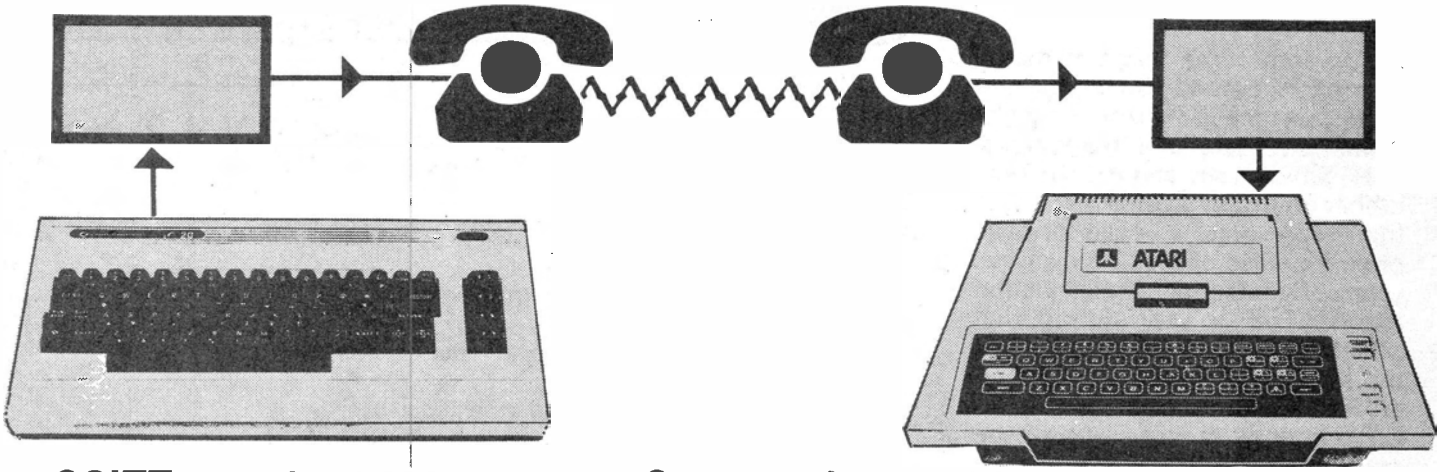
THE MAPLIN MODEM



★ **CCITT standard MODEM** ★ **Communicate with other computers**
★ **Easy-to-build** ★ **Exchange programs with other computer users**

by Harold Godwin

This modem will enable a home computer or VDU to communicate with other computers using CCITT standard tones, over the telephone. This means that you will be able to exchange programs with other people and in particular have direct access to the Maplin computer to order components etc. A modem works by converting the data input of marks and spaces, to two different audio frequencies. These audio tones are transmitted down the phone line to the other end where they are converted back to a digital signal by the modem.

So that data can be sent in both directions, four different frequencies are used, two for each direction. In order that two modems can communicate, one must be switched to the originate mode, which transmits 980 and 1180 Hz, and the other must be switched to the answer mode and transmits 1650 and 1850 Hz. Each modem receives the alternate pair of frequencies to those which it transmits.

The lower frequency is the mark condition in each case and it is usual for the terminal that makes the call to be switched to the originate mode. To prevent interference between the two directions of communication, filters are needed to pass the required frequencies in each direction. Although the frequency shift is only 200Hz, the required bandwidth of these filters depends upon the baud rate. At a baud rate of 300 baud and sending alternate marks and spaces, the first sidebands occur +/-150Hz from the carrier which is located midway between the mark and space frequencies. Therefore the minimum bandwidth for the filters is 300Hz.

Unfortunately a signal passing through a filter is delayed in time. All frequency components of the signal should be delayed equally, or jumbling and smearing of the data occurs. This is known as intersymbol or interbit interference. Minimising the delay distortion minimises the interbit interference. This is relatively easy over the centre 2/3 of the passband, but keeping the delay constant near the band edges is difficult, if not impossible to achieve. For this reason the bandwidth is widened. To maintain minimum delay at 300 baud requires an overall bandwidth of 400Hz. The overall performance of the modem is mainly dependant on the response of the filters, particularly the receive BPF (band pass filter).

Circuit

Two specialised IC's are used in this modem, the first is the 4412VP which is used to generate the required frequencies from a 1 MHz crystal. This IC is capable of transmitting American or CCITT standard frequencies, but pin 14 is earthed for the CCITT standard. The IC is switched between originate and answer by earthing pin 10 for the originate mode. The following pins are permanently earthed. Pin 15 which enables internal pull up resistors, reset pin 5, and pin 13 to inhibit a 2100 Hz tone which is normally transmitted for disabling line echo suppressors. Pin 12 is a carrier disable pin, no tone is

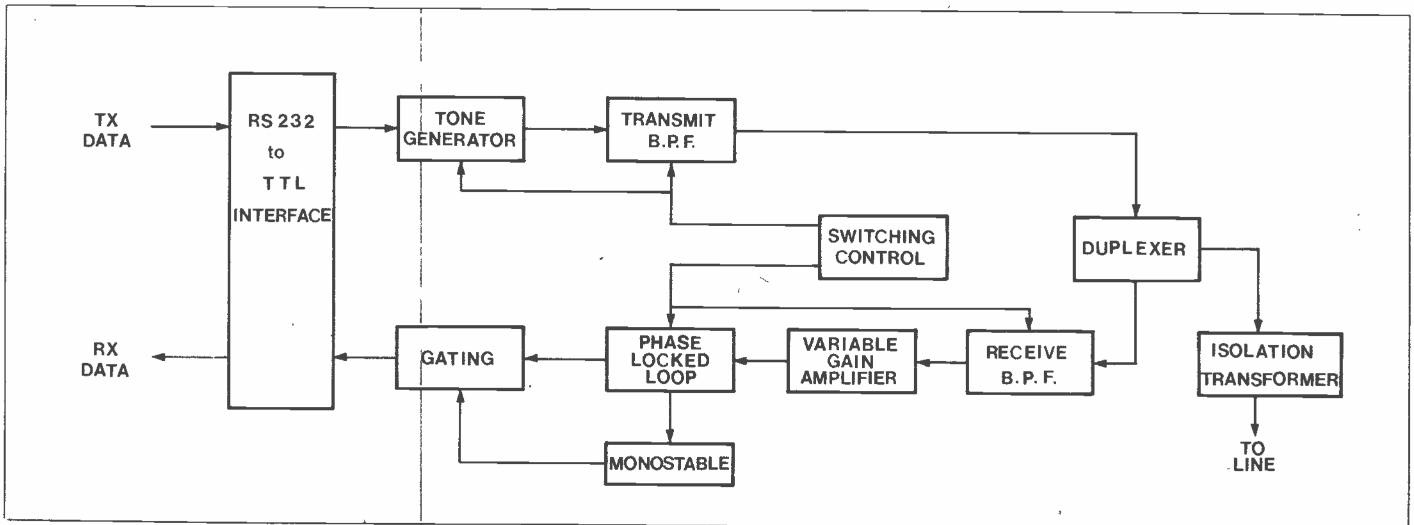
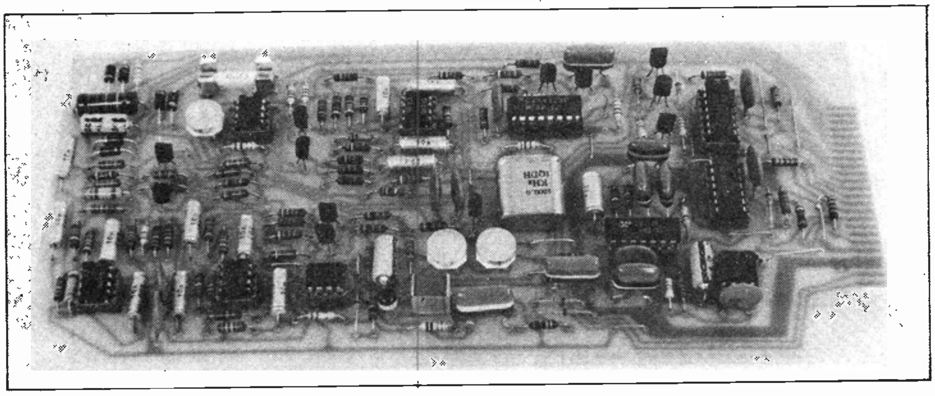
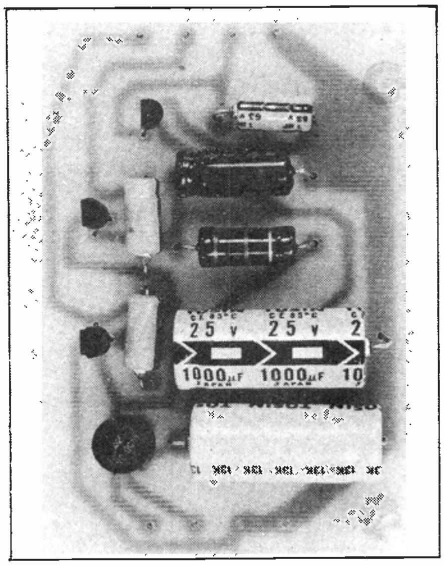


Figure 1. Modem block diagram



transmitted when this is earthed, but this facility is not used at present. Data is input to the IC on pin 11 and the audio tone is output on pin 9. The modulator output is an approximated stepped sinewave of 8 amptitude levels. Although each step is optimised so that the waveform has a maximum amount of signal energy at the fundamental frequency, a large number of harmonics are produced. For this reason, and to limit the transmitted bandwidth, the output is buffered by TR1 and passed through the transmit filter. The transmit filter, consisting if IC2 and associated components, is switched between originate and answer frequencies by TR3, 4, and TR1 switches the 4412VP.

There are two methods of connecting a modem to the phone system, acoustic coupling or direct electrical connection. Acoustic coupling has the advantage of being electrically isolated and easy to connect. However, there are problems, one is trying to exclude room noise, particularly if operating in a noisy environment. Another is the fact that the transmit tones will be heard in the telephone receiver considerably louder than the tones that are trying to be received. Although the receive filter would reduce this, there is a problem when operating in the originate mode. When transmitting a mark frequency of 980Hz, harmonic distortion (mainly from the carbon microphone of the handset) produces a second harmonic of 1960Hz. As this is close to the receive band of 1550 to 1950Hz, the receive filter provides little rejection and this interferes with the received signal. For these reasons it was decided to connect the modem to the phone line via a



British Telecom approved transformer.

Duplexer

The transmit filter output and receive filter input are connected to the line via a duplexer and isolation transformer. This allows the received signal to pass to the receive filter, properly couples the transmit signal to the line, terminates the line and attenuates the transmit signal appearing at the receive filter input. For maximum attenuation R16 = R17 and RV3 should equal the line impedance. RV3 is adjusted for maximum attenuation of the transmit signal. Although the line impedance is nominally 600 ohms, it will have a reactive as well as a resistive component. Therefore the duplexer should be considered as providing about 10db of attenuation, although in many cases better results will be obtained. D1 and D2 protect the modem from voltage surges from the line.

Receive filter

The receive filter consists of IC4, 5 and associated components. It is switched between the originate and answer frequencies by TR5 to TR8. It is an 8 pole Chebyshev filter and provides 35db of attenuation of the alternate channel. The overall gain of the filter is about 20db (less when receiving 1550 to 1950Hz). Close tolerance components are required for the filters and the resistor values are made up from two resistors in the majority of cases. IC6 is used as a variable gain amplifier to adjust for different receive levels. The output signal is rectified by D3 and used to control TR9 which acts as a variable impedance, adjusting the proportion of the output signal fed back to pin2. D4 and D5 limit the signal fed to IC7 to about 1.5V p to p.

Phase locked loop

Originally it was planned to use the demodulator section of the 4412VP to decode the received tones. Unfortunately the demodulator has been optimised for 200 baud when receiving CCITT tones, so in order to work at 300 baud it was decided to use an XR2211. This IC is a phase locked loop system especially designed for data communication. Referring to the block diagram for this IC, the input signal applied to pin 2 is amplified, limited and fed to the loop phase detector and quadrature detector. The output from the loop phase detector, at pin 11, is a DC voltage proportional to the phase difference between the VCO (voltage controlled oscillator) and the input signal. This voltage is filtered by C18, R46 and applied to pin 12 to control the VCO frequency. This locks the VCO onto the input signal and the control voltage at pin 11 is dependant on the incoming frequency over the tracking range of the VCO.

The control voltage is filtered by R45, C23 and compared with an internal reference voltage. As the input frequency changes the control voltage above and below the reference voltage, the data output on pin 7 changes. The reference voltage is decoupled by C22 on pin 10, and C19, R47, R48, RV1, RV2 determine the free running frequency of the VCO, which is set midway between the mark and space frequencies. The VCO frequency is switched between originate and answer mode by TR10.

The quadrature phase detector compares the VCO and the input frequency and ouputs a voltage when the VCO is locked to the input frequency. This voltage is filtered and drives the lock detect outputs. IC8 is a monostable which drives the lock detect LED and is gated with the data output from IC7. This allows data to be received only while the VCO is in lock and prevents spurious data filling the screen when there is no input signal.

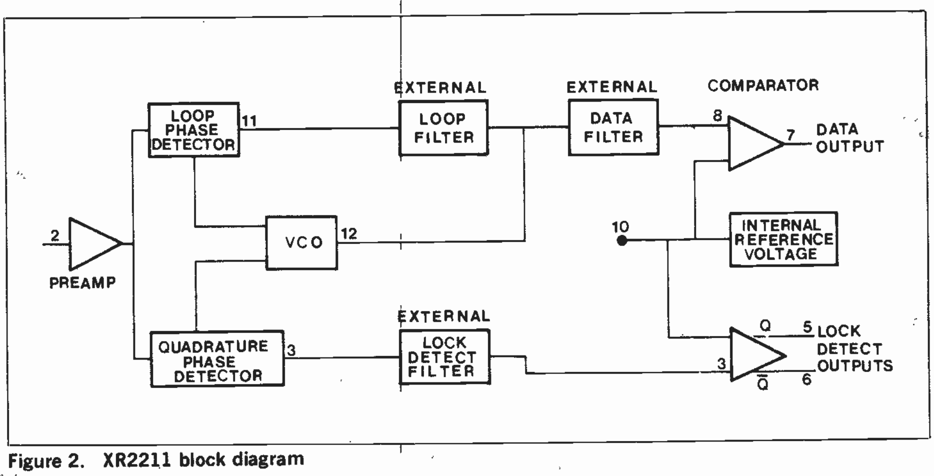


Figure 2. XR2211 block diagram

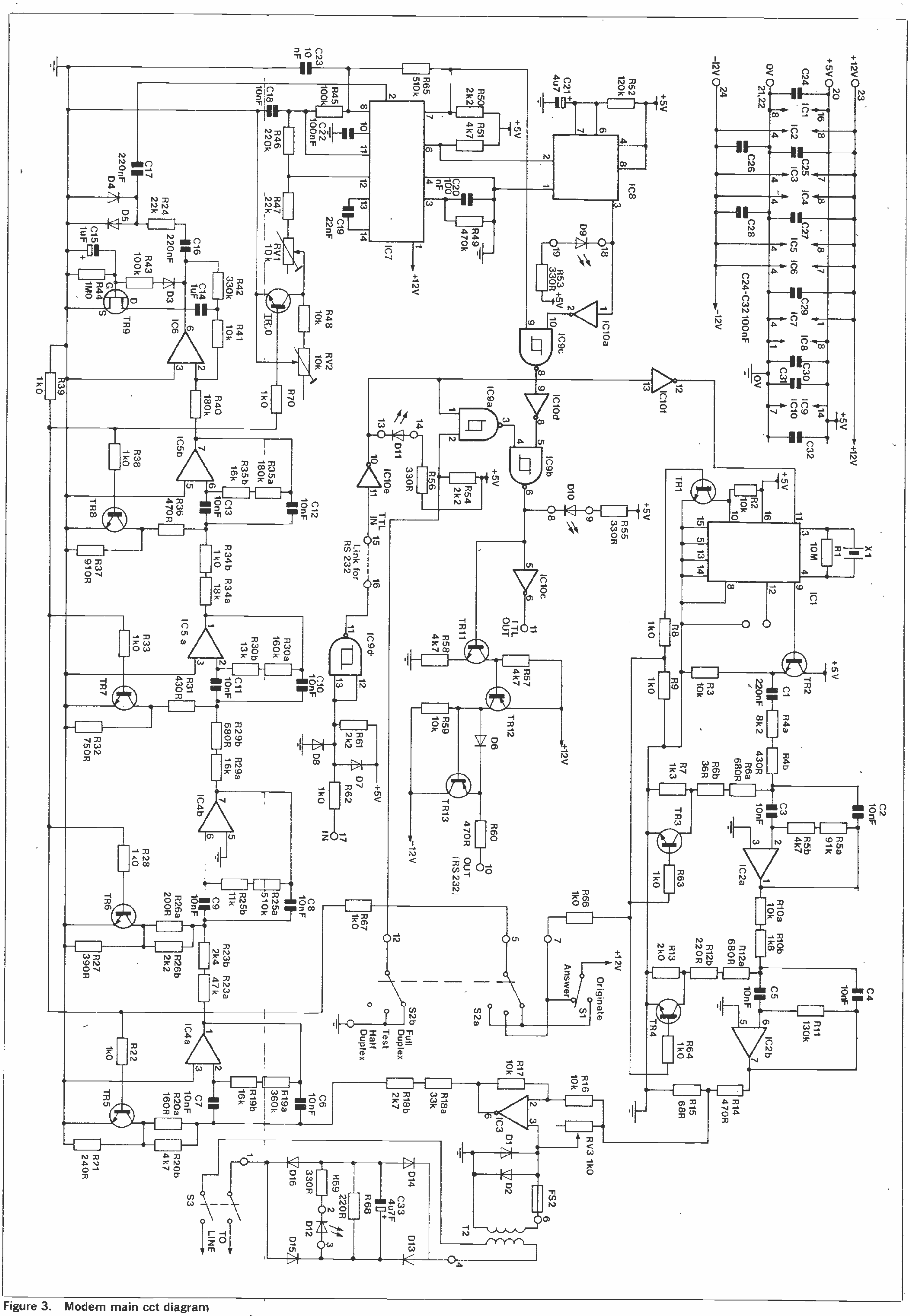
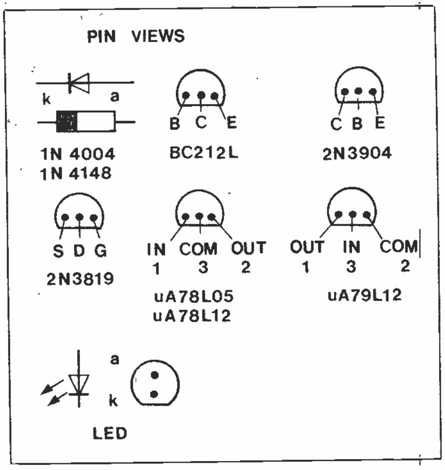


Figure 3. Modem main cct diagram



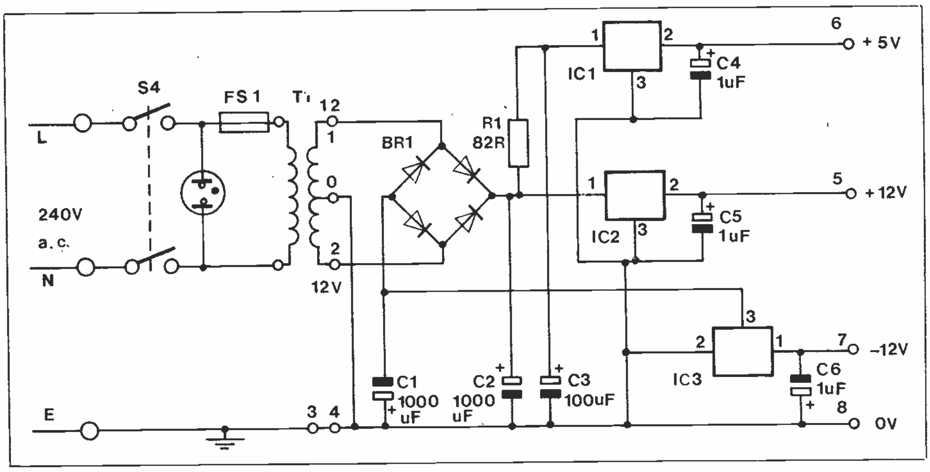


Figure 4. PSU circuit diagram

S1 switches the modem between originate and answer modes, and S2 switches between full-duplex, half-duplex and test positions. Full-duplex working allows data to be sent in both directions at the same time. Normally this means that the data received at the far end is sent back to the sender on the alternate channel. This is displayed on the senders terminal so that it can be seen exactly what was received at the far end. If the data is not echoed back, the modem can be switched to half duplex. This connects the transmit data via IC9a to the receive direction so that the transmitted data is displayed as well as that received. Obviously data cannot be sent in both directions at the same time as garbled information would be displayed. Note also that a mark condition must be received from the other end to allow the local data to be received via IC9b. The test position switches the BPF and IC7 to receive the same frequencies that are being transmitted locally. This allows the modem to be checked in local via the duplexer. This position could also be used to monitor a simplex transmission, when no signal is being received from the other end. D10 and D11 monitor the receive and transmit data respectively and are lit for a mark condition. IC10c drives the TTL output and TR11 to TR13 convert TTL levels to RS232 interface voltages of +/-12V. At the transmit side D7 and D8 limit the RS232 voltages and IC9d gives TTL level out. The strap must be connected if the RS232 input is used, otherwise IC10 pin 11 is the TTL input. The power supplies of +5V, +12V and -12V are supplied by the three low power regulators and associated components. R1 reduces the power dissipation in the +5V regulator.

Construction

There are two PCB's to be assembled, the main modem board and the power supply unit. These are printed with the component overlay to make assembly easier. Starting with the modem board, the resistors should be fitted first. It is suggested that the values are checked against the circuit diagram, as a wrong value in the filters would affect the response and would be difficult to find. Next the capacitors should be fitted, checking that C15, C21 and C33 are the correct way round.

It is recommended that IC holders are used and these are fitted next, but the IC's not yet inserted. The leads to the 1MHz crystal are bent so that the crystal lies flat against the PCB. The transistors and diodes are fitted next, checking that they are the correct type and the correct orientation. This leaves just the potentiometers, fuseholder and wire links to be fitted as shown on the legend. The power supply board is assembled in the same way, following the PCB legend.

A suitable case should be chosen from the wide range available that can take the two PCB's and transformers. The front panel should be drilled for the four LED's and switches. The fuse FS1 could be mounted on the front panel or at the back as desired. The 2 transformers should be mounted apart from each other to avoid mains hum. Two connecting sockets will be required to connect to the line and the computer. These are left for the constructor to choose.

The modem PCB plugs into a 24 way connector and is wired up as shown in fig. 5. Lengths of sleeving should be used over the socket connections to prevent short circuits. It is important that the feet are the correct way round, to prevent the PCB being plugged in the wrong way. When the wiring has been completed, the fuses can be inserted and the modem powered up without the IC's in. The power supply voltages should be checked to each IC socket and if correct, the modem switched off. Allow a few minutes for the capacitors to discharge and then insert the IC's and the modem can be tested.

Setting up and Using the System

The modem can be used with any computer that has a RS232 serial interface or the TTL inputs can be connected direct to a UART, if this is available, as on the Maplin VDU. Only 3 wires are needed between the computer and the modem, Tx, Rx data and 0 volts. If using the TTL inputs, these should be kept reasonably short. With S3 unoperated, connect the 2 line connections across the phone line. Normally there are 3 wires from the phone that connect to a terminal block on the wall. The line wires are the Red and the White.

The modem is most easily set up with an oscilloscope as follows. All signals are measured as peak to peak

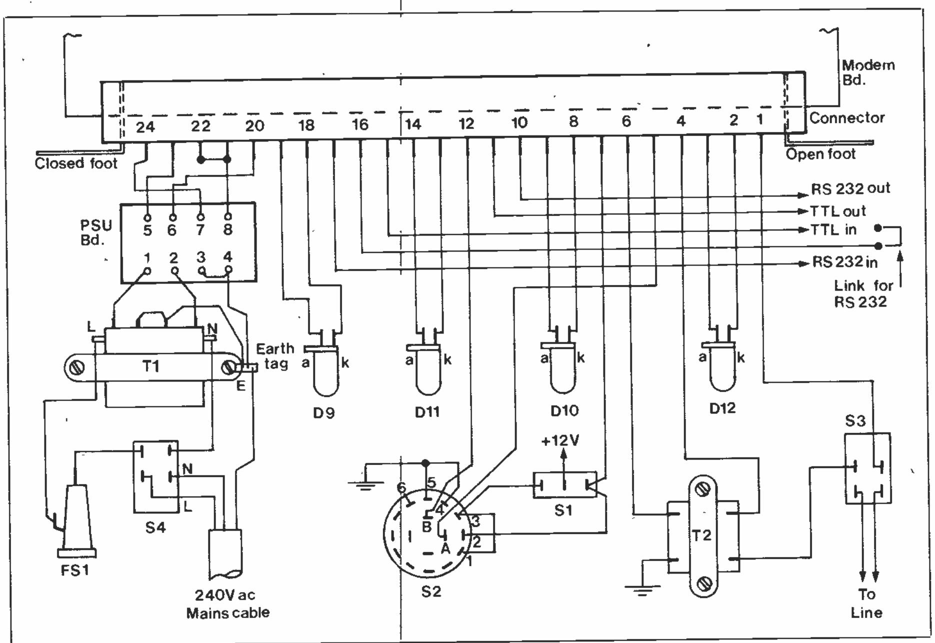


Figure 5. Wiring diagram.

voltages. The signal at TR1 emitter should be a stepped sinewave of 800 mv. The frequency should change if S1 is operated and if the data input is changed. Check the level at IC2B, pin 7. This should be about 8V when S1 is switched to originate, and 6V for answer mode. Dial a '1' from the phone to clear dialtone, operate S3, replace the handset, and D12 should light, showing that the phone line is being held by the modem. Note that no calls can be received while S3 is operated. People ringing the number will get engaged tone. Switch to originate mode and S2 to test. Measure the signal at IC5B pin 7 and adjust RV3 for a minimum signal at this point. Check the signal level at IC3 pin 3 to be around 500mv p to p. Restore S3 to normal and D12 should darken. IC7 has to be adjusted so that the free running frequency is midway between the mark and space frequencies. The easiest method is as follows. Switch to answer mode and test position, sending alternate marks and spaces, adjust RV1 for equal mark-space ratio at IC7 pin 7. Switch to originate mode and adjust RV2 for equal mark-space ratio. Note RV1 must be adjusted before RV2, as RV2 setting is dependant on RV1. Alternate marks and spaces can be sent by sending the ASCII code for 'U' continuously. The repeat key can be used on a VDU or a short program written for the computer that puts the computer in a loop and outputs ASC(U) to the serial port. The modem is now set up and is used as follows. With S3 normal and D12 unlit, dial the number required. When the number is answered, you must decide which end will be in the originate mode and whether half or full duplex working will be used. Switch the modems accordingly and operate S3 at both ends. The handsets can now be replaced at each end and data sent in each direction. The carrier lock LED will light when the tone is received from the other end and the receive data LED shows the data received. When you have finished, S3 must be restored to normal to clear down the call. When calling a British Telecom modem with automatic answer-in, the call will be answered after a few rings and then 1650Hz will be sent. Your modem should be switched to originate and a mark sent back within about 10 seconds or else the modem at the far end will clear down and you will have to call again. Normally when your mark is received, a signing on message is sent giving instructions on using the system.

PARTS LIST FOR MODEM MAIN PCB

Resistors - All 0.4W 1% carbon unless specified

R1	10M		(M10M)
R2, 3, 10a, 16, 17, 41, 48, 59	10k	8 off	(M10K)
R4a	8k2		(M8K2)
R4b, 31	430R	2 off	(M430R)
R5a	91k		(M91K)
R5b, 20b, 51, 57, 58	4k7	5 off	(M4K7)
R6a, 12a, 29b	680R	3 off	(M680R)
R6b	36R		(M36R)
R7	1k3		(M1K3)
R8, 9, 28, 33, 34b, 38, 39, 62, 63, 64, 70, 22, 66, 67	1k0	14 off	(M1K0)
R10b	1k8		(M1K8)
R11	130k		(M130K)
R12b	220R		(M220R)
R13	2k0		(M2K0)
R14, 36a, 60	470R	3 off	(M470R)
R15	68R		(M68R)
R18a	33k		(M33K)
R18b	2k7		(M2K7)
R19a	360k		(M360K)
R19b, 29a, 35b	16k	3 off	(M16K)
R20a	160R		(M160R)
R21	240R		(M240R)
R23a	47k		(M47K)
R23b	2k4		(M2K4)
R24, 47	22k	2 off	(M22K)
R25a, 65	510k	2 off	(M510K)
R25b	11k		(M11K)
R26a	200R		(M200R)
R26b, 50, 54, 61	2k2	4 off	(M2K2)
R27	390R		(M390R)
R30a	160k		(M160K)
R30b	13k		(M13K)
R32	750R		(M750R)
R34a	18k		(M18K)
R35a, 40	180k	2 off	(M180K)
R37	910R		(M910R)
R42	330K		(M330K)
R43, 45	100k	2 off	(M100K)
R44	1M0		(M1M0)
R46	220k		(M220K)
R49	470k		(M470K)
R52	120k		(M120K)
R53, 55, 56	330R	3 off	(M330R)
R68	220R 1W 5% carbon		(C220R)
R69	330R ½W 5% carbon		(S330R)
RV1, 2	10k cermet	2 off	(WR42V)
RV3	1k0 cermet		(WR40T)

Capacitors

C1, 16, 17	220nF polyester	3 off	(BX78K)
C2-13	10nF polystyrene 1%	12 off	(BX86T)
C14	1uF polycarbonate		(WW53H)
C15	1uF 63V electrolytic axial		(FB12N)
C18, 23	10nF polyester	2 off	(BX70M)
C19	22nF polystyrene 1%		(BX87U)
C20, 22	100nF polester	2 off	(BX76H)
C21, 33	4 7 63V electrolytic axial	2 off	(FB18U)
C24-32	100nF ceramic disc	9 off	(BX03D)

Semiconductors

D1, 2, 13-16	1N4004	6 off	(QL76H)
D3-8	1N4148	6 off	(QL80B)
TR1-8, 10, 11	2N3904	10 off	(QR40T)
TR9	2N3819		(QR36P)
TR12, 13	BC212L	2 off	(QB60Q)
IC1	4412VP		(QQ39N)
IC2, 4, 5	1458	3 off	(QH46A)
IC3, 6	uA 741 8 pin	2 off	(QL22Y)
IC7	XR2211CP		(QY43W)
IC8	NE555		(QH66W)
IC9	74132		(WH03D)
IC10	7404		(QX40T)

Miscellaneous

	PC board		(GB09K)
X1	1MHz MP crystal		(FY79L)
	Veropin 2141	1 pkt	(FL21X)
	Fuse clips	2 off	(WH49D)
FS2	Fuse 20mm 250mA		(WR01B)

POWER SUPPLY

Resistors

R1	82R 1W 5% carbon film		C82R

Capacitors

C1, 2	1000uF 25V elect. axial	2 off	(FB83E)
C3	100uF 25V elect. axial		(FB49D)
C4, 5, 6	1uF 63V elect. axial	3 off	(FB12N)

Semiconductors

IC1	uA78L05		(QL26D)
IC2	uA78L12		(WQ77J)
IC3	uA79L12		(WQ86T)
BR1	W005		(QL37S)

Miscellaneous

	PC board		(GB10L)
	Veropin 2141	1 Pkt	(FL21X)

ADDITIONAL PARTS REQUIRED

S1	Switch (Sub. Min Toggle A) SPST		(FH00A)
S2	Switch rotary 3B (BBM)		(FF76H)
S3	Switch (Sub. Min. Toggle E) DPDT		(FH04E)
S4	Switch dual rocker neon		(YR70M)
	Safuseholder 20		(RX96E)
FS1	Fuse 20mm 1A		(WR03D)
T1	Transformer		(WB10L)
T2	Transformer (Line Isolating)		(BK57M)
D9, 10, 11, 12	LED red	4 off	(WL27E)
	LED clip	4 off	(YY40T)
	Edge conn. 124		(FL85G)
	Edge conn. G		(FL91Y)
	Edge Conn. H		(FL92A)

A complete kit of parts is available for this project.
Order As LW99H (Modem Kit). Price £39.95.