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PROJECT STRETCH
FILE MEMO #5

COMPANY CONFIDENTIAL

SUBJECT: Input/Output

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The logical organization of Stretch's Input-Output section will be examined for ease of programming and efficiency of operation. Section 1 will describe briefly the basic I/O instructions and the logical execution of these instructions. Special conditions of I/O operations will be described in Section 2. Programming examples will be included to indicate the ease of handling normal I/O operations and special I/O conditions. A third section will describe the equipment involved in I/O operations and alternative equipment that may be used to increase speed of I/O operation.

Section 1

A basic tape I/O operation is reading or writing a record. Data transmission can be executed in two steps: (1) selection of I/O unit, and (2) setting number of words to be transmitted and assigning memory locations. These two steps may be programmed as two instructions:

	Read/Write Select	m	
#1	Load I/O Control word	m	x
		unit	

A Read Select m[1] causes the I/O unit specified by m to be started in motion. In order that tape speeds can be effectively and easily matched with computer speeds, I/O information is transmitted through a single word buffer. When the RDS instruction is executed the selected tape unit is connected to one of the tape buffer units. If there are no available buffer registers, the execution of the RDS instruction will be delayed until a buffer register is available.

If the I/O unit m is already in operation, the execution of the RDS instruction will be delayed until the unit is ready to accept the RDS instruction.

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1. m can be any number between 1 and 99.

Transmission of data between storage and the tape unit is controlled by a register termed the I/O control register. The I/O control register determines if another word is to be transmitted and the location of the data word in memory. After a word is transmitted, the word count (n) is decreased by 1 and the storage location of the data (DWA) increased by 1 (decreased by 1 if executing a Read Backwards instruction). When a buffer unit is ready to store in memory or needs a new word from memory, a signal is sent to the I/O C R to control transmission. As the I/O CR can concurrently control and coordinate the operation of multiple buffer units, the control information for a particular tape unit must be stored when another unit needs servicing.

Each I/O unit is semi-permanently assigned (1) a memory location (or Transistor Register) to hold control information for a tape unit when the I/O Control Register is in use. This word is termed the I/O Control word. When the contents of an I/O Control word are brought into the I/O CR, the number of the I/O unit associated with the information is retained in the I/O CR. Control information is brought into the I/O Control word by the execution of Load I/O Control Word. (LCW). LCW m places the contents of X into the control word associated with I/O unit m.

Although a record generally is stored in consecutive memory locations, there are applications where it is desirable to break a tape record into several groups. When a record is broken into groups, that are not necessarily stored in consecutive memory locations, the I/O CR can alter the storage address of data without special programming effort that would interrupt data processing. Alternation of the data storage address by an arbitrary amount is accomplished by carrying a reference to the next control word in the I/O Control word. This reference, termed ANG, is effective when the word count (n) for a group becomes zero. When the word count for a group (n) becomes zero the contents of the memory location specified by ANG, becomes the control information for the I/O unit being serviced.

Transmission of data between storage and the I/O unit can be terminated in three ways. (1) When a record is being read, the connection between the I/O unit a buffer and storage is suspended by an end of record gap (or mark). (2) Transmission is suspended by making ANG of a control word equal zero. When the word count (n) and the control reference (ANG) are both zero, the tape unit disconnects from the buffer and storage. (3) A field in the I/O Control Word, termed B, will cause the selected I/O unit to be disconnected from the buffer.

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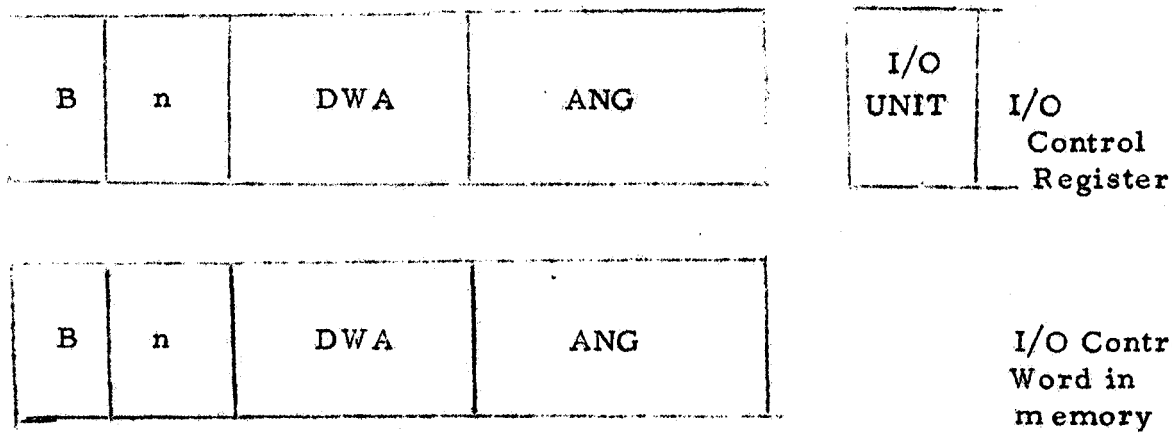
1. Contents of program counter and ANG field of CW are exchanged.

When reading, the tape continues in motion until the end of record gap is reached. In addition to disconnecting the I/O unit, the presence of the B field will cause a transfer of control to the locations specified by ANG. The previous contents of the program counter are stored in the control word (1). If the contents of ANG are zero, no transfer is effected, and the I/O unit is disconnected. Figure 1 shows the layout of the control word register and a control word in memory.

Figure 1



Where

B = break in bit
n = no. of words in group
DWA = memory location of data word
ANG = memory location of control word for next group

Execution of a LCW (Load I/O Control Word) instruction, LCQ m X, will cause the contents of memory location X to be loaded into the I/O Control Word for I/O unit m.

After a unit has been selected, and the I/O control word loaded, the transmission of a record between the tape and memory is essentially independent of processing. When memory cycles are needed, these cycles will be captured by the I/O section of Stretch without special programming effort. Figure 2 gives a schematic picture of the I/O section of Stretch.

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1. Refer to footnote, page 2

Figure 2
11/17/55
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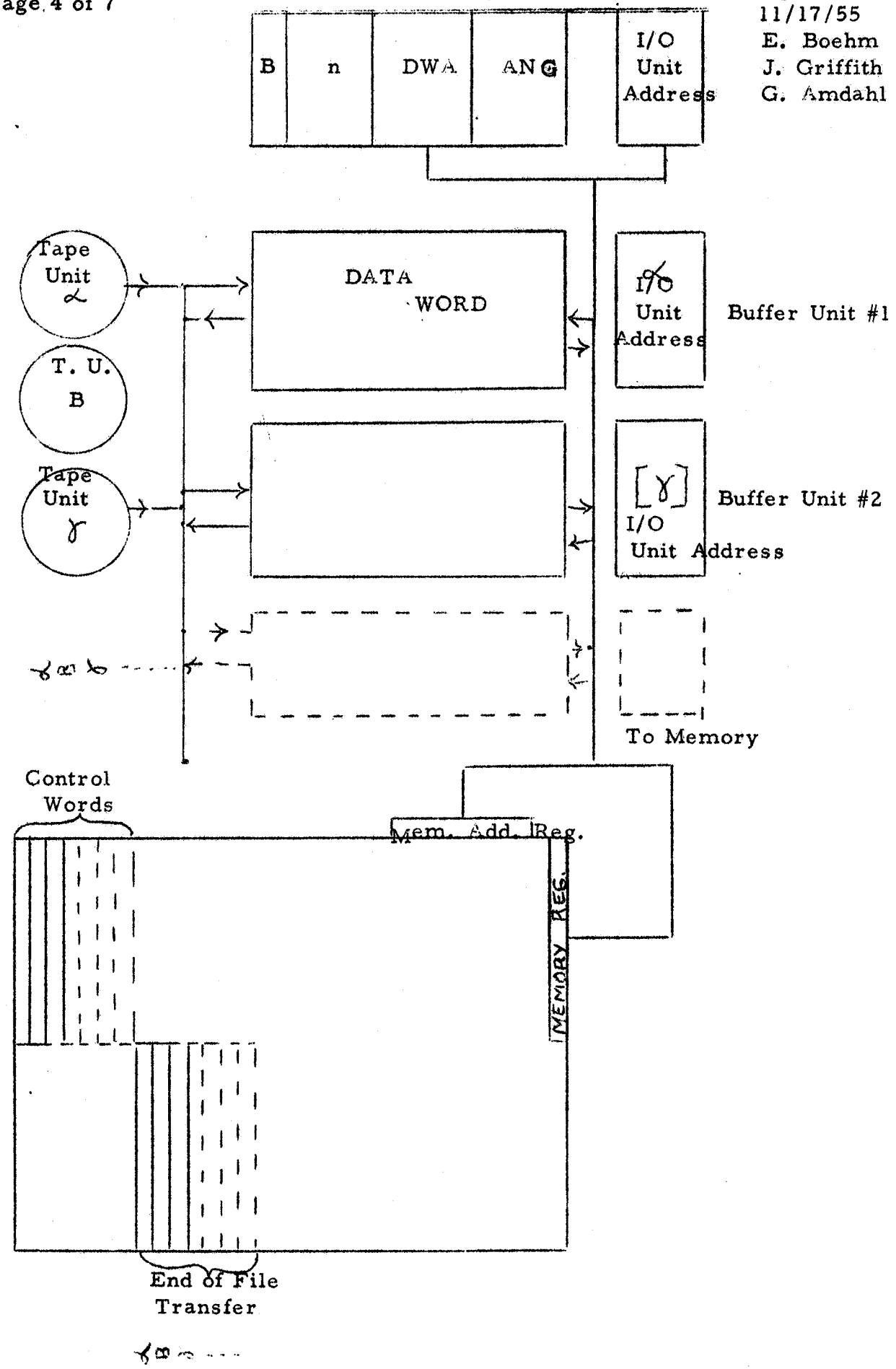

When a record is being read from tape and the buffer becomes full, a signal is sent from the buffer unit to the I/O Control Register. Upon receipt of this signal, the I/O unit address of the I/O CR is compared with the I/O unit address of the buffer sending the signal. If the two addresses are the same, the contents of the buffer are sent to the memory location specified by DWA. As data is transmitted, n is decreased by 1, and DWA is increased by 1. (DWA is decreased when Reading backwards). If the two I/O addresses do not match, the contents of the I/O CR are stored in memory at the location determined by the I/O unit address. The I/O CR is then loaded with the contents of the I/O Control Word corresponding to the unit requiring service. The new I/O unit number is loaded into the I/O control register. Data is then read into storage. If the I/O CR is servicing an I/O unit, when a tape buffer signals a need for service, the usurping of the I/O CR will be delayed until the previous servicing operation is completed. With many I/O units concurrently in action, it is possible for several units to require service at any one time. Buffer units will be assigned semi-permanent priorities which will enable the I/O CR to service the I/O unit with the most critical timing problem. For example, the buffers assigned to tapes will be assigned a priority higher than one used by cards or typewriters. If tapes move at speeds approximating 727 speeds, at least 10 tape units may be operated concurrently by the I/O CR.

Figure 3 summarizes the operation of Stretch's input/output section for the alternative contents of the I/O Control register.

	n_i	DWA	ANG	B	Execution
1.	$\neq 0$, n	i	$\neq 0$ [x]	OFF	C (Buffer) $\rightarrow$ Li, i $\Rightarrow$ i + 1, n $\Rightarrow$ n-1
2.	= 0	i	= 0 [x]	OFF	C (x) $\rightarrow$ I/O Control Register
3.	$\neq$ 0	i	= 0	OFF	Same as Case #1
4.	= 0	i	= 0	OFF	Disconnect I/O unit and Buffer.
5.	$\neq$ 0	i	$\neq$ 0 [x]	ON	C (P, C) exchanged with C (I/O CW [ANG])
6.	= 0	i	$\neq$ 0 [x]	ON	Same as Case #5 } disconnect
7.	$\neq$ 0	i	= 0	ON	} I/O unit & Buffer
8.	= 0	i	= 0	ON	}

FILE MEMO # 5 November 17, 1955

An illustrative program to write a record on tape 1 - from memory locations 1000-1276, 1500-1644, 1300-1304 is as follows:

	RDS	1
+1	LCW	1 α
+ 2	Processing instructions	

	B	n	DWA	ANG
α		277	1000	α+1
α +1		145	1500	α+2
α +2		5	1300	O

In addition to the I/O instructions described above, Read Select, Read Backwards Select, Write Select and Load I/O Control Word, there are instructions which select the operation and load the control word. These three instructions, Read and Load I/O CW, Read Backwards and Load I/O CW, and Write & Load I/O CW will be executed in the same manner as the separated Select and Load I/O CW instructions.

Sinultaneous I/O and computation combined with independence of the two functions permits one function to operate at different speed than the other. In order that the program will not attempt to process data not yet transmitted to the memory, two instructions are provided to test the contents of the I/O Control Word.

1. Compare I/O c.w. DWA - m - compare the absolute value of the control acc. with DWA of the I/O c.w. indicated by m. Set the control compare and equal selectors. Leave the contents of the control accumulator unchanged.

2. Compare I/O c.w. n - m - Compare the absolute value of the control accumulator with n of the I/O c.w. indicated by m. Set the control compare and equal selectors. Leave the contents of the control accumulator unchanged.

A program to insure that the 5th word of a 20 word record on tape 2 has been transmitted to storage before processing continues maybe written as:

```
α   Load CA                    B    program delay until 5th
α+1 Compare I/O c.w. n         2    word of record transmitted
α+2 Tr high I/O c.t.           α+1  to storage
α+3 process data
```

A program illustrating the use of the breakin bit follows:

```
α   Load C A    B          }
α+1 Comp. I/O CW m 2       }  test to see if 5th word of record
α+2 Tr Hi I/O  CR m α+1    }  has been read and stored.

α+3 Load CA X1    A0       }
α+4 Comp CA X2    D0       }  Test of 5th word to determine if
α+5 Tr Eq         α+x+7    }  rest of the record should be read
                           }  in.

α+6 Set B bit in I/O CW  m }  Disconnect the tape if the record
α+6.1 Tr                   }  is not to be processed.

α+7 Process record
```

In this case, a determination is made to see if the record is to be processed. If not, the tape unit is disconnected for the duration of the record, and reselected before the next record is reached. The act of disconnecting the tape for the duration of the record allows the available memory time to be used for other I/O processes and useful work.

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