f_o = 1/(2\pi C(R + VR1))$$

In fact, there is a hidden component in the series arm: this is the output resistance of inverter A2 and it must be compensated for by an increased resistance in the parallel arm. If this is not done, feedback varies as R is adjusted and it is impossible to obtain a good waveform over the tuning range.

AMPLITUDE LIMITING

No device for automatic amplitude limiting is shown in Fig.15. The job could be done by substituting a thermistor for the feedback resistance across A2 as in Fig.16. VR2 would then provide oscillation level adjustment and should have a mid-value equal to the working thermistor resistance.

Unfortunately, there are really no suitable thermistors available to the average hobbyist. The sub-miniature bead thermistors needed are very expensive. Cheap types are physically too bulky and do not heat up enough at the small signal levels in the circuit.
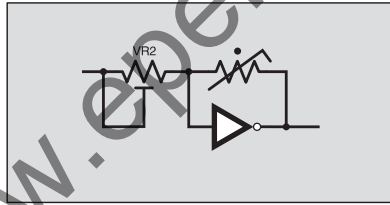

Fig.16. Using a thermistor in place of R_F in Fig.15.

V_{out} must drive enough current through the thermistor to reduce its resistance sufficiently to obtain low distortion. Since CMOS inverters cannot deliver much current it is desirable to keep the thermistor resistance fairly high, say 10k. The a.c. voltage across it is unlikely to exceed about 3V r.m.s. The power available to warm the thermistor is then 0·9mW. For reliable operation over a range of ambient temperature this amount of power must cause a temperature rise of at least 20°C.

If very low distortion is not required, a fairly good sine wave can be obtained from the circuit as shown in Fig.15 if set-up carefully, as follows:

Set R to maximum. Set VR2 for "just oscillating". Set R to minimum (zero). Without altering VR2, set VR1 for "just oscillating". Repeat this procedure then, if necessary, make minor adjustments so as to obtain the best compromise performance over the tuning range.

The final result will depend on how well the two sections of the potentiometer are matched. Linear-law two-gang pots are usually better than log-law, but give tuning
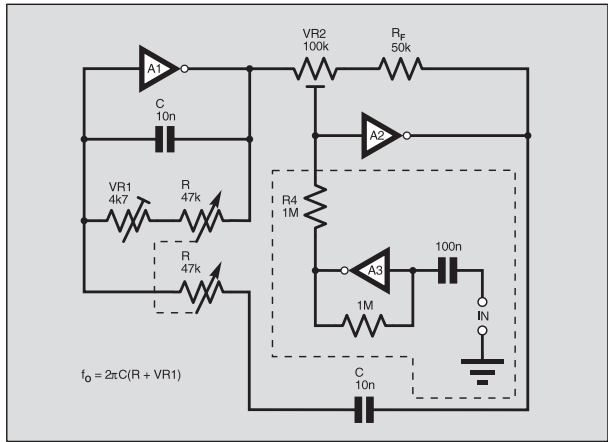

Fig.15. Inverter gate version of Wien oscillator. The A3 section can be added to inject an external synchronising signal.

scales which are very cramped at the high-frequency end. Frequency sweeps (max./min.) of 10 are then a practical limit, though the circuit will oscillate over a wider sweep.

The circuit can be used as a selective amplifier with input injected via a high-impedance buffer A3. In this case VR2 is a sharpness control and for greatest selectivity is set for "just not oscillating". The buffer amplifier may also be used, if required, to inject a frequency-locking signal into the oscillating circuit.

An injected signal of a few mV can synchronise the oscillator. How long it stays synchronised depends on the frequency stability of both the oscillator and the sync input. Injecting a larger signal increases the locking range but at the risk of false locks where one frequency bears some fractional relation to the other. (Often the waveform then shows some periodic distortion.)

Multi-band operation is possible by switching-in different pairs of capacitors C. For consistent performance each pair must be very accurately matched.

DUAL INTEGRATOR OSCILLATOR

An inverter with feedback from output to input via a capacitor (as with A1 and A3 in Fig.17) has a gain which falls off as the frequency is raised. In a sine wave oscillator this reduces the harmonics which result from distortion. The ability to yield good sine waves without special amplitude control circuitry is especially useful at very low frequencies, where conventional control using thermistors is difficult. (The resistance of the control device varies over the oscillation cycle and causes distortion.)

An inverter with capacitive feedback produces a phase shift. Two inverters, each giving a phase shift of 90° in the same direction, give a total of 180°, which is phase inversion. When cascaded with a simple inverter and connected in a ring, the overall feedback is positive at the 90° frequency. Here this is the frequency for which the reactance of C equals R.

An inverter with capacitive feedback is often referred to as a Miller integrator, or just an integrator. The frequency generated by the type of circuit in Fig.17 is the same as for a Wien network oscillator ($f_o = 0·16/(RC)$). With the values shown the
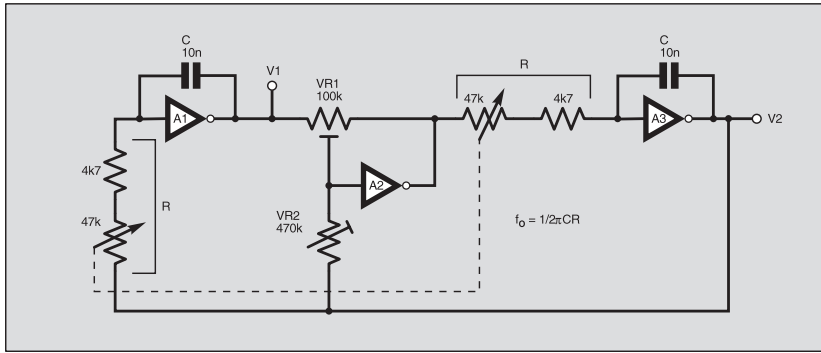
Fig. 17 Dual-integrator oscillator. Oscillation level is set by VR2. The two outputs V1 and V2 are equalized by VR1 and are 90° apart in phase.

range is roughly 300Hz to 3300Hz. The range can be switched by substituting other pairs of capacitors, accurately matched.

When R is in megohms and C is in microfarads, the frequency is in Hertz (Hz). Because of the good discrimination against harmonics it is easier to achieve a respectable sine wave than with the Wien oscillator.

The circuit also has the useful property of yielding two equal output voltages (V1 and V2) phased 90° apart ("in quadrature"). On the other hand setting up to achieve a good performance over the tuning band (by adjusting VR1 and VR2) involves using an oscilloscope and doing a fair amount of fiddling.

Start with VR1 and VR2 set halfway. Trim VR1 to equalise V1 and V2. Trim VR2 for the best waveform. The tuning range is somewhat affected by these settings. To achieve the best amplitude stability one of the fixed resistances in series with the tuning resistances may need to be trimmed (at the h.f. end of the band).

RING OSCILLATORS

The three inverters of Fig.18a are connected in a loop or ring. If the input to A1 is positive then the output of A3 is negative. Since this is fed back to A1, it opposes the positive input. The ring is a negative feedback loop with total feedback and (accidents barred) it will be stable. Accidents do happen, though, as will be shown later.

Referring to Fig.18b, if we now interpose between successive stages networks which produce 60° phase shift to signals at

some frequency then, going round the loop, the three phase shifts add up to 180°. This is inversion.

The reactance is twice the resistance for series C, shunt R, and the reverse for series R and shunt C.

The fed-back signal at A1 is now in step with the original signal. Feedback is therefore positive and the circuit oscillates. If the 180° phase shift occurs at only one frequency then that will be the frequency of oscillation.

PHASE SHIFTERS

Two standard ways of achieving phase shift are shown in Fig.18c to Fig.18d. The first is passive – the required 60° shift occurs at the frequency at which the series arm has twice the impedance of the shunt arm. At that frequency the attenuation factor is two (i.e. half the voltage is lost). This is likely to be much less than

the gain of an inverter so the circuit oscillates strongly.

Unfortunately, the strong oscillation drives the internal protection diodes into conduction. The effect is to raise the frequency spectacularly but unpredictably. It would be possible to add swamping resistances but a better alternative is to use the circuit in Fig.18d. Here the phase shifting is done by incorporating the RC network into an integrator, the amplifier being one of the inverters. The inverter input terminal is now a virtual earth point and the signal level there is low enough to avoid the worst effects of protection-diode conduction. In a ring of three such integrators each produces a lagging phase shift of 60°. The oscillation frequency is theoretically

$$f_o = 0·08/(CR)$$

As before, f_o is in Hertz when CR is in megohms times microfarads and so on.

RING VCO

If, in circuits using Fig.18c, the resistances and capacitances are reduced to zero the circuit reverts to that in Fig.18a. It might be expected to display a stubborn stability. Far from it! It oscillates, but at a high frequency.

The explanation is simple. We may have removed *our* Rs and Cs but the circuit has its own built-in equivalents. R is now the output resistance of each inverter and C the input capacitance of the following one.

In a particular case R might be 10kΩ and C might be 10pF. These act like those in Fig.18c. The 60° frequency is:

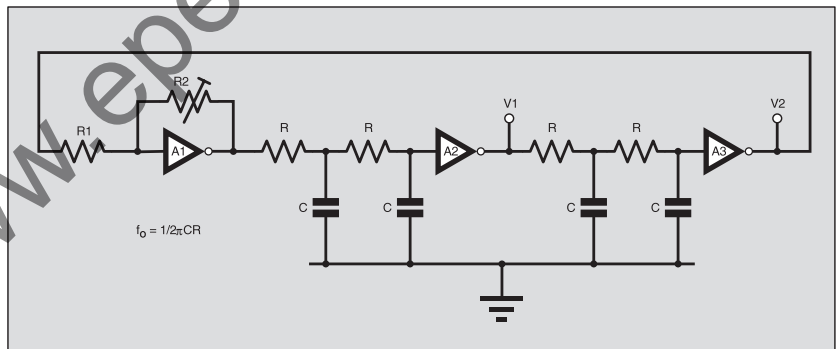$$f_o = 1/(\pi RC) = 3MHz \text{ approximately.}$$

Fig.19. Dual-quadrature oscillator. Each twin RC network produces 90° shift at f_o.
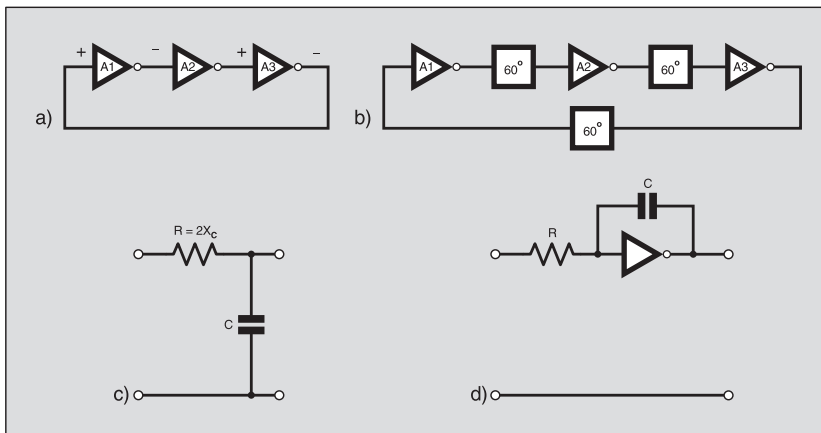
Both the output resistance and the input capacitance of an inverter are affected by the operating voltage. The output resistance is especially strongly affected.

In experimental tests using a CMOS 4069 inverter, biased to operate in the linear region of the input/output curve, the output resistance measured 16kΩ when V_{CC} was 5V, falling to 5kΩ when V_{CC} was 15V.

This means that the "zero component" ring of Fig.18a is in reality a voltage-controlled oscillator, with V_{CC} as its control voltage. Oscillation may be possible at V_{CC} down to 2V, where the frequency is quite low. At high V_{CC} it may be tens of megahertz.

Note that there is a real risk, at high V_{CC}, of the current drawn becoming excessive and overheating the chip. Note also that while standard CMOS i.c.s like the 4069

Fig.18. (a) Three-inverter ring. (b) With added phase-shift circuits. (c), (d) Alternative phase shift networks.

are rated to work at up to 15V their modern "equivalents" like the 74HC04 have much lower maximum V_{CC} ratings.

It is possible to bring down the frequency while retaining voltage control. Add real capacitors for C while leaving R at zero.

4-PHASE SHIFT RING

A ring with three equal phase shifters (Fig.18b) is a neat means of generating a three-phase signal. But suppose you need some other number of phases. Any number over two can be provided, with one precaution. The total number of inverters in the ring must be *odd*. If it is *even* there is overall d.c. positive feedback and the circuit latches up.

If you need an even number of phases you have to add one plain inverter (with no associated phase shift components) to keep the d.c. feedback negative.

One potentially useful arrangement is to have four shifts of 45° each. This enables outputs to be selected at multiples of 45°, notably 90°. The necessary fifth inverter can be used as a gain-adjustable stage to set the oscillation level. The frequency is that at which R and C have equal impedances, i.e. $f_o = 1/2\pi CR$.

The loop shift must be 180°. For a 3-section phase shift the average per section must be 60°, for four sections 45°, and so on.

It is also possible to generate outputs phased 90° apart with a 3-inverter ring (Fig.19). Here two pairs of double RC networks each generate a 90° shift. The frequency is about $1/(2\pi RC)$.

PHASE SHIFTING

In theory, three or more RC (or CR) networks can be cascaded to give an overall phase shift of 180°. A single inverting amplifier can then maintain oscillation, see Fig.20.

These circuits are usually referred to as "phase shift oscillators" (though of course phase shifting is involved in all the oscillators we have just been discussing).

Phase shift oscillators may look neat but they have two major disadvantages which stem from the fact that the second RC section loads the first, the third loads the second and so on. This greatly increases the attenuation at f_o. For a network with three cascaded RC or CR

sections, all with equal R and C, the gain needed to sustain oscillation is nearly 30. For a four-section network it is nearly 20. A single inverter may not provide enough gain.

The second snag is that it is no longer possible to pick off outputs evenly spaced-out in phase. Also, the voltage diminishes at each successive section.

A third problem is that the gain is not readily adjustable. If, however, one inverter provides more than enough gain a reduction can be made by shunting off some of the current into a second inverter (Fig.21), which presents a load of R1 and can be used as an output buffer. (This trick can be used with other oscillators.)

For a three-section RC network $f_o = 0.39/RC$. For a four-section RC network $f_o = 0.19/RC$.

Attenuation can be reduced by "tapering" the networks. Successive resistances are multiplied by a factor N and successive capacitances divided by N. As N is made very large the 3-section attenuation factor falls towards eight and the 4-section towards four. Making N = 10 achieves most of the improvement and even N = 2 is worthwhile.

The RC network discriminates against harmonics and even if the input to a multi-section network is a square wave the output is a fairly pure sine wave. However, it occurs at a high-impedance point and can only be used if picked off by a very high impedance buffer. This adds its own quota of distortion.

FORMIDABLE

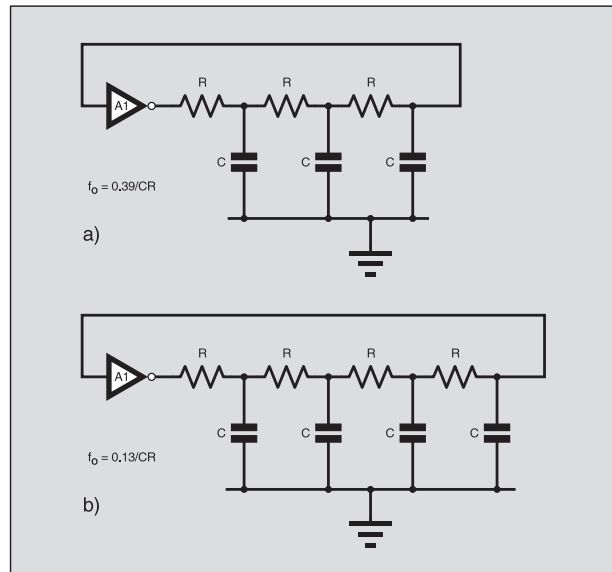Phase shift oscillators are fascinating circuits which over their long history

Fig.20. Phase-shift oscillators. (a) Three-section RC. (b) Four-section RC.

(they go well back into the valve era) have elicited from circuit analysts some formidable feats of mathematics. But if you need a low-distortion oscillator you will be well advised to leave them alone and stick to Wien or dual-integrator circuits!

Whilst we have concentrated on the use of basic CMOS inverter gates, the principles can equally well be applied through the use of dual-input inverting gates, such as NAND and NOR. □
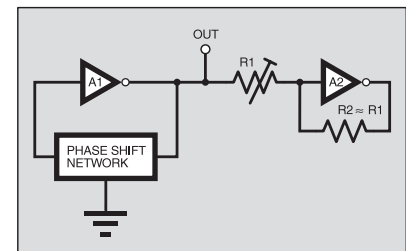

Fig.21. Gain-adjustment circuit. R1 acts as a load on A1.

INTERFACE
Robert Penfold

Adding MSCOMM Active-X control to your PC

THE two previous *Interface* articles were devoted to the use of the MSCOMM ActiveX control to permit serial communications with Visual BASIC programs. The advantage of this method is that it will work with any 32-bit Windows operating system, including Windows XP without the need for any third-party add-ons.

The main drawbacks are that this control is not included with anything less than the Visual BASIC Professional Edition, and it is something less than straightforward in use.

MSCOMM and VBA

Software topics usually produce a certain amount of feedback from readers, and the pieces on MSCOMM are certainly no exceptions. A few readers pointed out that this control is included with Microsoft Word and Excel as part of VBA (Visual BASIC for Applications).

On checking two PCs that had Microsoft Office installed but had never been loaded with Visual BASIC Professional, one had MSCOMM and the other did not. VBA is not only included with Microsoft applications, it is also provided with some software from Corel, Autodesk, etc. However, VBA is not always installed when the "Typical" option is chosen during installation. It is sometimes necessary to return to the installation disk in order to add VBA.

The presence or absence of MSCOMM probably depends on the exact software installed on the PC. The more upmarket the software the greater the chances of success. It would certainly seem to be the case that it is not included with all versions of Microsoft Office.

It is not difficult to ascertain whether MSCOMM is present on a PC. Launch Windows Explorer and then use the search facility to scan the hard disk for a file called MSCOMM.OCX. The MSCOMM ActiveX control is not installed if this file is not present on the hard drive. If this file is present, it would probably be possible to use it with one of the free versions of Visual BASIC as well as with VBA.

Same Difference

VBA is not really intended for producing normal software, and its usual role is in the production of extra commands for applications programs. However, "at a pinch" it can be pressed into service as a means of producing software for use with PC based projects.

The first task is to launch VBA from within the host application, and it is normally accessed via the Tools menu.

With Microsoft Word for example, it is launched by selecting Macro from the Tools menu and choosing Visual BASIC Editor from the submenu.

No form is produced when VBA has finished loading, but a form can be added by selecting User Form from the Insert menu. You then have something like Fig.1, which is similar to the normal arrangement in Visual BASIC.

The next task is to go in search of the MSCOMM control, and the first step is to choose Additional Controls from the Tools
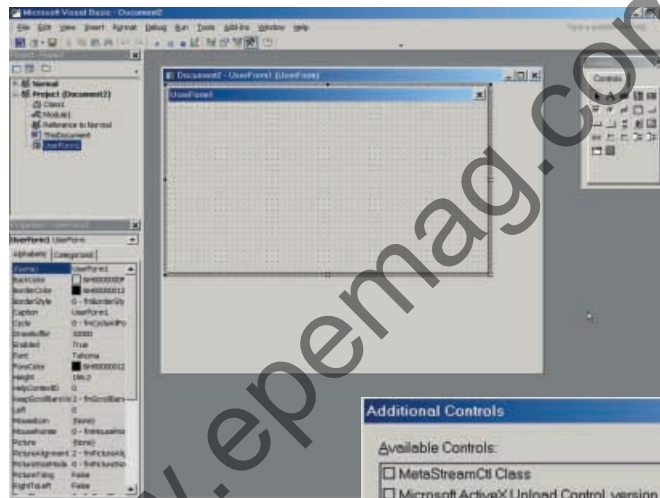

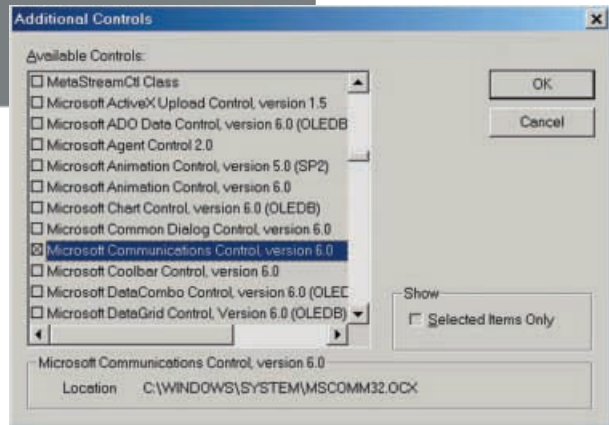Fig.1 (above). The Visual BASIC for Applications (VBA) set up and ready to use.

Fig.2 (below). Adding MSCOMM, if it is available.

menu. This brings up a window like the one of Fig.2, and it is then a matter of scrolling through the list looking for MSCOMM. It will not be called MSCOMM in this list though, it is more likely to be called "Microsoft Communication Control version 6.0" or something similar to this.

Having found the right entry in the list, tick its checkbox and then operate the OK button. A yellow telephone icon should then appear in the Toolbox, and this enables MSCOMM to be added to the form in the usual way.

VB or not VB

Although VBA seems to be widely regarded as identical to Visual BASIC, there are differences. The fact that VBA is not designed to produce standalone programs enforces a few changes, but there are differences in the code, such as the exact structure of conditional routines.

Programs written for Visual BASIC will usually require at least a small amount of rewriting in order to make them work with VBA. This point is demonstrated in the first VBA listing (Listing 1), which is for a simple program that reads single bytes from a serial port and displays them on a label component.

In addition to MSComm and a form, it requires two buttons and a label. The captions for buttons one and two (CommandButton1 and CommandButton2) are respectively changed to START and EXIT.

Listing 1

```
Private Sub UserForm_Click()
End Sub

Private Sub CommandButton1_Click()
MSComm1.PortOpen = False
End
End Sub
```

```
Private Sub CommandButton2_Click()
MSComm1.RThreshold = 1
MSComm1.InputLen = 1
MSComm1.Settings = "9600,n,8,1"
MSComm1.CommPort = 1
MSComm1.InputMode =
            comInputModeText
MSComm1.PortOpen = True

End Sub

Private Sub MSComm1_OnComm()
If MSComm1.CommEvent = 2 Then
Label1.Caption = Asc(MSComm1.Input)

End Sub
```

Operating the START button switches on communication with the serial port, selects the required port, and sets the required operating parameters. This works in the same way as the code for the Visual BASIC version described in a previous *Interface* article.

The routine used for MSComm1 reads single characters from the port, converts each one to its ASCII value, and then writes that value to Label1. In the original program an If...Then...End If structure was used to check that the right OnComm event had occurred. If the right event had occurred (i.e. a new byte of data had been received), the port was read, the conversion was made, and data was written to the label.

With VBA the If...Then...End If structure is not quite the same, and the original routine just causes an error message when used with VBA. In this case the routine can be reduced to a single line of code, with no End If statement required at the end of the routine. In fact it must be omitted or an error message will be produced.

The routine for the EXIT button simply closes communications with the serial port and closes the program. The VBA version of the program works as well as the original Visual BASIC version, and it can be seen working within VBA in Fig.3.

Output

The second VBA listing is for a simple serial transmission program. The form is equipped with START and EXIT buttons, as in the serial port reading program. It also has a label, but this time it is used to show the value generated by a scrollbar.

The latter is used to generate the values that are transmitted, and its MAX setting should be set at 255. It will then generate integers from 0 to 255, or single bytes of data in other words.

Listing 2

```
Private Sub CommandButton1_Click()
MSComm1.PortOpen = False
End
End Sub

Private Sub CommandButton2_Click()
MSComm1.PortOpen = True
End Sub

Private Sub Label1_Click()

End Sub

Private Sub MSComm1_OnComm()
End Sub

Private Sub ScrollBar1_Change()
MSComm1.Output =
            Chr$(ScrollBar1.Value)
Label1.Caption = ScrollBar1.Value
End Sub

Private Sub UserForm_Click()

End Sub
```


Fig.3. The serial reader program operating within VBA.

Fig.4. The serial transmission program. Values set on the slider control are transmitted from the serial port.

In this case the VBA program can be much the same as its Visual BASIC equivalent. It is the routine for the scrollbar that actually transmits the data, and the new value is sent each time that a change occurs.

The Chr$ function is used to convert the value from the scrollbar into an equivalent ASCII character which is then sent to the serial port for transmission. The unprocessed value is displayed on the label component so that the user can see what values are being sent. Again, the VBA program works as well as the Visual BASIC version, and it is shown running in Fig.4.

Lockout Situation

Programs are saved using the Save Document option under the Edit menu. Once the document has saved, this option changes to Save XXXX where XXXX is the program name that you

chose. Note that the main Word document can be empty, and there is no need to add any dummy text. To use the program on another occasion, load the relevant document and go to the Visual BASIC Editor again. This should contain the program.

There can be a problem when tying to run the program, with an error message appearing. This points out that Macros have been disabled and that the program cannot be run. Macros are disabled by default as a means of reducing the risk from macro viruses.

Selecting Macros from the Tools menu followed by Security from the submenu enables the security setting to be changed. A dialogue box appears and it has radio buttons that offer three levels of security.

The lowest level enables macros to be run with "no questions asked". You will be asked whether or not you wish to run the program if the middle setting is selected, and macros are blocked if the highest level is used.

If you are used to VBA and its version of the BASIC dialect, VBA programs can be a valid approach to producing software for your PC projects. Even if you do not have MSCOMM on your computer system, VBA can still be used with third party add-ons such as **Inpout32.dll** to access the serial and parallel ports.

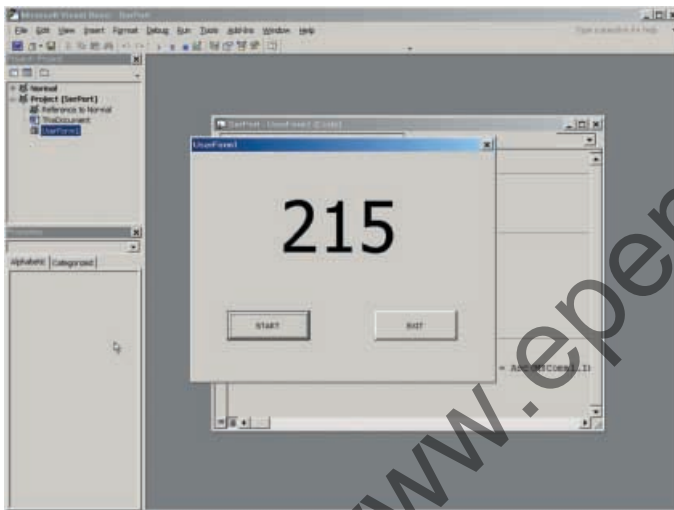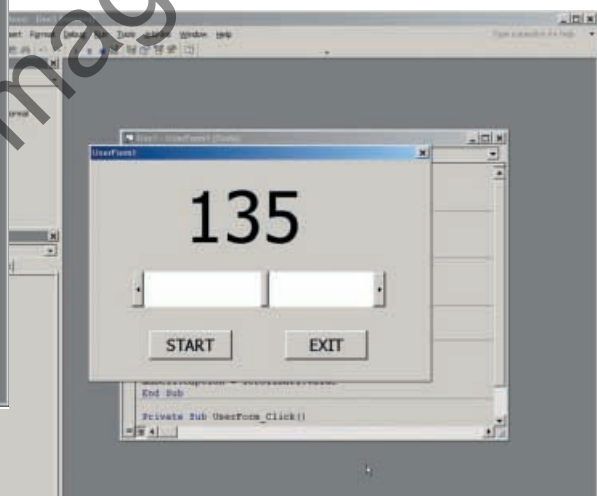One of the free versions of Visual BASIC probably represents a better starting point for those starting "from scratch". Either way, it is possible to get into visual programming at no cost.

Binary Mode

A couple of readers have pointed out methods of using MSCOMM in binary mode so that the string conversions can be avoided. This is a subject that will be considered in detail when the problem has been investigated fully.

Strangely, the Microsoft documentation recommends that the text mode is used for all data transfers using MSCOMM. A possible reason for this is that some facilities of MSCOMM seem to disappear when the binary mode is used. The text and conversion method is a bit cumbersome, but it does have the saving grace that it actually works quite well.