The Acorn Econet

The low-cost system for interconnecting computers and their peripherals

FILE STATION

STATION 1   STATION 2   STATION 3   STATION 4   STATION 5   STATION 6
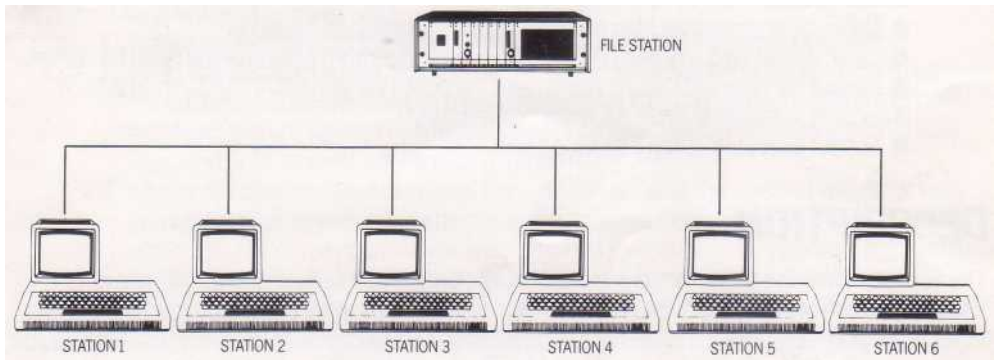
"To *our* knowledge the Econet is by far the lowest cost *network* available *in the world*

A ten station network with 400K byte file station costs around £3,000 and as little as £50 for each additional station.

- Full High Level Software Facilities
- High Speed Data Transfer
- Easy four wire interconnection
- Ideal for classroom use
- Up to 1 Kilometre separation
  Directly compatible with all Acorn systems

INTRODUCTION

The Econet communications network system was developed by Acorn to enable a number of Atoms and/or other systems to communicate with one another and to share facilities such as disks and printers.The Econet was primarily developed for use in schools and colleges but also lends itself to many office and business applications.

ECONET SPECIFICATION

- Up to 255 stations per Econet.
- Econets may be joined together by Gateways.
- Connection by 4-wire cable to each station (typical cost 12p per metre).
- Station separation up to 1 kilometre.
- Data transfer rate up to 210 kilobaud.
- Differential signals for high noise-immunity and minimal radiation.
- Clash-detect circuitry and collision-arbitration algorithm minimise the need for retries.
- Econet hardware fits inside Atom case; eurocard version for Acorn System 2/3/4.
- Econet software in 4K ROM, fits on Atom board.
- Econet executed automatically on BRK.

DESCRIPTION

The Econet network is totally democratic in that all stations have equal status and, unless specifically prohibited, any station may communicate with any other without recourse to an intermediary. The only unique station is the one that generates the network clock, but this may be an Atom or a larger system.

ADVANTAGES OVER A TIMESHARING SYSTEM

Each Atom station costs less than a typical terminal on a timesharing system.

Each station runs programs at maximum processor speed; adding extra stations does not slow the system down.

Each station is independent of every other; a fault on one station does not affect the others. The Econet is far more flexible than a timesharing system since extra facilities can be added as self-contained units without affecting the remainder of the system.

FILE STATION

The shared disk facility is provided by a station dedicated to running a program known as the 'file server' which organises disk files for the network. The file station may be an Acorn System 3, 4 or 5 or an Atom with disk. The shared disk may hold both public and private files; public files may be accessed by all users whereas private files are available only to the user that created them, or to a privileged user. Commands are available to LOAD, SAVE, and DELETE BASIC and machine-code files, to print a catalogue of the disk, and to change the access priority of files. Users may only create or delete their own files, but may also be granted access to other user's files. The file server also supports random access files.

PRINTER STATION

In the simplest possible configuration the printer station can be a printer connected to an Atom running the 'print server' program. Files submitted to the station will be printed immediately if the printer is free; otherwise a 'BUSY' message will be given. In larger configurations the printer station will include a disk unit so that files submitted for printing can be spooled to disk until the printer is free. The 'print spooler' program manages the print queue, and can run on an Acorn System 3, 4 or 5 or on an Atom with disk.

ATOMIC NETWORK OPERATION

All the stations on the Atomic Network are connected together by the network. The system is totally democratic; all stations have equal access to the network. There is no specific direction of flow of data; the network simply ensures a path between any pair of stations.

For the network to work efficiently no two stations must attempt to send data across the network at once. This is ensured by three rules:

1. Before transmitting on the network a station listens until the network is free.
2. If two stations start transmitting simultaneously, each believing the network to be free, the collision will be detected by the 'collision-detect' circuit on each station's Econet interface; this is triggered by the presence of an intermediate logic level on the data lines, and both stations will then stop transmitting.
3. After a collision has been detected, each station causing the collision will either retry immediately, or abandon the attempt and continue listening until the network is free again. The course of action taken is determined by a 'collision-arbitration' algorithm which ensures that no two stations go through the same sequence of actions.

In practice these procedures give very efficient use of the net, with the minimum number of retries. During the time that two stations are in communication the network is kept continuously busy, so there is no opportunity for another station to interrupt and cause a collision. Once the conversation is finished the network is released, and other stations waiting to use it will again compete to gain access to it.

HARDWARE

ATOM ECONET INTERFACE

The Atom Econet interface is contained on a narrow board which connects internally to the Atom. The board contains driver circuitry for direct connection to the network, and includes space for clock-generation circuitry enabling the Atom to be used to generate the network clock. The station number is programmed by links on the board.

The software to interface to the network is provided in a 4K EPROM which is accommodated in the utility ROM socket on the Atom. The Econet gains control automatically on switch-on, or on pressing BREAK, and the station identifier is displayed on the screen. The ROM contains all the low-level network interface routines, which can be called from user programs to implement special-purpose protocols, and the command interpreter containing the additional Network Operating Systems (NOS) commands.

EUROCARD ECONET INTERFACE

An alternative eurocard interface board is available to connect Acorn Systems to the network.

STATION IDENTIFICATION

All of the circuit boards on the network have a unique station address which is set, using eight links, to be in the range 1 to 255. Thus up to 255 stations may be attached to a single Econet.

NETWORK WIRING

Stations are connected together by two twisted-pair cables. A sheathed cable such as BICC type TM-6704 is recommended, and this cable is currently available for around 12 pence a metre.* The readily available 5 pin 180 degree DIN plugs and sockets are recommended for use as connectors on the Econet; the signals are connected as follows:

        Pin 1   Data, non-inverted
        Pin 4   Data, inverted
        Pin 2   Common 0 volts (optional)
        Pin 5   Clock, non-inverted
        Pin 3   Clock, inverted

Signals travel along the Econet wiring at about 180,000,000 metres per second and it is important that no more than half a clock cycle of phase error exists between the data and clock. At a clock frequency of 200 kHz this phase error is equal to 2.5 microseconds, and so the maximum network length is 450 metres. By reducing the clock to a frequency of 100 kHz the line length can be extended to 1 kilometre.

LOW-LEVEL PROTOCOL

All the stations on the network communicate using a simple low-level protocol. This protocol is implemented in terms of 'frames' which are provided by the hardware. A frame is made up as follows:

      1. A hardware-generated opening flag.
      2. The 8-bit address of the destination station.
      3. The address of the source station.
      4. An 8-bit port number.
      5. A number of data bytes.
      6. A hardware-generated 16-bit CRC.
      7. A hardware-generated 8-bit closing flag. Thus data may be directed to a specific station, and to a specific port at that station. The provision of port numbers allows a station to indicate the purpose of its message.

The low-level protocol is best explained with the aid of an example. Consider the task of station A transmitting data to station B on port P:

   Station A - - - - - - - - - - - - - - - > Station B
                            Port P

      1. When the sending station has established that the network is free it attempts to transmit to station B a short 'scout' message. Scout messages contain the destination address, the source address, and the port number. Stations are interrupted by the arrival of an opening flag.
      2. Assuming that there was no collision during the transmission of the message the receiving station is able to check whether there are any outstanding receive requests for station A on port P.

3. If the receiver expects a message it sends a short reply message to station A indicating that the main body of the message should be sent.
4. On receipt of this reply station A then sends the data part of the message.
5. Finally station B will send another short reply message indicating that the data was received successfully.

SOFTWARE

The network software can be divided into three parts:

1. The Econet interface software, contained in every general purpose station. This comprises:

    a. The Network Operating System (NOS), which controls the commands available to the user at stations.

    b. The low-level primitives which are called by the NOS commands, and which can, if required, be called from user programs to implement special-purpose protocols.

This component of the Atomic Network Software is described fully later.

2. The file station software:

    a. The file server program which controls disk storage and supports a shared filing system for all the users on the network.

This is described fully on a separate information sheet.

3. The printer station software, which is either of:

    a. The print server, providing printing of one file at a time.

    b. The print spooler which maintains a print queue on disk.

This is described fully on a separate information sheet.

NETWORK OPERATING SYSTEM (NOS)

The Network Operating System, or NOS, takes over from the resident operating system when an Atom or an Acorn System is attached to the network. The NOS provides a set of commands that replace the equivalent cassette or disk-operating system commands; in addition, it provides several special commands for performing functions associated with the network.

NOS Commands
SAVE, LOAD
Used for saving or loading BASIC or text files.
For example:
SAVE "MYPROG" *
SAVE, * LOAD
equivalent commands for saving or loading areas of memory, or machine-code files.
For example:
* LOAD "MYPROG"
* CAT
gives a catalogue of the user's directory on the currently-selected disk.
* DELETE
Deletes a user's file from the disk.

*VIEW
This enables a user to take a copy of the screen of a specified station, and display it. The VIEW command automatically tests the graphics mode, and displays the screen in the correct mode. For example:
* VIEW 238
views the screen of station number 238. *
REMOTE
allows a user to take over a specified station; the master system becomes a terminal to the slave system, and the slave's keyboard is disabled. Anything typed at the master terminal appears on both screens. If required, the master can reset the slave system by typing CTRL-O. For example: * REMOTE 238

* ROFF
this is the complementary command to * REMOTE
by which the master can release the slave. *
NOTIFY
enables a user to send a message to another
user across the network. For example:
* NOTIFY 238 YOU HAVE FORGOTTEN THE '$'. In
addition there are a number of commands to the
file server associated with altering the access
status of a user's files, the current directory, and
the current disk.

LOW-LEVEL PRIMITIVES

The network software contains the following primitive operations:
TRANSMIT
Transmits a specified number of bytes to a specified station and port. To execute the operation a
control block containing the following information is set up:

      1. Destination station; 0=> broadcast.   3. Start address of data.
•   2. Destination port number;16 to 255.   4. End address of data.

RECEIVE
To receive a number of bytes on a specified port from a specified station a receive control block
must be set up; this comprises:

      1. A flag indicating whether the reception requests have been fulfilled.
      2. Source address. 0=> any station—set to specific station on reception.
      3. Port number. 0=> any port, set to specific port on reception.
      4. Start address in memory where incoming data is to be placed.
      5. End address— modified to true end address on completion of reception. The
following operations PEEK, POKE, RESET, and START are special in that they are obeyed on
demand. A machine invokes these operations by calling the transmit routine, which takes the
address of a control block as an argument.
PEEK
This allows the user of a machine to read an area of memory of another station into a specified
area in his own machine. A control block of the following form must be passed to the transmit
routine:

      1. Station number.
      2. 0.   5. To address in distant station.
      3. 1=> PEEK, 2 => POKE.   6. From address in local station.
      4. From address in distant station. 7. To address in local station.

This is implemented as an 'immediate' operation; a message is sent to the distant station which
recognises this as a special operation and transmits the data to the requesting machine.
POKE
This allows one machine to transfer a number of bytes into a specified area of memory on a
distant station. The control block is similar to that used for PEEK.
RESET
This operation causes the distant station to enter a loop in anticipation of being sent a START
operation.
START
Resets the distant machine's program counter and processor status register, and jumps to any
desired program location.

SOME QUESTIONS ANSWERED

Q. The collision-detect appears to depend on the detection of conflicting data on the network. What happens if two stations just happen to transmit the same message at the same time?

A. A third byte of every message consists of the station identifier. This is guaranteed to be different for the two messages, so a collision will always be detected by the time three bytes have been transmitted; i.e. within 120 msec.

Q. What restrictions are there on the shape of the network?

A. Provided there is only one path between any two stations (i.e. no loops), any layout is suitable.

Q. On a large network is any extra termination needed?

A. For operation at the highest clock rates the stations at the extreme ends of the line are provided with terminating circuits; these are accommodated on the Econet interface board.

Q. Although the maximum clock rate is quoted at 210 kHz, surely the maximum rate at which data can be read from disk by a station is much lower than this?

A. To read one sector, or 256 bytes, from the disk takes 16 msec; the time required to transfer this across the network is only 6 msec. Thus the total time required is 22 msec, giving an effective transfer rate of about 100 kbaud. For every transfer there are, of course, overheads to take into account; these include reading the directory from disk, disk latency, and waiting for the network to be free.

Q. What happens if a station is unplugged from the net during a data transfer?

A. The net will continue to work perfectly even if a station is removed. The only restriction is obviously that the station generating the clock must remain.

Q. What if a station is left connected, but its power supply is unplugged? **A. Again, the network will not be affected.**

Q. Might a student be able to upset the network by reprogramming his/her station's identifying number?

A. The station numbers are programmed by links on the station's Econet interface, and therefore are secure to intervention.

Q. Supposing twenty students simultaneously attempt to load their files from disk; what will be the longest delay?

A. The total time taken to load a file of about 1K from disk, from typing the command to completion, is about 1 second. The last student to be granted access to the network would therefore have to wait 19 seconds. Under normal circumstances the users would access the network at slightly different times, in which case the maximum wait would be greatly reduced.

Q. Can there be more than one file server per Econet?

A. Yes, additional file servers may be added to increase the amount of permanent storage available to the network, and to share the load placed on existing file servers.

Q. I initially have a requirement for a network with two Atoms as stations, and no file server; can I still use the Cassette Operating Systems of Atoms connected bathe network?

A. Yes, the NOS can be disabled or enabled by software, thus permitting the COS to be used instead.

Q. Could we use the Econet for the transmission of digital signals such as speech?

A. Yes, the Econet will cope with the two-way communication of digital speech, and the one-way transmission of higher quality signals.