POWER LINE MODEM

The NE5050 from Philips Components has been designed for sending and receiving data over the AC mains network, coaxial cables or twisted-pair cables. The modem described here is a mains-based application of the NE5050. It works in conjunction with an error-correcting computer program for exchanging data or remote control of equipment.

by J. Bareford

A modem (acronym for MOdulator/DEModulator) is almost invariably used where the distance between computers, or a computer and peripheral equipment, exceeds the capabilities of the well-known RS-232 interface with associated cables. In practice, this means that some sort of modem is necessary when the data rate and distance exceed 1200 baud and about 30 metres respectively. In most cases, the modem is located physically close to the computer or peripheral (sometimes it is internal to it). Modems generally use frequency-shift-keying (FSK) of a carrier to convert the logic levels received from the computer's RS-232 outlet into tones that can be carried over, say, the telephone network. In receive mode, the tones from the modem at the other end of the line are demodulated and converted to RS-232 levels for sending to the computer.

The present modem does not use FSK, but ASK (amplitude shift keying) for reasons discussed below. Similar to certain types of intercom, the NE5050-based modem is connected to the remote station via the mains network.

Background to amplitude shift keying

The mains network is by no means ideal for data communication. Impulse noise, voltage dips, line impedance modulation and high-frequency signals are but a few of the sources of interference to be taken into account. Improperly decoupled fluorescent tubes, dimmers, refrigerators and washing machines are notorious for the high levels of 'mains pollution' they cause.

Clearly, the design of a practical mains modem should anticipate high levels of interference and possible corruption of data owing to the above appliances.

In radio technology, it has been known for almost 100 years that CW (*continuous wave* or modulation type A1), or simply switching the transmitter on and off, is the simplest, yet most interference-resistent, modulation method available. Figure 1 shows how CW is used by the present modem — a 120 kHz carrier is generated and digital input data determines when the carrier is to be superimposed on to the mains lines. Collision, or more precisely *summing* of data, however, occurs when two modems connected to the network

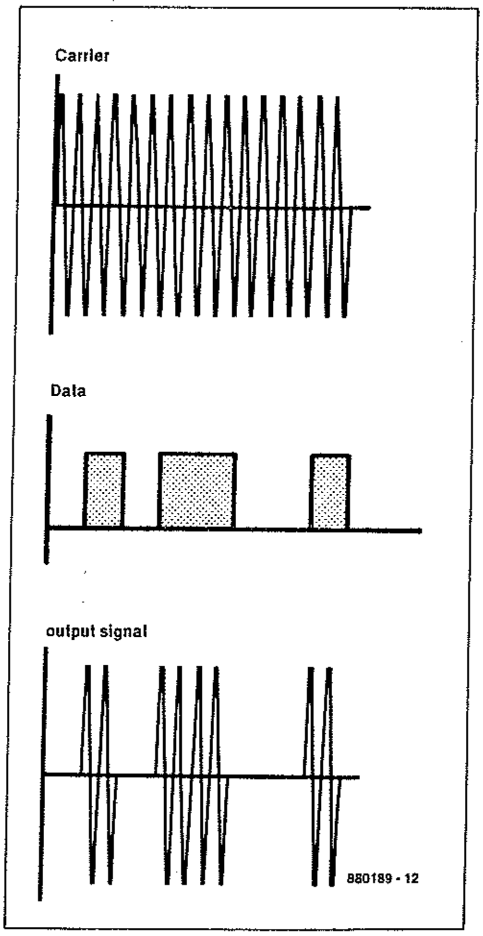


Fig. 1. The modem uses amplitude-shift keying (ASK) for sending data via the mains network.

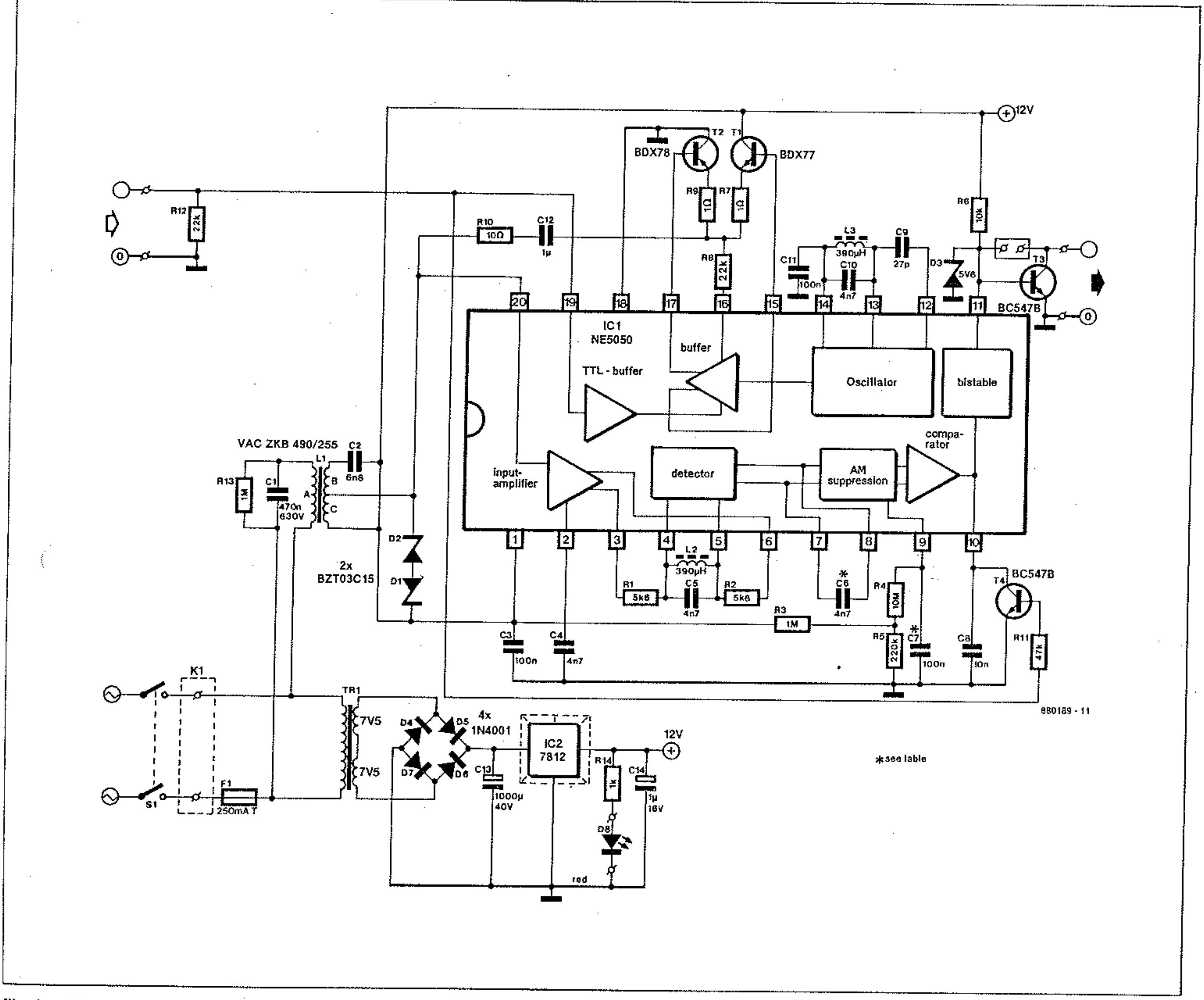


Fig. 2. Circuit diagram of the power-line modem.

trans… simultaneously. Thanks to the use of ASK, this only leads to distortion of data, not to overloading of the modem input. By setting up an error-detecting data exchange protocol in the computer, messages between modems can be repeated until they are correctly received. The use of a communications program on the computer for combatting data collision and interference simplifies the modem hardware considerably, and at the same time makes it virtually computer-independent.

An integrated modem

Apart from the electrical connection and the component values, the circuit diagram of Fig. 2 shows the internal structure of the central part, the NE5050 in position IC_1.

The transmitter in the modem chip is composed of a carrier oscillator, a TTL buffer/input amplifier, and a line driver that also functions as the amplitude-modulator. External components C_9, C_{10} and L_3 tune the oscillator to 120 kHz. Capacitor C_{11} does not form part of the tuned circuit, but serves to decouple the internally generated supply voltage of ½U_b which is used for biasing the oscillator. The generated carrier is applied to the line driver in which amplitude modulation takes place. The carrier is modulated by the data signal applied to pin 19 of the chip. Together with T_1, T_2, R_7, R_8 and R_9, the driver forms a class-AB output stage that gives the ASK signal enough power to be superimposed on to the mains lines. For reasons of safety, this is done with the aid of a double-insulated line transformer with a turns ratio L_{1a}:L_{1b}:L_{1c}=1:4:1. A number of components with specific functions are arranged around this transformer. C_{12} and R_{10} ensure a sufficiently high termination impedance for the line driver. C_1 suppresses the mains frequency (50 or 60 Hz), and D_1 and D_2 have the double function of transient suppressor and limiter for the received 120 kHz signal. Under no conditions should the indicated diodes be replaced by common zener diodes which these are far too slow in this application, and, therefore, unable to protect the mains modem chip from damage by voltage surges.

The input of the modem, pin 20, normally receives not only the signals from

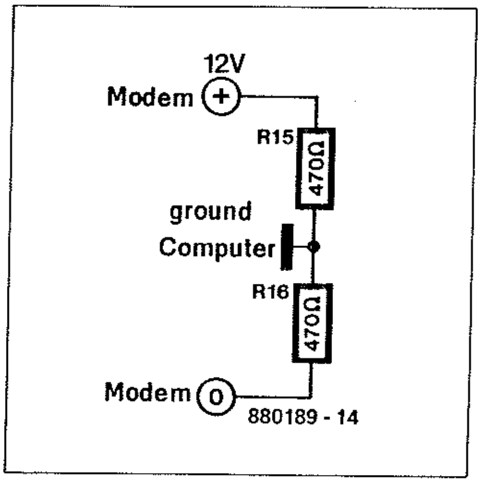


Fig. 3. Simple extension of the modem interface to enable connection to an RS-232 outlet.

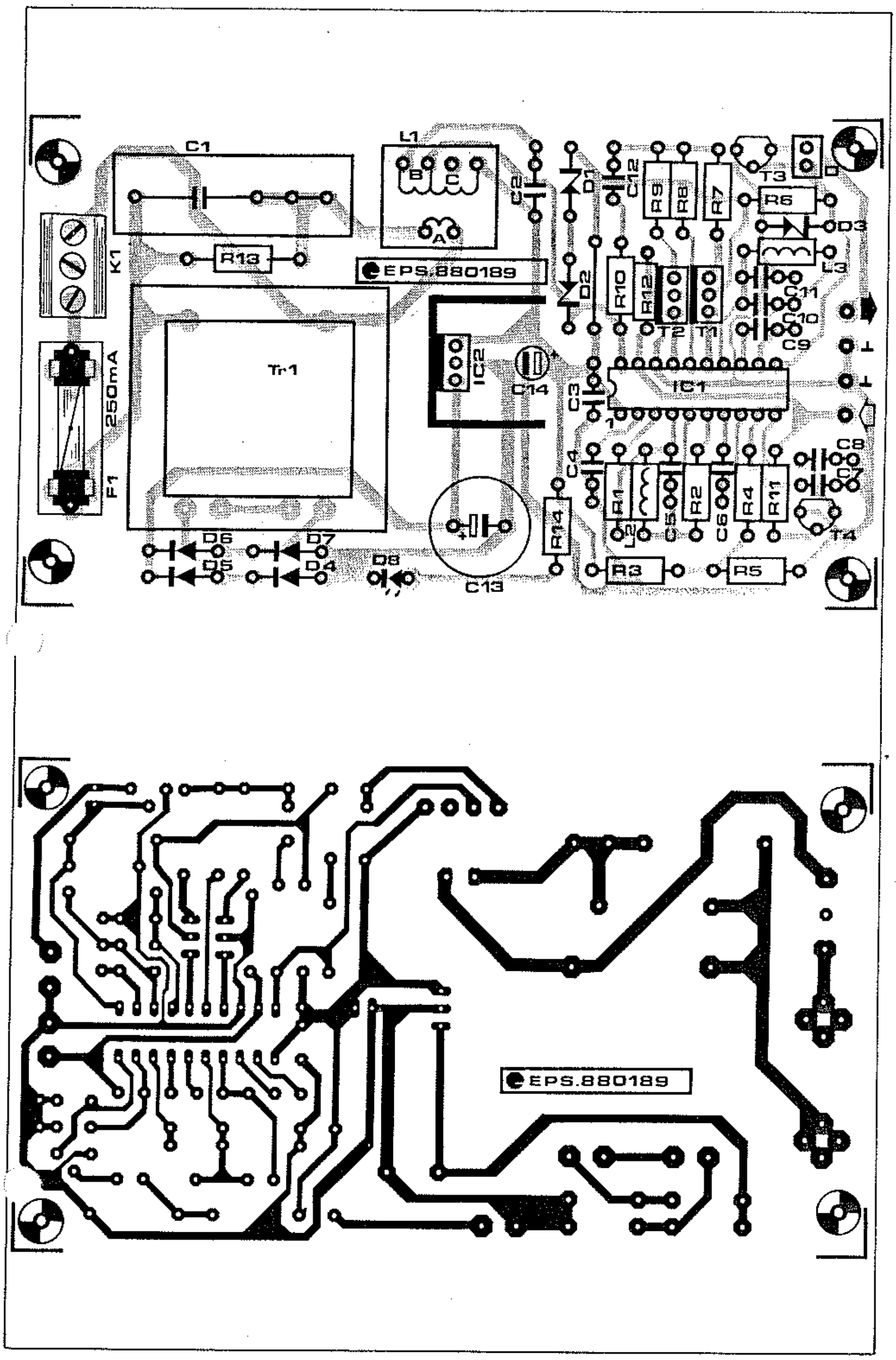


Fig. 4. Printed-circuit board for the mains modem.

Parts list

Resistors (±5%):
R_1;R_2=5K6
R_3;R_{13}=1M0
R_4=10M
R_5=220K
R_6=10K
R_7;R_9=1R0
R_8;R_{12}=22K
R_{10}=10R
R_{11}=47K
R_{14}=1K0

Capacitors:
C_1=470n; 630 V
C_2=6n8
C_3;C_7;C_{11}=100n
C_4;C_5;C_6;C_{10}=4n7
C_8=10n
C_9=27p
C_{12}=1µ0
C_{13}=1000µ; 40 V; radial
C_{14}=1µ0; 16 V; radial

Semiconductors:
D_1;D_2=BZT03C15⁺ (Philips Components)
D_3= 5V6; 400 mW zener diode
D_4. . .D_7 incl.=1N4001
D_8= red LED
T_1=BDX77⁺
T_2=BDX78⁺
T_3;T_4=BC547B
IC_1=NE5050⁺ (Philips Components)
IC_2=7812

⁺ Listed by Universal Semiconductor Devices Ltd.

Miscellaneous:
L_1= VAC ZKB 490/255 (VAC Vacuumschmelze GmbH • Werk Hanau • Grüner Weg 37 • 6450 Hanau 1 • West-Germany. Tel. +49 6181 362-1; telex 4184863; fax +49 6181 362645).
L_2;L_3=390µH
S_1= double-pole on/off switch.
F_1= 250 mA delayed action fuse with PCB-mount holder.
Tr_1= PCB mount transformer; 3 VA; 2×7.5 V @ 200 mA.
K_1= 3-way PCB-mount terminal block.
Heat-sink for IC_2.
Moulded ABS enclosure, e.g. Bopla E440, or OKW A9030065.
PCB Type 880189 (see Readers Services page).

other modems, but also its own transmitted signal. In the present application, the receiver is, however, disabled while the modem is in transmit mode. This is achieved by having the transmit input drive T_4. When this is turned on, it pulls the comparator output, pin 10, low, so that the bistable can not change state. When the data input line is low, no carrier is transmitted.

The received signal is first applied to an amplifier provided with a band-pass characteristic. The high-frequency roll-off point is internally set to 300 kHz. Dimensioning C_4 allows defining the lower roll-off point in accordance wit the carrier frequency used. To ensure selectivity at the carrier frequency, a band-filter, L_2-C_5, is inserted between the input amplifier and the detector. C_6 and components internal to the detector create a low-pass filter for shaping and cleaning the digital pulses. This filter not only suppresses high-frequency signals, but also sets the maximum data rate — in this case, to 1 Kbit/s. Background signals at the mains frequency are rejected by the AM-suppressor. This works by storage of the average direct voltage level in C_7. When no input signal is available for more than 4 s, the voltage on C_7 would rise slowly to a value that results in a logic high level at the output. This is prevented by R_1, R_4 and R_5.

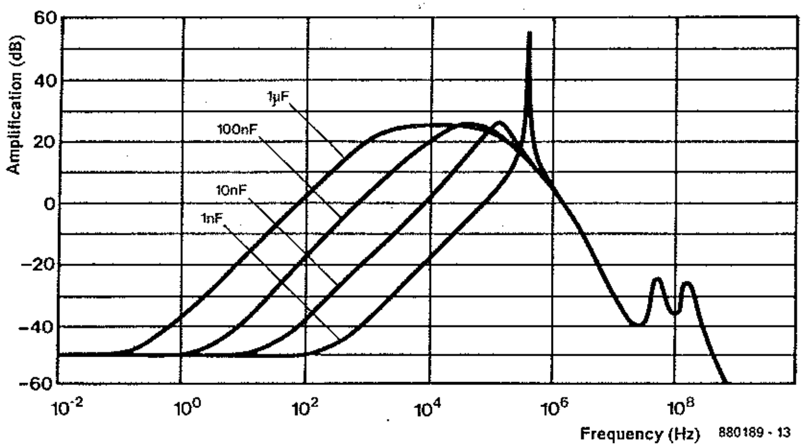
The comparator, in combination with C_8, cleans the detected pulses, whose edges are straightened again by the inter-

Table 1.

Interface configuration options

Component	TTL	HOMENET	RS-232
D_3	1	0	0
T_3	0	1	0
J_1	1	0	1

1 = fit component
1 = omit component



Fi[illegible] Receiver amplifier gain vs frequency for different values of the high-pass capacitor.

nal bistable. This has an open-collector output that drives a simple computer interface set up around T_3. Table 1 lists the possibilities of configuring this interface in accordance with three interfacing standards. Since an RS-232 interface works with positive and negative voltage levels, the interface should be extended as shown in Fig. 3. R_{15} and R_{16} simply raise the ground potential of the interface to half the supply voltage of the modem. This results in the circuit driving the RS-232 interface in the computer with a voltage swing of ±6 V, which is adequate for correct operation in most cases. Ground of the circuit is, therefore, **not** ground of the RS-232 interface. One additional resistor, R_{17}, is needed to protect the data input of the modem against the voltage levels of up to ±12 V supplied by the computer's RS-232 driver.

Noise suppression by the modem can be improved by increasing the value of C_6 and C_8 to 10 nF and 100 nF respectively. This measure effectively results in a lower bit-rate of 300 per second, but speed up communication between modems since less information needs to be sent back and forth on account of corrupted data. Finally, some experimenting may be required with the value of C_4 — a lower value results in a narrower bandwidth of the input amplifier. Possible capacitor values lie between 470 pF and 1 nF.

Construction: safety first

For your own safety, the power line modem must never be constructed on a printed circuit board other than the one shown in Fig. 4.
Completion of the board with reference to the parts list is not expected to cause difficulty. The unit is fitted in an ABS enclosure provide with a grommet and a strain-relief clamp for the mains cord. The connector or socket for the bidirectional serial link to the computer should be located as close as possible to the rfelevant connections on the printed circuit board, so that the wires can be kept as short as possible.

One adjustment

To begin with, the data input of the modem should be held at about +5 V. This is easiest done by connecting a 27 kΩ resistor between the input and the +12 V line in the modem. Never apply power until a thorough check of the completed board, and the way it is connected to the mains, has been made.
Power up and use an oscilloscope to inspect the waveform at pin 20 of IC_1. Adjust the core in L_1 for maximum amplitude of the carrier. When an oscilloscope is not available, an analogue voltmeter may be used instead, but only if this is known to be able to work at 120 kHz in the alternating voltage range.

Sending and resending packets: enter Kermit

As already hinted at, reliable data communication with the modem can only be achieved when the computers at both ends run a communications program capable of error detection and correction. Owners of the Commodore C64 computer are advised to use General Electric's excellent program HOMENET.
The prototype of the power line modem was tested under control of the PC communications package PROCOMM version 2.4.2, whose capabilities are outstanding considering the cost. PROCOMM is set to the Kermit mode with the following line settings (ALT-P; option 7): 8 data bits; 1 stop bit, no parity; 300 baud; half-duplex and a time-out of 999 ms. In Kermit mode, PROCOMM allows the user to define the packet size. Initially, go to the Kermit setup menu, and select a small packet size to keep resending time low.
The Kermit protocol works basically as follows. The first packet sent by the computer is accompanied by a CRC byte (CRC = *cyclic redundancy check*). The CRC byte generally provides better results than a *checksum* by virtue of a different method of calculation: the checksum is obtained by addition, the CRC by division. After reception of the data in the remote computer, the CRC is checked, and a message is returned to indicate whether or not the packet has to be resent. This process is repeated, if necessary, until correct data has been received.

Once the maximum feasible parameters for data communication with the aid of the Kermit protocol are known with both modem stations, the chat mode in PROCOMM can be selected for on-line communication between connected PC stations.

HOMENET is a registered trademark of the General Electric Corporation. The HOMENET communications package for C64 computers may be obtained by contacting The Industry Standards Staff, General Electric Corporation, Fairfield CT 06431, U.S.A. Reference: Philips Components AN1951.

Procomm is a registered trademark of Datastorm Technologies Inc., P.O. box 1471, Columbia MO 65205, U.S.A. The latest version of Procomm is stated to cost US $35.00 including disk. Datastorm's auto-answer BBS service can be contacted 24 hours a day and 7 days a week on telephone number USA 314 449-9401.

Note: in Philips Components' *Application Note AN1951* on the NE5050, a line transformer identified as TOKO AMERICA #707VX-T1002N is recommended for 110 V mains networks.

Readers are advised that Mains Signalling in the UK is subject to the provisions of British Standards BS6839. Further information on the subject may be obtained from BIMSA (BEAMA Interactive and Mains Systems Association), Leicester House, 8 Leicester Street, LONDON WC2H 7BN, telephone 01-437 0678.