An acoustically-coupled modem for computers

One of the most satisfying aspects of personal computing is writing your own programs and exchanging these programs with other computing enthusiasts. Now we have made it easier to communicate: you can send your programs over telephone lines with our acoustically-coupled modem. It is simple to build and uses just a handful of readily available economical ICs.

by JOHN CLARKE

What is a "modem"? Modem is a contraction of the two words modulator demodulator. This describes the purpose of a modem. It is used to encode information in a format suitable for transmission over telephone lines and to decode incoming information.

Strictly speaking, the cassette interface found in most personal computers is also a type of modem. It also encodes and decodes information, in this case in a format suitable for storage on cassette tape.

Some modems are permanently connected to telephone lines. This is certainly the case for Telex (teletype) and document facsimile services. Large computer data networks also employ directly connected modems.

In less demanding applications or where only one telephone line is available, acoustically coupled modems are employed. These enable a user to communicate with a computer data network from anywhere, providing there is a telephone handy!

Now the modem has become available to personal computer users. Anyone may purchase a "Telecom approved" modem (more about this aspect later) for use with his or her personal computer. In operation, you dial your friend who must also have a modem and computer, and after some discussion (unintelligible to the computers) you each place your telephone handsets into the modems. The computers then begin to communicate. From this point, the operation is as simple as saving or loading a program from a cassette.

As with the cassette interface in most personal computers, all modems use a system of FSK, "frequency shift keying". But whereas the two frequencies used on cassette interfaces which conform to the "Kansas City Standard" are 2400Hz and 1200Hz (where a "1" is equivalent to 2400Hz and "0" is equivalent to 1200Hz), modems in Australia conform to the CCITT standard. This standard embraces so-called "full duplex" modems which can transmit and receive simultaneously.

The new "Electronics Australia" acoustically coupled modem can be described as "half-duplex" which means that it can either transmit or receive data and it can be switched from one mode to the other. But it cannot perform the

HOW THE CIRCUIT WORKS

The circuit of our modem can be broken down into four major sections: transmitter, receiver, interfaces and power supply. Perhaps it is easiest to understand if we begin by describing the transmitter section.

Five integrated circuits and three transistors make up the transmitter circuit and the heart is IC4 and IC5, two 555 timer ICs connected as monostables. When used as a monstable, the 555, upon being triggered, delivers a positive pulse from its output which lasts for a time determined by the resistance and capacitance associated with its threshold control, pin 6. After this time, the output stays low until the 555 is triggered once again.

In this circuit, both monostable timers are reset and triggered simultaneously. Why? Well, the idea is that one monostable, IC5, is the source of the high tones (1850Hz) while the other, IC4, is the source of the low tones (1650Hz). By having the monostables reset and triggered simultaneously, the two tones will be locked together and thus be easier to decode by the receiver circuits.

IC1 and transistor Q3 accomplish the resetting and triggering of IC4 and IC5 in a circuit arrangement which looks a little complex but is really fairly simple, as can be demonstrated by reference to Fig. 1: Waveform A is the data being transmitted; when A is high, the output of IC1a goes low, disabling IC1d. At the same time, IC1b and IC1c are enabled, so that they pass output signals from IC4 (waveform B) through a 180pF capacitor (waveform E) to transistor Q3. When the base of Q3 is pulled negative by waveform E, pins 5 of both monostables are pulled briefly low, which causes them to reset.

Shortly after resetting has occurred, pin 2 of both monostables also goes low. This triggers both monostables for a new cycle and the output of both (pin 3) reverts to the high state. So whenever waveform A is high, IC4 actually controls the resetting and triggering of both monostables and the resultant waveform B is fed through flipflop IC3a to become the transmitter waveform.

A similar process occurs when waveform A is low: IC1d and IC1c are now enabled so that the output from pin 3 of IC5 is coupled through to Q3 and pin 2 of both monostables. So when waveform A is low, IC5 controls the resetting and triggering of both monostables (waveform C). And when IC5 is in control, waveform B and C are identical; this means that even though waveform C is the desired frequency in the latter case, waveform B, fed to flipflop IC3a, gives the correct transmitter frequency (waveform D).

IC2d gates the transmitter signal through when the transmit switch is

This photograph shows the modem working in conjunction with a typical personal computer system.

on and IC2c, Q1 and Q2 buffer the signal to drive the loudspeaker. Flipflop IC3b and a LED give visual indication that the transmitter is working.

The receiver circuitry consists of a 4136 quad operational amplifier package, a 565 phase-locked loop and a 741 op. amp. A small loudspeaker is used as a microphone connected to a non-inverting amplifier, IC6c, with a gain of 101. The amplified signal from IC6c is filtered with a bandpass filter made up of two third-order Butterworth filters — a low-pass filter IC6b and high pass filter, IC6a. These filters provide minimum phase distortion.

Further amplification is provided by IC6d and the output from this is capacitively coupled to the phase-locked loop (PLL), IC7. The free-running frequency of the PLL is set to 1750Hz by the .033uF capacitor at pin 9 and the 4.7k trimpot and 1k resistor connected to pin 8.

The error voltage from the phase-locked loop is smoothed by a three-stage filter connected to pin 7 and then fed to a comparator, the 741 op amp, IC8.

When a logic "0" signal is received at pin 2 of IC7, the PLL will lock onto this causing the voltage-controlled oscillator of the PLL to suddenly shift from 1750Hz to 1850Hz. As this happens, the output signal from the phase comparator, pin 7 of IC7, becomes negative with respect to the reference voltage at pin 6 of the PLL. This potential difference will force the DC comparator, IC8, to swing negative and this output signal will be clamped at approximately −0.6V by D4 when the "0" is received.

Similarly, if a logic "1" signal is now received at pin 2 of IC7, the PLL will lock to 1650Hz, resulting in the phase comparator output becoming greater than the DC reference at pin 6 of IC7. So the voltage comparator, IC8 responds with a positive-going output voltage clamped at about +5V. Thus the IC8 output is compatible with TTL levels.

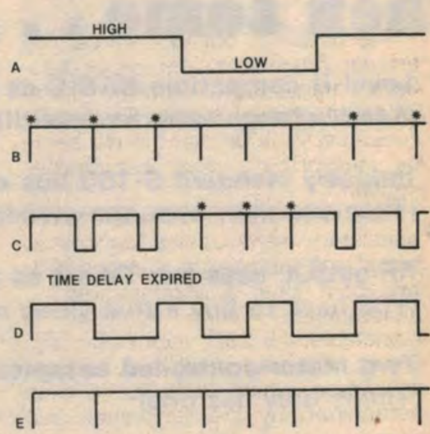

FIG. 1

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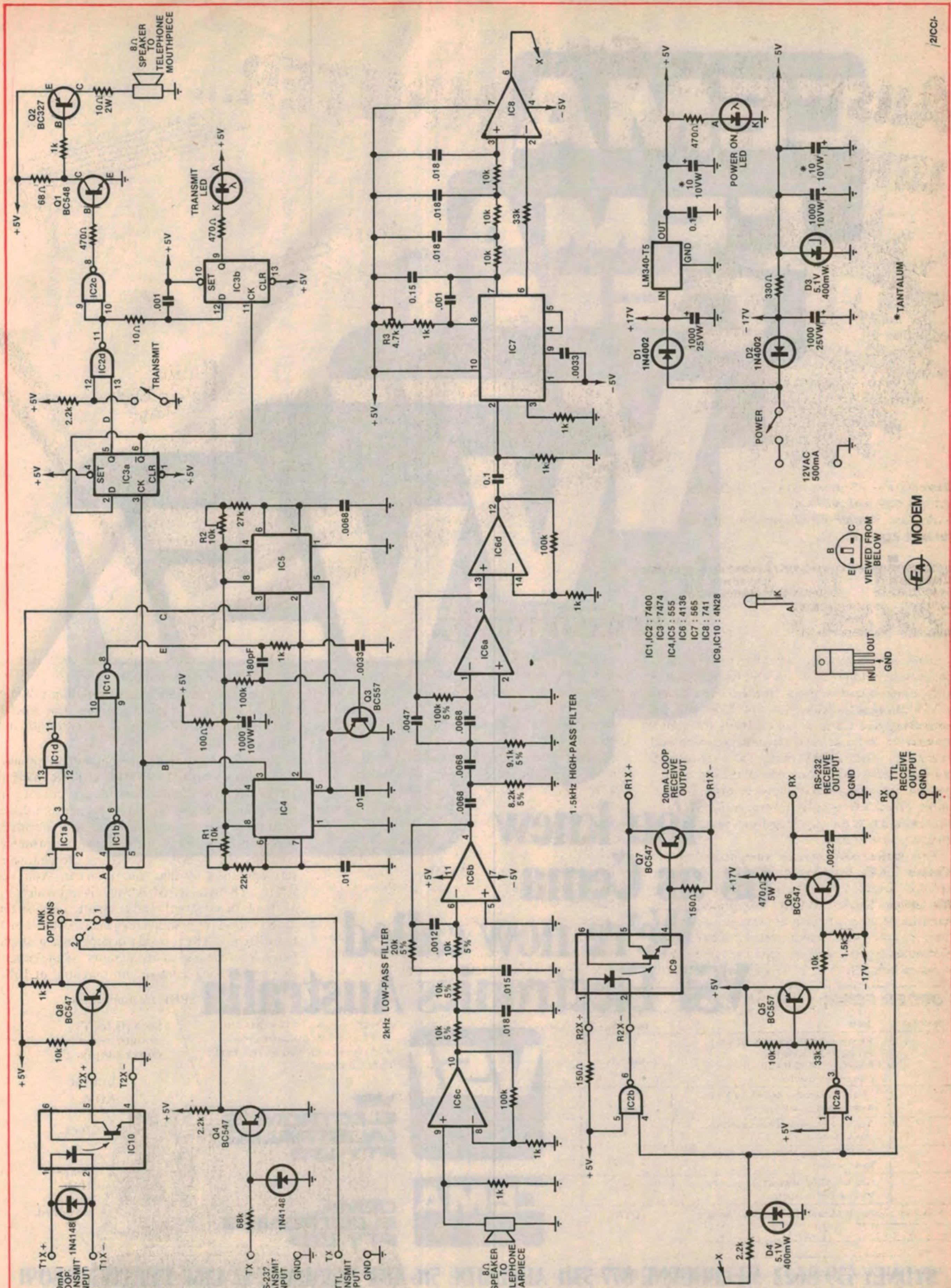

MODEM
VIEWED FROM BELOW
IC1,IC2 : 7400
IC3 : 7474
IC4,IC5 : 555
IC6 : 4136
IC7 : 565
IC8 : 741
IC9,IC10 : 4N28
2kHz LOW-PASS FILTER
1.5kHz HIGH-PASS FILTER
20mA LOOP TRANSMIT INPUT
RS-232 TRANSMIT INPUT
TTL TRANSMIT INPUT
8Ω SPEAKER TO TELEPHONE EARPIECE
8Ω SPEAKER TO TELEPHONE MOUTHPIECE
20mA LOOP RECEIVE OUTPUT
RS-232 RECEIVE OUTPUT
TTL RECEIVE OUTPUT
TRANSMIT LED
POWER ON LED
LINK OPTIONS
TRANSMIT
POWER
12VAC 500mA
LM340-T5
*TANTALUM

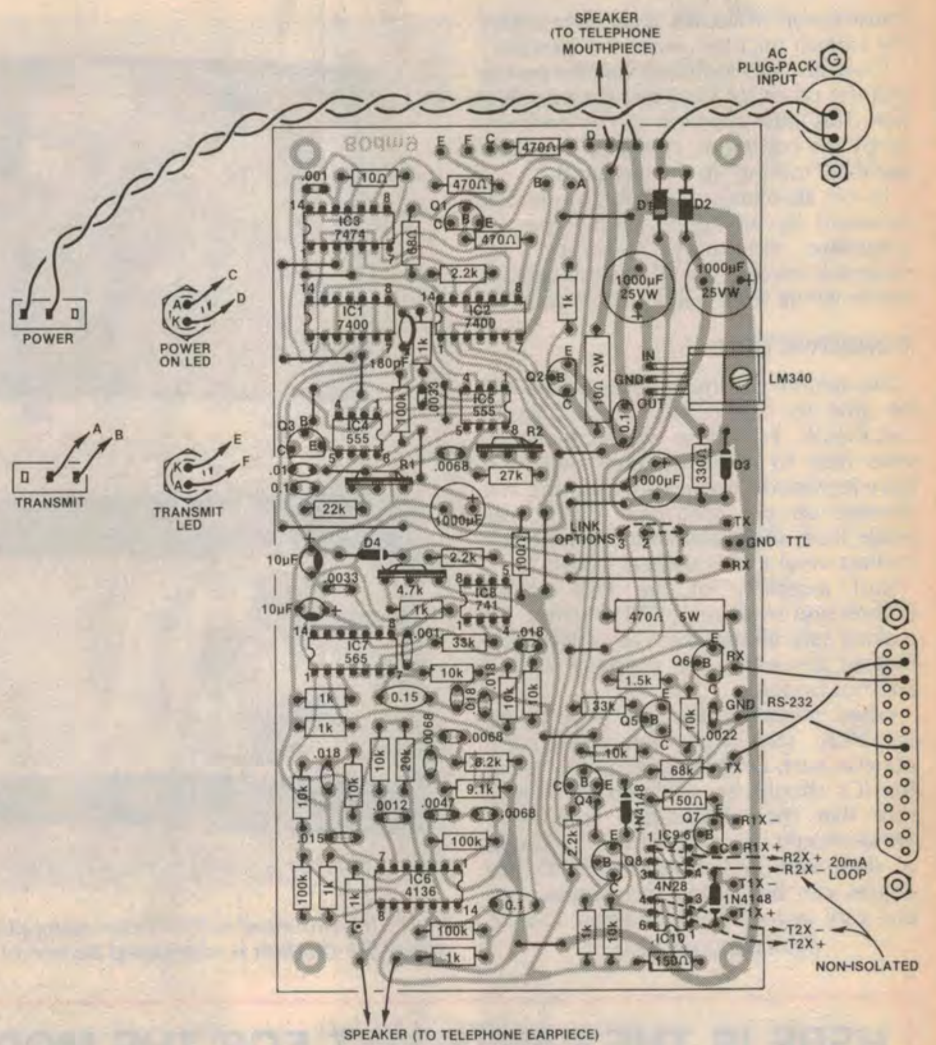
transmit and receive modes simultaneously. Therefore, our new modem uses the following two frequencies for encoding (decoding) the digital values of "1" and "0": 1650Hz and 1850Hz, respectively.

As such, this modem is suitable for serial data transmission rates up to 300 Baud. We'll explain these terms: "Serial" data transmission refers to data transmission one "bit" at a time over one signal line; as opposed to serial communication, parallel data transmission refers to a method whereby eight "bits" are transmitted at a time, over eight separate lines (for a typical "eight-bit" microprocessor).

One baud is equal to one bit/second. 300 baud is equal to 300 bits/second and corresponds to an audio frequency of 150Hz. So what happens in this FSK system is that the transmitted digital data causes the modem to switch between the two designated frequencies, 1650Hz and 1850Hz, at a rate of 150Hz. The result is unholy bedlam and not fit to listen to – but it can make sense to another modem and computer!

Where serial ports (interface) are provided on personal computers they generally conform to one of three standards (as far as voltage levels and source and load impedances are concerned): RS-232, 20mA loop or TTL (ie, 5V logic levels). Naturally, our new modem is compatible with all of these.

(Some personal computers do not have a serial port, notably the Tandy TRS-80 and Dick Smith System-80. At some time in the next few months we shall feature a suitable adapter for these two computers, so that these too, can be used with a modem such as this.)



The component overlay diagram shows the modem wired for standard RS-232 operation. Provision has also been made for 20mA loop and TTL level interfaces.

WHAT IT LOOKS LIKE:

Our modem is designed to be easy to build as well as easy to use. This meant that we had to design metalwork which could be fabricated relatively easily while still producing a unit compatible with the "difficult" shape of a standard telephone handset.

Consequently, our modem has a simple U-shaped chassis and cover assembly which is held together with eight self-tapping screws. On top are two foam plastic pads, each with a circular cutout to closely fit the mouthpiece or earpiece of a standard telephone handset. Under each of these cutouts, mounted underneath a grille (or pattern of holes) is a miniature loudspeaker. One of these is used as a microphone, to "listen" to the telephone earpiece.

The other loudspeaker "drives" the telephone mouthpiece at loudness which, while it is unpleasant to the human ear, is adequate for reliable

How the circuit works . . . ctd from p63

As mentioned previously, we have incorporated 20mA loop and RS-232 serial interfaces. TTL-compatible input and output can be directly used as the receive/transmit signals or the serial interfaces can be used. The receive interfaces are directly connected to the TTL output from IC8. The transmit interfaces on the other hand need to be selected with the linking options shown.

Some explanation is necessary for the 20mA loop interface. We have provided for an opto-coupler in this circuitry, however, some computers with the 20mA loop interface will already have opto-couplers. In this case, the opto-couplers should be removed and the transmit/receive connections made to the Rx2 and Tx2 positions shown on the overlay.

Power supply for the modem uses a plugpack transformer to drive positive and negative half-wave rectifiers, D1 and D2, which feed 1000uF/25VW filter capacitors and thence positive and negative 5V regulators. The positive 5V regulator is a three-terminal regulator, LM340-T5 (or A7805) while the negative regulator, which supplies a very light load, is a 330 ohm resistor and 5.1V zener diode. The output from the half-wave rectifiers also provides nominal ±17V rails for the RS-232 interfaces.

transmission while not likely to overload the carbon microphone in the handset.

There are two switches, one for power and the other for transmit/receive selection. This latter function can be performed by the computer, provided there is a suitable "routine" in the program.

To be absolutely safe, the modem is powered by an approved (by the appropriate electricity authority) AC plugpack transformer. This eliminates all mains wiring from within the modem.

CONSTRUCTION:

We assume that most constructors will be able to obtain kits which include metalwork. For those who cannot or who wish to make up their own, we have provided a metalwork diagram. We dressed up our prototype which was made from sheet aluminium, with black contact vinyl and Scotchcal labels.

Start assembly of the PCB coded 80dm9 and measuring 170 x 95mm, by making sure all the holes are drilled and that all the tracks are properly etched and not bridging.

When mounting the components on the PCB, start with the small components such as resistors and links. Next, the ICs should be soldered in making sure that their orientation is correct. These should be soldered in a minimum of time with a fine tipped iron. The diodes can be placed in position with due care as to their orientation as well.

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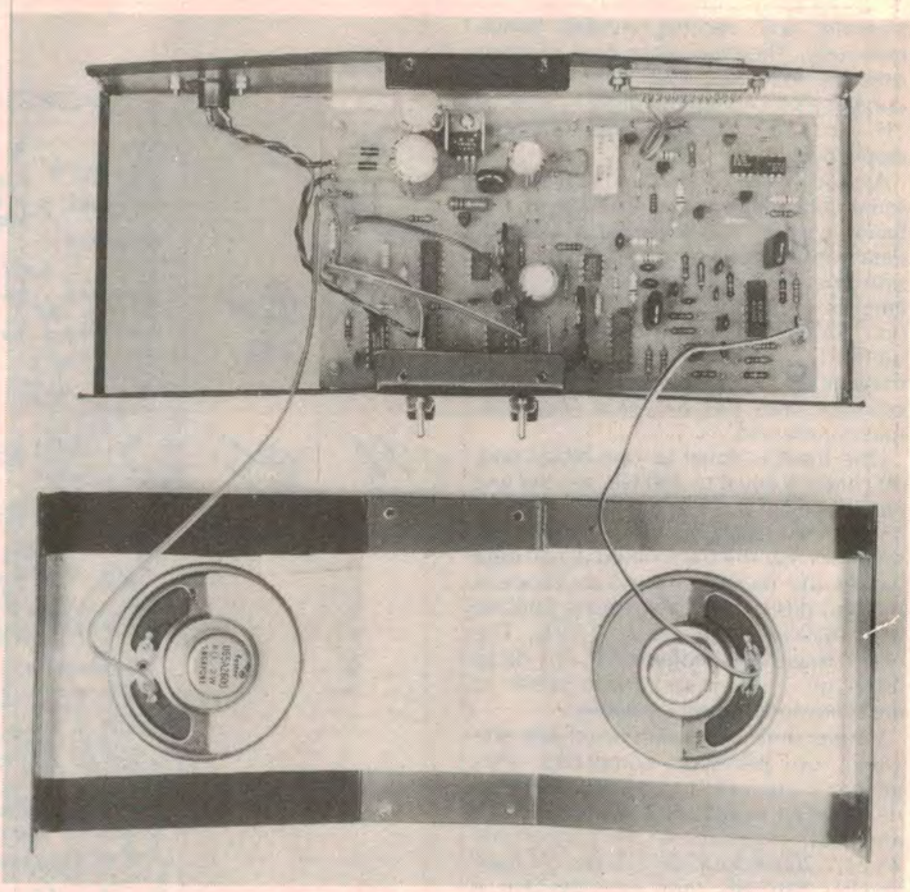


The PCB is mounted in the chassis using plastic snap-on board supports. Mains wiring within the modem is eliminated by use of an external 12VAC plugpack supply.

HERE IS THE PARTS LIST FOR THE MODEM

- 2 SPDT switches
- 2 57mm 8 ohm speakers
- 2 red LEDs and bezels
- 1 PC board, 170 x 95mm, coded 80dm9
- 1 DB-25S female panel mount socket
- 1 12VAC 500mA AC plugpack, Ferguson PPB 12/500
- 2 pads foam rubber 110 x 105 x 20mm thick
- 1 panel-mounting two-pin DIN socket
- 4 Richco plastic board supports
- 1 metal case (see text)
- 2 Scotchcal labels

SEMICONDUCTORS

- 2 7400 quad nand gates
- 1 7474 dual-D flipflop
- 2 555 Timers
- 1 4136 quad op. amp
- 1 741 op. amp.
- 1 565 phase-locked loop
- 1 LM340T5 5-volt regulator
- 2 1N4002 rectifier diodes
- 2 5.1 volt 400mW zener diodes
- 1 BC547, 548 NPN transistor
- 1 BC557 PNP transistor
- 1 BC327 PNP transistor

CAPACITORS

- 2 1000uF/25VW PC electrolytic
- 2 1000uF/10VW PC electrolytic
- 2 10uF/16VW tantalum
- 1 180pF ceramic
- 1 0.15uF greencap
- 2 0.1uF greencap
- 1 .015uF greencap
- 4 .018uF greencap
- 3 .01uF greencap
- 4 .0068uF greencap
- 1 .0047uF greencap
- 2 .0033uF greencap
- 1 .0012uF greencap
- 2 .001uF greencap

RESISTORS (¼W, 5% unless otherwise noted): 4 x 100k, 1 x 33k, 1 x 27k, 1 x 22k, 1 x 20k, 6 x 10k, 1 x 9.1k, 1 x 8.2k, 2 x 2.2k, 8 x 1k, 3 x 470 ohms, 1 x 330 ohms, 1 x 100 ohms, 1 x 68 ohms, 1 x 10 ohms, 1 x 10 ohms 2W, 1 x 4.7k vertical trimpot, 2 x 10k vertical trimpots.

INTERFACES

20mA loop:

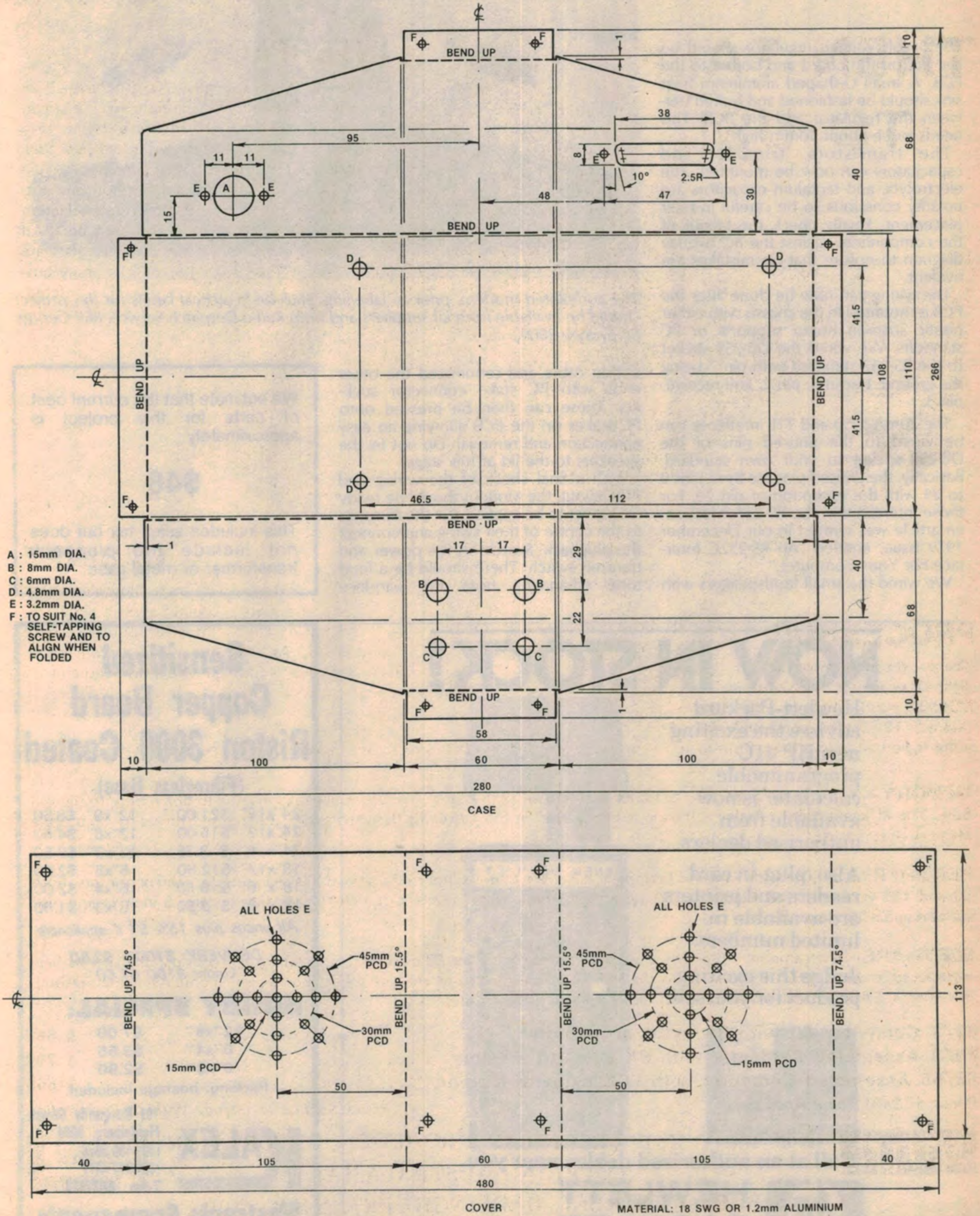
- 2 4N28, TIL116 optocoupler
- 2 BC547 NPN transistors
- 1 1N4148 diode
- 1 x 10k ¼W, 1 x 1k ¼W, 2 x 150 ohm ¼W.

RS-232:

- 2 BC547 NPN transistors
- 1 BC557 PNP transistor
- 1 1N4148 diode
- 1 .0022uF metallised polyester capacitor (greencap)

1 x 68k ¼W, 2 x 10k ¼W, 1 x 33k ¼W, 1 x 2.2k ¼W, 1 x 1.5k ¼W, 1 x 470 ohm 5W.

NOTE: Resistor wattage ratings and capacitor voltage ratings are those used for our prototype. Components with higher ratings may generally be used provided they are physically compatible.



This diagram is for readers who prefer to make their own metalwork. 18 SWG or 1.2mm aluminium is recommended.

Acoustic modem

The 5 volt voltage regulator should be laid flat on the board and bolted to the PCB. A small U-shaped aluminium heat sink should be fashioned and bolted between the regulator and the PCB. This needs to be about 10mm high.

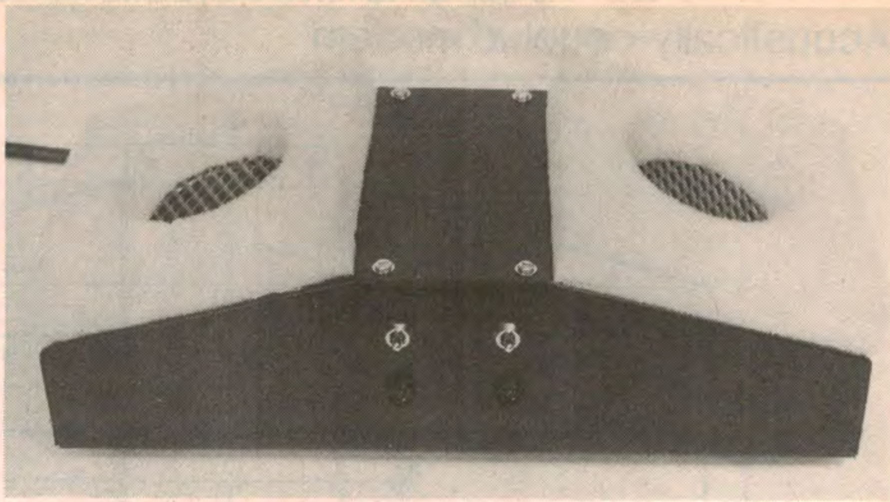
The transistors, trimpots and capacitators can now be mounted. The electrolytic and tantalum capacitors are polarity conscious so be careful in their placement. Finally check the layout of the components against the PC overlay diagram to ensure that no mistakes are evident.

The wiring can now be done after the PCB is mounted in the chassis with either plastic snap-on board supports or PC standoffs. We wired the DB-25S socket to the RS-232 standard with pin 7 being the ground; transmit, pin 2; and receive, pin 3.

The 20mA loop and TTL interfaces can be wired to the unused pins of the DB-25S socket to your own standard. Basically, the unused pins are from pins 9 to 25 with the exception of pin 20. For those interested in the RS-232 interface, an article was written in our December 1979 issue, entitled "An RS-232C Interface For Your Computer."

We wired the small loudspeakers with ribbon cable and terminated the other ends with PC stake connector sockets. These can then be pressed onto PC stakes on the PCB allowing an easy connection and removal. Do not fix the speakers to the lid at this stage.

With a final check of the wiring and PCB layout, the Modem should be ready for power to be applied. Set the trimpots to the centre of their swing and connect the plugback. Switch on the power and transmit switch. There should be a loud tone emanating from the earpiece

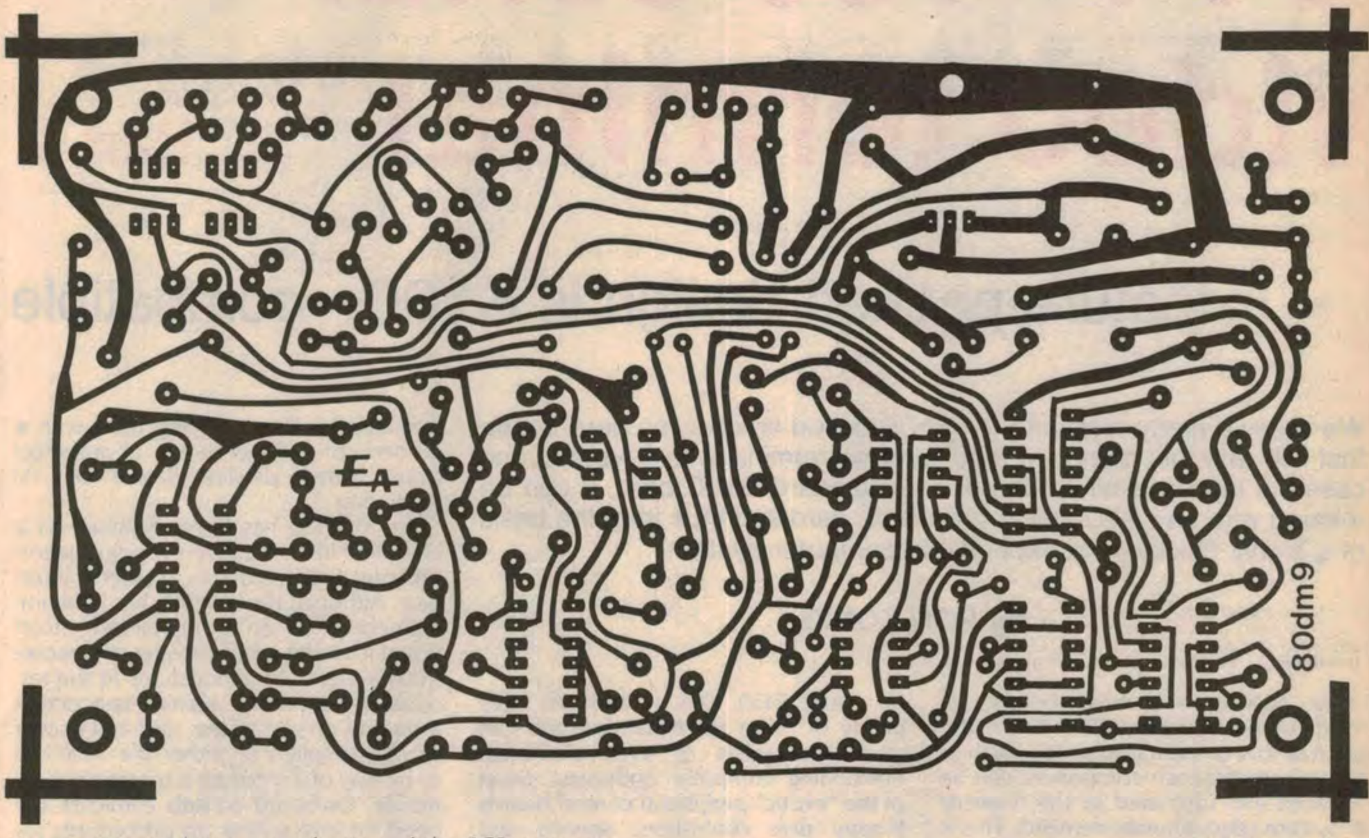


The completed modem, prior to labelling. Stick-on Scotchcal labels for this project should be available from kit suppliers and from Radio Despatch Service, 869 George St, Sydney 2000.

We estimate that the current cost of parts for this project is approximately

$48

This includes sales tax but does not include the plugpack transformer or metal case.



Here is an actual size reproduction of the PCB pattern.

loudspeaker. Check the power supply rails with a meter.

Setting up the modem can be done with a frequency meter or oscilloscope. Place the probe at pin 5 of IC3. Temporarily make the link for the RS-232 interface as shown on the component overlay. This will bring the transmitter input high. With the power applied and the transmit switch off (to stop the noise) read the frequency. The uppermost trimpot adjacent to the 555 timer is the one to adjust for a reading of 1650Hz. Now temporarily provide a link between the Gnd and the TTL transmit interface input. This will bring the transmitter input low. Adjust the lower pot adjacent to the 555 until a reading of 1850Hz is obtained.

The phase-locked loop can be adjusted by applying the probe to pins 4 and 5 of IC7, the 565. Remove the loudspeaker connected to the input of IC6 at the left hand side of the PCB. Adjust the frequency reading with the trimpot adjacent to the 565 until 1750Hz is obtained.

(Note that, ideally the above checks with a frequency meter must be performed in order that the modem be compatible with any other modem complying with the same standard).

Well that just about concludes the description of the Modem. All that is left to do is to fix the speakers to the lid with epoxy adhesive and to connect the link option for the RS-232 or 20mA interface and then begin transmission. The 565 may require fine adjustment when actually being driven from the computer to obtain a reliable transmission.

A CAUTION:

Although we believe that this modem will work satisfactorily over telephone lines, we must point out that the use of an unapproved device contravenes Telecom regulations. As far as we know, this modem could serve as the basis of a unit which could be submitted for approval by Telecom.

Telecom specifications state that for the most reliable operation of the carbon microphone in standard handsets, the microphone should lie at an angle to the horizontal, ie. not in the attitude it takes when used with our modem. Therefore, if used for longer than a few minutes (say, ten or more) it is possible that data transmission will become unreliable due to "packing" of the carbon microphone.

If this proves to be the case, one of two strategies could be used: (1) send data for short periods only; or (2) arrange for the modem to lie on its side, with a suitable cradle for the handset, so that the carbon microphone lies in an "ideal" attitude. We have not experienced any problems in our experiments.