Pioneering Innovation in Early British Computers

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This three-volume set has required an extensive amount of research to find information about the English computer systems. This involved repeated searches of the Web to ferret out often hidden or differently labeled documents. Some members of the Computer Conservation Society (CCS) have graciously suggested places to look and repositories of documents. I thank them very much for their assistance as well as for their hospitality at CCS meetings I have attended.

In undertaking my research and, in order to ensure that I have done my due diligence, I read through extensive amounts of documentation - 500 articles, books, reports, brochures, and manuals. This has taken considerable time, but I hope the reader will find the amount of information captured here to be helpful in understanding these important (and often overlooked) systems.

This book is based on publicly available information on the web. Where previous books have been published on some of these systems, I refer the reader to these tomes rather than extracting information from them.

Very important (and often overlooked) the family cats – Scooby Doo, Tatiana, and Boris – who have kept me company by sitting on my desk or flopping on my keyboard expecting head rubs while I was digesting data or writing.

Additional thanks go to my wife for her forbearance as I spent many days and nights writing the first two volumes.

Finally, I dedicate this book to my mother, Dolores, who is 98 this year and continues to do well.

CAVEAT: This volume is based on the best publicly available documentation that I have been able to locate that is relevant to the systems described herein.

Note: Volume Two, *English Computer Systems and Industry,* will be published by Cambridge Scholars Publishing Co. later in 2024.

Note: Volume Three, *English Computer Systems and University Developments*, is a forthcoming volume to be published by Cambridge Scholars Publishing.

INTRODUCTION

ENGLISH COMPUTER SYSTEMS

Due to their seminal role in demonstrating the utility of the von Neumann architecture, we discussed a few of the English computing machines in earlier volumes. England was heavily involved in computing machine design from the early 1940s. During the late 1940s and 1950s, the majority of computer design and engineering was done by British universities and national laboratories. In the earliest days, the three main centers for British computer development were University of Cambridge, University of Manchester, and the National Physical Laboratory at Bushy Park.

By the late 1950s, these institutions were joined by several government establishments, including the Telecommunications Research Establishment (TRE), the Post Office Research Station at Dollis Hill, the Royal Aircraft Establishment, and the Atomic Energy Research Establishment. In the private sector, companies such as J. Lyons & Co., Ferranti Limited, and the English Electric Company presented early offerings into the commercial marketplace Wilcock (2010) describes the consolidation of many of these early British computer manufacturers and other telecommunications companies into what would later become known as Fujitsu-ICL.

In 1945, the National Physical Laboratory opened a computing research center at Teddington with Alan Turing as its director. Turing led the design and construction of the Pilot Ace which eventually led to the English Electric Deuce. The Pilot Ace was described in Volume I; *Birthing the Computer: From Vacuum Tubes to Relays*.

In the 1950s and early 1960s, Ferranti Ltd collaborated with the University of Manchester to develop the Manchester Mark I, Pegasus, Mercury. and the Atlas computers. Ferranti was the leading British computer manufacturer for almost a decade, but was not able to translate this leadership position into a sustainable market share, and so, sold its computer division to International Computers and Tabulators (ICT) in 1963 (Wilcock 2010).

From the early 1960s British computer manufacturing was led by other companies, which led to key innovations in computer design. It is noteworthy that the last of the Manchester computers - the Manchester

MU5's - design and concepts survives to this day in Fujitsu machines by way of the ICL 2980.

A key driver of computing in Britain was the UK government which provided state support for UK universities to purchase computing systems. Harold Wilson, Leader of the Labour Party in 1963, expressed his vision for Britain's technological future in his famed "white heat" speech in which he called for Britain to be forged in the white heat of the scientific revolution". (Verdon and Wells 1995) When Wilson came to power as Prime Minister in 1964, he set up the Ministry of Technology to implement his vision. In January 1966, 'A Report of A Joint Working Group on Computers for Research', also known as the "Flowers Report" (not to be confused with the later 1976 'Flowers Report' on nuclear power and the environment) noted the dismal state of computing in the UK's universities (Flowers 1966). This report proposed a program that balanced the increasing the UK's weak economic situation computational needs of the universities by restricting purchases to within a limited financial framework. As a result, the Computer Board for Universities and Research Councils was formed to oversee the use and financing of computing in the UK higher education system. Verdon and Wells (1995) describe the history of the Computer Board through its first 25 years, both men having served on it in the early 1970s. Clark (2010) further describes the role of the British government in the provisioning of advanced computers to the UK universities.

Note: The International Computers and Tabulator, Ltd, later renamed International Computing, Ltd. will be described in a forthcoming volume entitled *International Computing, Ltd: The Way Forward*.

Convention: In this volume, 'K' indicating a memory size or data volume means 1,024. Thus, 64K words means 65,536 words.

PART I

ELLIOTT BROTHERS

Source: Lavington 2022e

William Elliott founded Elliott Instrument Company in 1804 after serving as an apprentice to a compass and drawing instrument maker. When Elliott's sons entered the business in 1850, the company became known as William Elliott & Sons, later changing to Elliott Brothers in 1853 after William Elliott died.

Originally developing its own scales and scientific instruments, Elliott progressed to supplying a variety of equipment, including experimental electrical apparatus - to individuals such as Michael Faraday, Sir Humphrey Davy and Charles Babbage (considered by some to be the Father of the Computer). From 1908, it provided fire control computers using electro-mechanical analogue technology to the British Admiralty until the end of World War II. During World War II, Elliott Instrument Company supplied electro-mechanical gunnery control equipment to the Royal Navy.

However, by 1946, Elliott Brothers was lagging behind its competitors in developing a capability in electronic equipment. The British Admiralty was concerned and convinced the company to develop new capabilities in advanced electronic fire control systems and target tracking radar. It leased the company a factory in Borehamwood, Hertfordshire to serve as a base for a research team of young scientists and engineers whose mission was to design and build several digital computers for classified projects.

As Elliott was a diverse company, it realized that computing machines had a wide array of uses and developed several generations of machines both for internal use and commercial sale. The company introduced its first computer, the Elliott 152, in 1950. Subsequent computers were each one-off systems designed for specific purposes. In 1957, Elliot changed the company name to Elliott Automation to reflect the widespread use of computers in the diverse industries that Elliott operated in. The Elliott logo is depicted in Figure 1-1.

Figure I1. Elliott Brothers Logo
Source: Elliott UNKb

Throughout the 1950s, it was the only "non-academic, non-Government team developing its own range of computers" (Clarke 2007). The company focused its machines on meeting a specific customer need. To this end, they viewed computers as being embedded within a system rather than as stand-along devices.

A detailed history of Elliott Automation is contained in Simon Lavington's carefully researched book: *Moving Targets - Elliott Automation: The Dawn of the Computer Age in Britain 1947-67* (Lavington 2011). A video, *The Story of Elliott Automation*, 1946-1986, by Simon Lavington, is available from the Computer Conservation Society.

In 1961, Elliott made roughly half of all the new computers sold in the UK that year. Many of these were sold to companies involved in industrial process control. However, the company's financial picture deteriorated in the mid-1960s. The UK government engineered a merger with English Electric Company. In 1968, a further merger with GEC resulted in the mainstream computing divisions being sold to International Computers Ltd (ICL), with GEC retaining the military and process control divisions. GEC was later acquired by BAE. As with many such mergers across the computing industry, illustrious names disappeared in these mergers (Lavington 2022e).

CHAPTER ONE

EARLY ELLIOTT COMPUTING MACHINES

Source: CCS, 2004a

Through the later 1800s, Elliott Instrument Company, Hertfordshire produced a variety of instruments including telegraph and electrical equipment. By the early 1900s, naval instrumentation, such as fire control systems using electro-mechanical analog computers, was a major product. Elliott did not fare well during World War II, but in 1946 the UK Ministry of Defense (MOD) began discussions to explore the new digital techniques. The MOD leased buildings at Borehamwood, Hertfordshire to Elliott, which became its Research Laboratory (ERL). During their time at Borehamwood, the team at Borehamwood built several classified digital computers and, by 1951, had begun to look at commercial applications of their digital technology.

Clarke (2007) examines the early days of a computer development at ERL. As Elliott explored the possibilities of the new technology, thermionic valves were selected as the basic binary element. They had an expected life time of 1500 hours. To ensure reliability of a system, Elliott instituted daily maintenance to detect failing tubes and replace them. In a machine with hundreds of tubes, this became an onerous task, so ERL devised the plug-in-module which could be easily replaced and repaired off-line. Based on a glass substrate with crossovers and resistors, and mounted germanium diodes and pentodes, this became the model for logic modules. These modules were the basic elements for the Elliott 400, the Ferranti Pegasus and later machines. As Clarke notes, just like subroutines, these logic modules could be combined in different structures to create the subsystems of the machine architecture, which eased maintenance, and increased reliability, and replication in manufacturing.

As Merry (1993) notes:

> "The thinking required in the logical design, particularly of the control functions, therefore required the designer to envisage successive machine states represented by circuit states changing autonomously and quickly under the inexorable flow of serial data. This is a duality which is difficult to represent

conspicuously in any diagram form, and was quite beyond the descriptive mathematical techniques of the time."

It revolutionized the design and development of computing machines by making their architecture very simple. The next section describes the early machines that benefited from this development and the insights it engendered in designing machine architectures.

1.1 Elliott 152

Source: Lavington, 1980; Lavington, 2011

The Elliott 152 was designed at the ERL in Borehamwood, England to support the English Admiralty's MRS5 (medium range system 5) Naval gunnery, fire control project. The Elliott 152 utilized a flying spot scanner and Williams-Kilburn Tubes for its working store and it used vacuum tubes for its computational circuits. The time to multiply two fixed-point numbers was 60 microseconds. It ran its first program in 1950, almost a year before Whirlwind (Lavington, 2008b). It was a one-of-a-kind real-time computer system designed to analyse radar signals. Early design problems delayed its actual operation until mid-1951. It was finally shut-down in 1952 at the end of the Elliott's MRS54 contract with the Admiralty.

1.1.1 The Beginning

The MRS54 contract effort was commenced in October 1946 under the direction of John Coales. Its objective was to develop a target-tracking radar that would directly control Naval gunnery. A control program, running on the Elliott 152, and interfaced with the guns and radar would perform 3D trajectory prediction and fire the guns at the appropriate time to intercept the target.

The computer would send a command to the radar unit, which would send back an integer. The Elliott 152 would then calculate an update position for the target. The pulse rate used was one every microsecond with an assumption that over 30% of these would not yield useful data. To access the target, the Elliott 152 had to perform an update of range, bearing, and elevation every four msecs. The update values were calculated to 14-bit accuracy.

The initial version of the Elliott 152 was completed in September 1950.

1.1.2 PROCESSOR ARCHITECTURE

The Elliott 152 processor architecture is depicted in Figure 1-1. Its components are described in Table 1-1 (CCS 2004s).

The basic control cycle of the machine was based on 16-digit times plus a 4-digit gap within which all arithmetic and logic operations could be performed.

If the Elliott 152 had been operated in single instruction, single word mode, it would not have been able to perform the necessary real-time control and analysis for radar detection operations. Multiple data streams were executed in parallel with multiple data transfers between RAM and the functional units.

Data was received from the radar, also known as the Director. Data was output to the ship's guns.

Four programs were stored in their own Read-Only Memory (ROM), which allowed the calculations for bearing, range, and elevation to occur concurrently. The programs were stored on either glass plates or stiff cardboard with 0's and 1's represented as clear or opaque spots. The slides were read by a CRT flying-spot scanner.

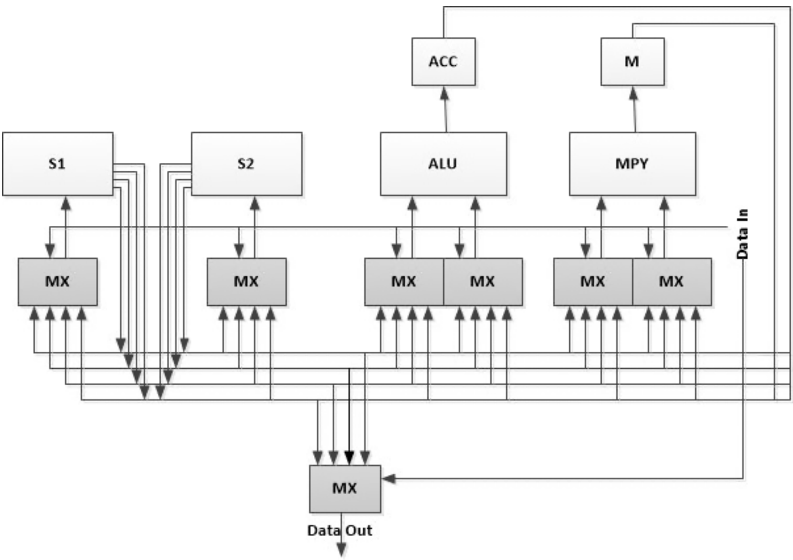

Figure 1-1. Elliott 152 Processor Architecture
Source: Adapted from CCS-2004s, Lavington, 2011

With 16-bit words and an access time of 3 usecs per digit, a multiplication could be completed within 60 usecs. The basic cycle time of the Elliott152 was set at 60 usecs consisting of 16-digit periods plus a 4-digit gap.

Harry Carpenter, who designed the basic architecture, realized that this cycle time would not yield the performance required for real-time digital fire control cited above. So, the system was designed to support several instruction streams to be executed in parallel. Four programs were stored in respective ROMs allowing concurrent calculations to occur.

Table 1-1 Elliott 152 Components

Component	Size	Description
Accumulator (ACC)	1 word	Implemented as a circulating loop of delay elements.
Extend Accumulator (M)	2 words	Double word accumulator.
Scalar Arithmetic/Logic Unit (ALU)	16 bits	Provided fixed-point arithmetic and logic circuits using sub-miniature pentodes. Addition, subtraction, AND, and shift operation.
Memory(S1,S2)	64 words	Each implement using two 32-bit CRTs with 16-bits per word and 3-usec digit time.
Multiplier Units (MX)	32 bits	Performed multiplication of two integers.
Fast Multiplier Unit (MPY)	32 bits	Used a “wiffle tree” design to perform a multiplication n 60 usecs.

1.1.3 MEMORY

The Elliott 152 memory used 16 Williams-Kilburn Tubes each with a capacity of 256 digits represented as 16-bit words. Program were stored on either glass slides or punched cards. A flying spot scanner was utilized to access the digits on these media.

The instruction length was 20 bits. Each slide/card stored 16 instructions. Numbers were stored as two’s complement fractions with the decimal point located two bits to the right of the most significant bit. Since the computations only required positive numbers, there was no need for negative multiplications.

1.1.4 System Operation

The computer and the radar were connected by two coaxial cables – one carried a timing signal derived from the computer's clock, while the other carried duplexed commands and data. When the radar received a command, it transmitted an integer to the computer. The computer sent a command to the radar every millisecond (or about 1,000 pulses).

An assumption was made that one out of every three pulses would not carry useful data due to glint, noise, etc. This translated into a need to average over four radar returns when computing trajectories. This required the Elliott 152 to produce an update of range, bearing, and elevation every four msecs to an accuracy of 14 bits, which yielded a precision of about one minute of arc. Input to the Elliott 152 was about 70,000 bits per second, while output was about 10,500 bits per second.

1.2 The Elliott Nicholas

Source: ONR 1953a, Hersom 2002, CCS 2004s

Elliott then commenced the design of the Nicholas, another one-of-a-kind computing machine. The Nicholas (Nickle Delay Line Storage Computer), which used nickel magnetostrictive delay lines, was begun in mid-1952 and became operational in December 1952. It consisted of several racks of circuit plates (cards). One rack contained the arithmetic, routing and control units.

Magnetostrictive nickel delay lines were used for storage. Main memory consisted of 65 long lines with a storage capacity of 1024 words and an effective access time of 6.5 msecs. Five short delay lines implemented the accumulator, multiplicand, order, order number, and address counter registers. Words were 32 digits in length. They stored two 16-digit single address instructions consisting of a 10-digit address and a 6-digit function code. Average computing speed was about 100 operations per second or about 10 msecs per instruction. Backing store was a 2500-word magnetic drum.

It was initially used for trajectory calculations of about 1400 orders. However, it also provided general purpose support to the Theory Group and was used by Peter Hunt of the De Havilland Aircraft Company to perform flutter calculations on 10x10 matrices for the Comet – the world's first jet aircraft.

1.3 ELLIOTT 153 AND OEDIPUS

Other early machines include the the Elliott 153 and the OEDIPUS. The Elliott 153 (its internal project number) was designed to support direction finding (DF) calculations. It was delivered to Scarborough, England, where it operated until the mid-1960s. The OEDIPUS was built to support classified cryptanalytic computations for GCHQ. Its development was a collaborative effort between GCHQ, Elliott, and Ferranti. It became operational in 1954, and was in active service until 1959. OEDIPUS was a pre-wired computing machine with a parallel-access, associative (i.e., content-addressable) ROM of 20K characters capacity

Dina St. Johnston (1930 - 2007)
One of the female pioneers of English computing, Dina St. Johnston, started working at Elliott's Borehamwood facilities in 1953 where she worked in the Theory Division. By 1954, she was responsible for the programming of the Elliott 153 Direction Finding computer. She later left Elliotts to form her own consulting and contracting company, (later named Vaughan Systems and Programming), becoming one of the first women in the computer industry to have her own company. VPS performed software contracts and training for its clients. In 1969, VPS claimed that "VPS was the first registered independent Software unit in the UK (February 1959), that was not a part of a computer manufacturer, not a part of a computer bureau, not a part of a users' organization, and not a part of a consultancy operation." (As quoted in Lavington 2009f). Source: Lavington 2009f

1.4 EARLY COMPUTER ASSESSMENT

As CCS-E1X2 (2004e) noted, the Elliott 152 was a fixed-program stored program computer, but not considered general-purpose. It does seem to be the first example of a real-time, on-line process control computer. Some might argue that the MIT Whirlwind was the first real-time, stored program computer. However, it did not reliably run its first program until March 1951 while the Elliott 152 was operational in 1950 (Kaisler, 2016).

The Elliott 152 demonstrated some advanced techniques in computer construction such as the use of printed circuits on glass plates, plated through holes in printed circuit boards, use of semiconductor diodes, and plug-in units. All of which (except glass plates) would become standard units of construction in the following years.