The Ferranti Microminiature Digital Computer

A Description of the Ferranti Argus 400 High-Speed, General-Purpose Computer, which utilizes Silicon Integrated Logic Circuits, Serial Arithmetic and Ferrite Core Storage

A NEW microminiature, general-purpose digital computer for airborne applications has been introduced by the Automation Systems Division of *Ferranti Ltd.** Known as the Argus 400, this high-speed computer has been designed to give high standards of reliability in adverse environmental conditions and employs a new range of *Ferranti* silicone integrated logic circuits and certain other special techniques for internal connections.

The advantages of using digital computation rather than analogue for airborne applications are well known and include: (i) greater flexibility—it only being necessary to re-programme the form of the control equations; (ii) accuracy—extremely high and only limited, to all intents and purposes, by the standard of the information fed in from transducers; (iii) economics—can perform an extremely large number of functions.

To take full advantage of these features, the Argus 400 has been conceived to combine all analogue tasks into a comparatively simple digital control with (a) high reliability, (b) comparatively low cost—a complete system costs in the region of £20,000, (c) extremely high power, and (d) versatility that allows the addition of a modular range of microminiature input/output equipment enabling systems to be 'tailor-made' to fit requirements exactly.

TECHNICAL DETAILS

Argus 400 is a general-purpose binary digital computer using serial arithmetic and ferrite core storage. Binary-negative numbers are stored as 2's complement, and word length is 24 bits.

Operating Speed

Add/Subtract	12 μS
Multiply	21–156 μS (average about 80 μS)
Divide	156 μS
Shift	7·5 μS up to 14 places increasing to 11·75 μS for 24 places
Modification	Modification adds 5·75 μS to the basic order times
Branch (conditional jump)	7·5 μS

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REFERENCE TO LITERATURE

(1) 'Ferranti's Lightweight Inertial Platform,' AIRCRAFT ENGINEERING, Vol. XXXVI, No. 11, 429th Issue, November 1964, pp. 356–358.

Storage

Storage takes the form of in-built core stores in 4,096-word blocks, with a semi-indirect addressing system being used above 12,288 words. Core store cycle time is 2 μS.

Order Structure

The order structure is identical to the Argus 100 order code, having thirty functions as listed below. Seven working accumulators are provided; three of which can be used as modifier registers, to be added to the main address before execution of the instruction. Fourteen bits are used for the main address, thus giving access to four 4,096-word blocks, of which the first is reserved for a few special registers and the input-output equipment.

Interrupt Facilities

In its basic configuration the computer has interrupt facilities with eight levels of priority.

Direct Store Access

Digital signals to and from external equipment can be directly transferred into and out of the core store without disturbance to the normal computer programme and the permissible data rate is over 50,000 words/sec.

Dimensions of central processor with 4,096-word store are 12·6 in. long, 7·5 in. wide, 7·7 in. high; the power unit is; 12·6 in. long, 3·7 in. wide, 7·7 in. high.

Thus the volume of the central processor with 4,096-word store is 0·51 cu. ft., and that of the power unit 0·25 cu. ft. Weights are respectively: 16 lb. and 13 lb.

Power

The power unit outputs are plus 4·5 volts and minus 30 volts. The power is supplied through a small accumulator contained in the power unit which is continuously charged from the normal vehicle or ground mains supply. This system enables the computer to run for a short time in the event of interruptions in the main supply and makes it immune to mains transients.

Power consumptions are as follows: central processor—20 watts; first 4,096-word core store—30 watts; additional 4,096-word core stores—each 4 watts; input/output equipment—dependent on system size; power unit—for 22–29 volts d.c. consumes 100 watts for an 80-watt output.

Construction

The logical circuits used in Argus 400 are single-chip silicon integrated circuits mounted in sealed 8-lead T05 transistor cans. They constitute a new range of elements developed jointly by the Automation Systems Division and the Electronics Department of *Ferranti Ltd.*, and combine economic design characteristics with high operating speed. Fewer than 600 elements of fourteen types are needed for the central processor, as compared with over 1,000 for some alternative ranges of elements.

The elements are soldered through six-layer printed circuit boards, which in turn are connected to a multi-layer interconnection circuit by miniature wrapped joints. The overall size of the processor is 7½ in. by 12 in. by 2½ in., which fits into a standard A.T.R. aircraft equipment case. The use of 'ground planes' in the printed circuit boards together with a high operating threshold designed into the circuit gives the system a high degree of protection against induced transients on the voltage operating levels.

The core store uses a matrix stack of 2 micro-sec. cycle time. The 0·030 in. cores are mounted in sets of 4,096 on six printed circuit panels. Three more panels contain wrapped joint pins, resistors and diodes, bringing the total size of the stack to 6 in. by 3 in. by 2 in. This is mounted on a 7½ in. by 12 in. interconnection board, together with timing circuits, driving circuits (combined micro-circuit and normal transistor circuits) and thin-film sensing amplifiers, to make a complete 4,096-word 24-bit store of the same size as the processor.

The complete general-purpose computer comprises a processor, one or more store units and an input-output unit. These units are interconnected by means of wrapped joints to a flexible printed circuit, so that individual units are fully accessible when the outer case is removed. The flexible circuit carries 122 parallel signal tracks, and is so arranged that the connection of extra units such as stores is simple. The only plugs and sockets are those mounted on the case for external connections. All wrapped joints are made with a

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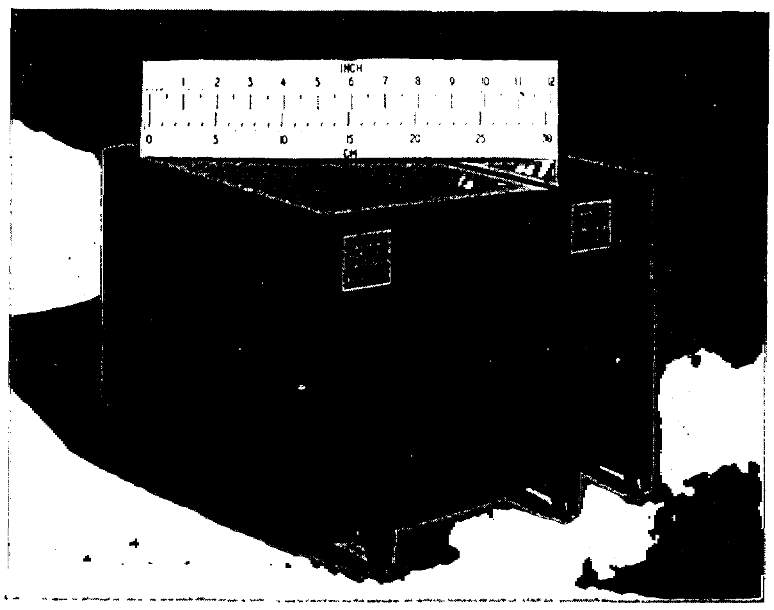

Fig. 1.—The Ferranti Argus 400 microminiature digital computer along with its power unit fitted in standard ATR cases.

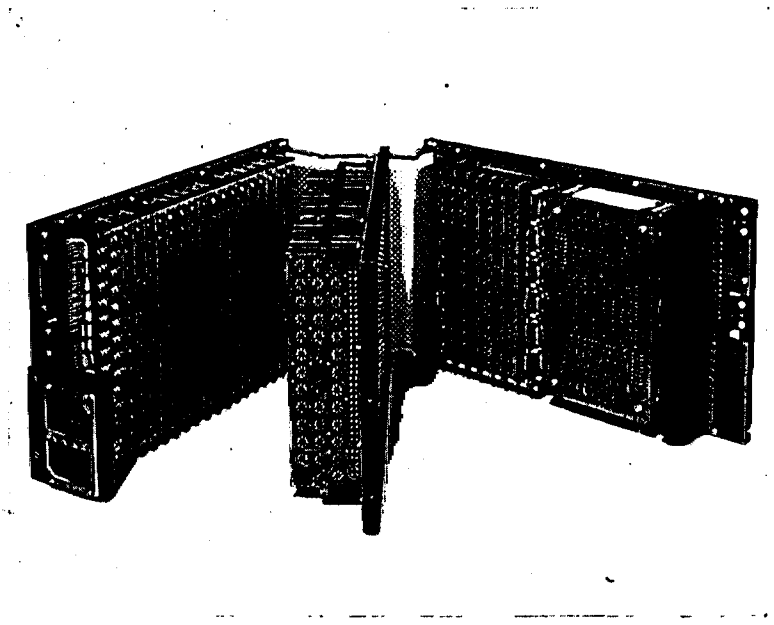

Fig. 2.—An exploded view of the Ferranti Argus 400 microminiature digital computer.

along a line of print, they move in small 'saccades' or jumps. It is during the brief pauses or 'fixations' between saccades that the reading is done.

The slow reader finds that he has to fixate on every word in order to understand what he reads. The reason for this is that he has never tried to train his eyes to see a group of words at each fixation. One way of developing the wider eye span (the amount taken in at each fixation) necessary for this is to try to read a newspaper by reading vertically, that is, letting the eyes move straight down the column and cutting out much of the horizontal movement. This 'vertical translation', as it is sometimes called, is not easy to develop, but with practice every day over two or three weeks it becomes progressively easier and will be found to provide a technique which is quite adequate for reading much of the material in one's daily newspaper.

Another problem facing the slower reader is regression, or going back to read something a second time. Most slow readers regress more out of habit than because lack of comprehension forces them to. If one is regressing more than once or twice a page on material of no more than usual difficulty, it is likely that the regressions can be greatly reduced in number without permanent damage to comprehension. The faster reader does not need to regress so often because his greater speed means that the process of connecting words and phrases into a meaningful whole is so rapid that there is little chance of his losing the thread of what the writer is communicating to him. Only when the meaning is obscure or when he wants to make a mental note of a particular phrase or sentence does he regress. To conquer the habit of regression, one must resolutely refuse to regress. Comprehension will suffer at first, and for this reason it is advisable to have regular daily reading practice sessions of about 15-20 minutes. If one refuses to regress during these sessions, it is only a matter of one week or two that significant reductions in the frequency of regressions is noticed. This is because the refusal to regress compels the brain to concentrate more on the act of reading. Improvements in comprehension usually accompany this improvement in concentration.

In addition to the points that have just been made, a simple method which will reveal how much one is capable of improving one's ability to read more effectively can be described. If the reader takes his favourite morning newspaper and selects a passage from it—preferably a regular daily feature that is usually about the same length—this passage can be used for a week in the following way:

On Monday—read the piece selected *at normal speed*. Time yourself to see how long it takes. Note down the time taken. Setting the paper aside, write down the main points the writer has made. Now check with the original and allow yourself a percentage (for example, if the writer made five main points and you gave three of them correctly, this is a 60 per cent level of comprehension). Calculate your speed in words per minute (divide the number of words in the passage—an approximation will be sufficient—by the time taken, in seconds, and multiply by sixty). Make a note of your results in a notebook and cut out the article you used and keep it for reference.

On Tuesday—following the same procedure, try to read faster and to understand better than you did on Monday. This element of 'self-competition' is of considerable importance in improving reading efficiency.

On Wednesday, Thursday and Friday—keep trying to read faster and to improve your comprehension score.

On Saturday—follow the same procedure and then compare your performance with your performance on Monday. You will find that simply by trying you are already beginning to read faster, which means your eye span must be widening. If you have refused to regress, this too will reflect itself in the increased speed. You will also find, very probably, that your comprehension percentage has improved.

This exercise carried out over only one week, obviously does not constitute a comprehensive reading efficiency training course, but it should serve to show you that you can improve your reading skills if you want to. It is this 'if you want to' which is the operative clause, for little improvement is possible, no matter what kind of course is followed, if the student does not really see the need for improvement or if he thinks that in his case improvement is not readily attainable.

A final warning. Every slow reader who begins the process of increasing his reading speed and trying to raise his level of comprehension should remember that improvements in personal efficiency are not made without determination and sustained effort. There is no magic, overnight way, no 'instant' rapid reading. Regular daily practice of the skills mentioned and of the other related skills which most courses teach is necessary, but given this practice, anyone can solve his reading problem by achieving a greater efficiency in reading.

TABLE III
Results of Another Adult Class

Occupation	Age	Reading Speed			Comprehension		
		From	To	% change	From	To	% change
Electronics Engineer	33	239	472	+ 97	47	80	+33
Journalist	54	297	330	+ 13	53	70	+32
Housewife	52	296	658	+122	73	90	+23
Executive	35	239	510	+110	49	86	+77
Student	20	270	520	+ 93	80	90	+13
Student	18	220	500	+136	70	85	+17
Electronics Engineer	35	231	548	+138	67	77	+15
Manager	60	283	575	+109	76	83	+ 9
Teacher	38	198	486	+145	73	83	+14
Engineer	30	258	532	+106	43	67	+55
Engineer	43	202	577	+131	57	73	+22
Group Average:				+109			+32

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powered wrapping tool giving a fixed number of turns —a technique of proved high reliability.

For airborne use, cooling is by externally-supplied cooling air in accordance with A.R.I.N.C. standards. The open construction of the computer and its low-power dissipation (less than 120 mW/cu. in.), requires comparatively little air flow. A design incorporating an indirect cooling system in a sealed case is also available. For ground use, the computer is mounted in a 19½ in. long case, which contains a small fan.

Programming

The Argus 400 uses the standard *Ferranti* Argus order code, so the programming manual and other programming handbooks, written for the 100 and 300 series Argus models, are immediately available for 400 users. Similarly, programmes written for the Argus 100 and 300 series computers can be run without alteration on the Argus 400.

Standard software packages delivered with all Argus computers include machine commissioning and acceptance test programmes, diagnostic programmes, peripheral equipment test programmes, initial orders, assembly, machine code tracer, Argus on-line check and the Argus autocode. Additional standard Argus sub-routines are available from the Argus Programming Library, which is continually being expanded and reviewed.

Programme Input

Normal programme input is by five-track punched paper tape. Tape readers operating at 300, 500 and 1,000 characters per second are available as standard (there are ten characters per order). An alternative system, for higher speed input, is based on the use of a magnetic tape cassette.

Data Input-Output

A wide range of input-output units is available, some of which are listed below. In a small system, specialized equipment is provided within the computer case, but in larger systems a standard interface or highway, links the computer with one or more peripheral units of standard design.

(i) Selection of digital inputs, grouped single bits or complete words.

(ii) Generation of digital outputs to operate lamps, output printers, decimal visual display, relays, etc.

(iii Selection of analogue inputs. Analogue to digital converters have up to twelve-bit resolution, an overall accuracy of 0·1 per cent.

(iv) Generation of analogue outputs. For high-speed output (e.g. to a cathode ray tube display) a register is used to drive a digital-analogue converter. For slowly-varying outputs an impulsive drive combined with a feedback loop is preferred.

A system known as 'direct digital control' is available; the equipment which compares demanded value in the computer store with actual value and generates correction signals, is combined with the equipment used for reading large numbers of analogue signals and storing their magnitude within the core store. The direct store access system is used, thereby freeing the computer programme from the repetitive and time-consuming task of controlling input and output in detail.

(v) Control of synchronous units such as magnetic tape decks or data links.

(vi) Interrupt control and priority logic as required.

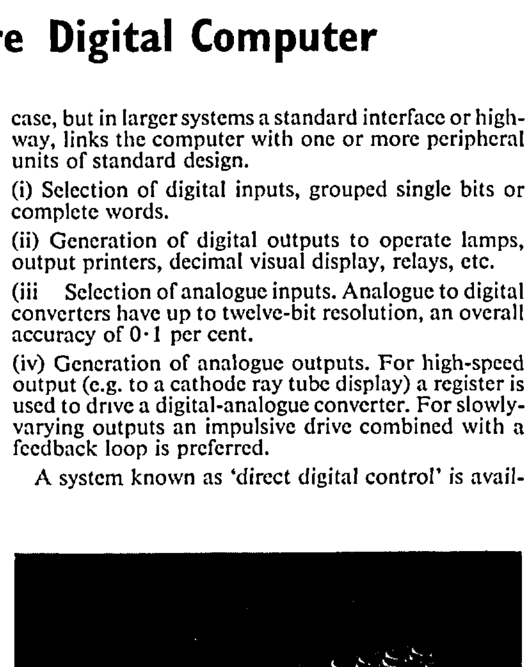

Fig. 3.—A typical printed circuit card for the Ferranti Argus 400 digital computer showing microminiature integrated circuits.

Input/Output System Capacity

The order code allows over 4,000 input/output channels to be directly addressed. Eight 'busy' signals can be examined to ascertain the condition of peripheral equipment. Using direct store access a data transfer rate to or from the core store of over 50,000 words per second can be obtained.

GENERAL

Ferranti Ltd. was one of the first companies in the world to manufacture electronic digital computers and are well established in the field. *Ferranti* conventional solid state computers are used in the Bloodhound Weapons System and in industrial process control applications. The company pioneered the world's first direct digital control application of a computer to an *I.C.I.* chemical plant at Fleetwood, Lancashire, and were the first company in the world to install a computer for the direct control of a radio telescope at Jodrell Bank, Cheshire.

This experience in control in many different applications, both military and civil, with stringent requirements on reliability has influenced all aspects of Argus 400 design and conception.

The Argus 400 forms, with the *Ferranti* Type 700 lightweight inertial platform, a lightweight inertial navigation system of advanced design and this must prove a major application for aircraft purposes. The Argus 400 with its range of input/output equipment is also suitable for marine and ground vehicle applications where high reliability and ruggedness are important.