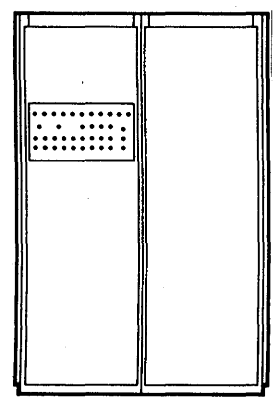
COMPUTER CONTROL

SPECIFICATIONS



THE TRW-330 DIGITAL CONTROL COMPUTER

TRW Computers Company

a division of ***Thompson Ramo Wooldridge Inc.***

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DESCRIPTION OF THE TRW-330 COMPUTER

INTRODUCTION

TRW digital computers designated as the TRW-330 series are "second generation" computers. Their design is based upon the extensive experience of TRW Computers Company in the application of digital control computers to industrial processes.

The TRW-330 is a medium-speed, serial machine with extremely flexible digital and analog input-output facilities, and adaptable command structure and memory size. The rack-and-panel construction of the TRW-330 permits the computer to be assembled in a variety of forms, and the computer can be supplied in cabinets that will withstand rugged or hazardous industrial environments. Thus, each model of the TRW-330 series is designed to meet the requirements of a specific customer. Although the initial investment in a TRW-330 system can be limited to meet the immediate requirements of an installation, TRW-330 systems can be expanded later to accommodate an expanding plant or a more extensive control system.

Six computers of the TRW-330 series have been ordered or installed. One TRW-330 is controlling program switching at television station KNXT, the CBS outlet in Los Angeles. Two TRW-330 computers are now being installed for data gathering and toll registration on one of the nation's most heavily traveled thoroughfares. Two TRW-330 computers have been ordered by TVA for their Paradise Units 1 and 2 power generating stations in Kentucky. One TRW-330 will be used by Great Lakes Steel Corporation for control of their basic oxygen steel furnaces in Detroit.

Because it is a second-generation computer, the TRW-330 is very reliable. It uses many of the field-proved circuits and components of the RW-300 Digital Control Computer. RW-300 computers have operated over 300,000 hours, and have an up-time record of better than 99 percent. The same conservative design techniques that have resulted in excellent RW-300 reliability ensure the reliability of the TRW-330.

MEMORY CHARACTERISTICS

The memory of the TRW-330 is a magnetic drum that rotates at approximately 3600 rpm. Divided into 64 tracks of 128 words per track, the basic memory capacity of the TRW-330 is 8,000 words. The memory is expandable to over 132,000 fully addressable words in blocks of 4,096 words.

Parity bits generated and stored with each word written into memory are checked with each word read out of memory; if a parity error occurs, the parity flip-flop is set and a parity error light on the computer control panel is lit. A command -- "jump on parity error" -- can be used by the programmer to exit to a routine that handles a parity error.

Average access time in general storage is 8.3 milliseconds. A fast-access track with a capacity of 128 words is provided. For this track, average access time is 2.1 milliseconds. A one word fast-access register reduces access time to 130 microseconds.

The TRW-330 memory has permanent storage tracks that accommodate programs (e.g., load program) that should not be altered by computer programmers or operators. Other tracks are "guarded". The guarded storage features of the TRW-330 provide memory protection to a degree that is unattainable in a core memory. Program-writable tracks are also provided.

WORD FORM

The TRW-330 data word is composed of 28 bits, including sign; a 29th bit is used as a parity bit. The number system is two's complement, fixed-point binary.

A modified single-address instruction system is employed. Instruction words are composed as shown on the following page.

REGISTERS

The basic arithmetic register is a 28-bit accumulator, or A register. The 28-bit B register is both an extension of the A register and a secondary arithmetic register. The 16-bit C register and the 28-bit D register supplement the A and B registers. The B, C, and D registers are addressable, permitting their contents to be used as operands.

The 16-bit index (I) register can be loaded, switched, or decremented by any amount. Any instruction that is indexed (a 1 in bit position 19) uses the index register as a modifier of the operand address. The index register facilitates counting, loop control, and similar functions.

An 8-bit X register is used for shift-and-count operations.

In addition to the A, B, C, D, I, and X registers that operate under program control, the TRW-330 has the usual complement of control registers.

COMMAND STRUCTURE

The TRW-330 has an extremely flexible command structure. The standard instruction repertoire (listed in Table I) contains several commands, such as square root and a variety of scans, that are particularly useful in process control. In addition to the standard commands, special commands suited to the user's application are also available.

The basic operation codes are modified by bits 25, 26, 27, and 28 which specify the "mode" of operation. These modes of operation afford the TRW-330 a calculating speed higher than that normally attained by a computer employing a drum memory.

Bit	Octal	Significance	
29		parity	
28, 27		delayed mode operand mode	The "mode of operation" is discussed in the paragraph titled <u>Command Structure</u>.
26, 25		execution code	
24, 23, 22, 21, 20		basic operation code	The 32 possible basic operation codes are modified by the "mode" of operation, as specified by bits 25 through 28.
19		index indicator	
18		spare bit	
17		These bits normally specify the track address of the operand.	In operand mode, bits 1 through 16 contain the operand.
16, 15, 14	E		
13, 12, 11	F		
10, 9, 8	G		
7	J	These bits normally specify the sector address of the operand.	
6, 5, 4	I		
3, 2, 1	J		

ABCD EFG HIJ

In mode N, called the "normal mode", the address of the next instruction is the address of the last instruction, incremented by two. Instructions are stored two words apart and the operand is stored between the two commands on the same track, or on any other track.

In mode D, called "delayed mode", (controlled by Bit 28), the location of the next instruction is one word after the sector address of the operand, but on the same track as the last instruction.

In mode O, called "operand mode", (controlled by Bit 27), the operand is the 16 least significant bits stored in the command itself.

OPERATING SPEED

With optimum storage locations, all commands except block transfer, multiply, divide, shift, scan, and square root are executed in two word times, or 260 microseconds. Word blocks of from one to 128 words are transferred from any one track to any other track in 33.5 milliseconds. Full-length (27-bit operands) multiply commands are executed in 4.1 milliseconds.

The maximum instruction rate is 3840 instructions per second. Operating speeds for typical programs range from 800 to 1200 operations per second, depending upon the nature of the program. Optional commands available with the TRW-330 can reduce total computation time for specific applications.

PROGRAM INTERRUPT FEATURES

The TRW-330 is equipped with a highly sophisticated automatic interrupt capability. As many as 112 interrupt lines can be connected to the computer. The priority interrupt system can handle multiple interrupts on these lines in the order of their importance with respect to each other and to the program in progress. Thus the program can be interrupted only by a higher priority function.

When an interrupt signal is received, the TRW-330 automatically stores the address of the next instruction as a re-entry address, and enters the appropriate interrupt routine. After the interrupt has been processed, the computer transfers to the re-entry address and continues the interrupted program.

The priority interrupt system can inhibit other interrupts during the processing of an interrupt; or it can inhibit interrupts of a lower priority from entering while allowing higher priority interrupts to break in. Thus the interrupt with the highest assigned priority will always be completely processed first.

DIGITAL INPUT AND OUTPUT FACILITIES

The TRW-330 can have several thousand addressable digital input lines. These lines can supply on-off type information to the computer system (such as operational status of contacts, switches, etc.), as well as coded digital information (from tape readers, digital clocks, etc.).

In some applications of the TRW-330, automatic digital inputs applied directly to memory have been used to accumulate a count of events as they occur, without interrupting the computer's control or data-gathering program. This automatic counting capability permits the TRW-330 to record switch closures that occur at rates up to 60 per second.

Several thousand addressable digital output lines may be included to supply on-off or binary-coded information to paper-tape punches, automatic typewriters, displays, indicators, relays, etc.

ANALOG INPUT AND OUTPUT FACILITIES

The TRW-330 analog input-output subsystems are designed to meet the requirements of each installation.

Analog inputs are converted to digital values and digital outputs to analog values by the analog input-output subsystems. Analog inputs are from process instruments that measure pressures, flows, temperatures, and other process operating conditions; analog outputs are voltages or currents used to regulate setpoints, adjust controls, and drive trend recorders.

The analog input subsystem can accept up to 1024 analog input signals with conversion **accuracies within 0.1 percent. The computer can accept analog input signals in ranges** of either zero to +10.23 volts, or -10.23 to +10.23 volts. Signals from thermocouples and other instruments with low-level outputs are filtered to attenuate noise, and are amplified before being applied to the analog subsystem. Through a relay-selection technique, a single variable-gain amplifier can accommodate all input signals, both high- and low-level. Amplifier gain is controlled by bit patterns associated with individual inputs.

Digital equivalents of instrument values are stored in the drum automatically at the rate of 60 per second. The sequence in which values are recorded is controlled, independent of program operation, from an analog control track. The contents of the control track itself can be changed by the computer program, so that instrument values can be read in any desired sequence and frequency. In this way, certain values can be **sampled every second (or more frequently); some every five seconds, some every minute, and so on. With a single scan command, alarm limit scanning of an entire analog input track can be performed automatically in 34 milliseconds.**

As many as 128 separate analog outputs can be supplied. Analog outputs to incremental servos or stepping motors can be either automatic or under program control. The output signals can be provided either as constant-voltage or constant-current sources. In case of power failure, or equipment failure of any kind, the output circuitry remains set at the last available setpoint.

FAIL-SAFE SYSTEM DESIGN

A fail-safe detector is normally employed in all control systems designed by TRW Computers Company. This device guards against the possibility of the computer losing its place in the program due to a variety of causes, such as a partial malfunction of a circuit. Periodically the program must reset this timing device, which is independent of the computer. If the device fails to get a reset signal, it signals the computer to resume its programmed calculations at a preassigned starting point; if the malfunction persists, the fail-safe detector sounds an alarm to alert the operator.

TRW-330 PROGRAMMING AIDS

Programming aids for the TRW-330 include loading, assembling, verifying, tracing, diagnostic, documentation, and equation interpretation routines. Also, a TRW-330 simulator routine is available for use with the IBM 7090 computer. This routine allows the user to check out TRW-330 programs off-line or allows the user to have all programs written and verified prior to receiving the TRW-330.

Symbolic operation codes that are used with an assembler routine have been chosen for their mnemonic characteristics.

TABLE I

Typical TRW-330 Instruction List

Instruction	Mode	Indexable	Remarks
Load A	N, D, O	x	
Load B	N, D, O	x	
Load C	N, D, O	x	
Load D	N, D, O	x	
Load I (Index reg.)	N, D, O	x	
Load X	N, D, O	x	
Store A	N, D	x	A "1" in bit 25 makes this a "repeat" command; storage continues in sequential sectors, controlled by number in X register.
Store B	N, D	x	
Store D	N, D	x	
Add	N, D, O	x	
Subtract	N, D, O	x	
Multiply 7	N, D, O	x	See note 3
Multiply 14	N, D, O	x	
Multiply 21	N, D, O	x	
Multiply 27	N, D, O	x	
Divide 7	N, D, O	x	See note 3
Divide 14	N, D, O	x	
Divide 21	N, D, O	x	
Divide 27	N, D, O	x	
Square Root	N, D, O	x	

TABLE I (Continued)

Instruction	Mode	Indexable	Remarks
Reduce I	N, D, O	x	
Merge	N, D, O	x	
Extract	N, D, O	x	Bits 18 through 28 of A set to zero in Operand Mode.
Shift A Right	Arithmetic Open		See notes 1 and 2 for definition of shift modes.
Shift A Left	Arithmetic Open		
Shift A Left	Logical Open		
Shift A Left	Logical Closed		
Shift A Right	Logical Open		
Shift A, B Left	Arithmetic Open		
Shift A, B Right	Arithmetic Open		
Switch A and B	N		
Switch A and C	N, D		
Switch A and D	N, D		
Switch A and X	N		
Clear A and B	N, D		
Complement A	N		
Jump Unconditionally	N	x	
Jump on Overflow from Shift, Add, or Subtract operations	N	x	
Jump on Parity Error	N, D	x	
Stop and Jump	N		
Jump on Low Bit in A-Register	N	x	
Jump on Index Register Non Zero	N	x	
Jump on $\pm$ Zero A-Register	N	x	
Jump on Negative A-Register	N	x	
Record Next Instruction and Jump	N	x	
Block Transfer		x	See note 4
Scan	N, D	x	
Special Scan	N, D	x	
Digital Scan	N, D	x	
Start Analog Scan	N, D	x	
Activate Control Signal	N, D		
Digital Input			See note 5
Digital Output			See note 5

TABLE I (Continued)

NOTES

1. Definition of shift modes

   (a) Arithmetic Shift

      1. Fill with sign bit on right shift and zero's on left shift.
      2. Indicate overflow on left shift.
      3. Do not shift sign bit on left shift.

   (b) Logical Shift

      1. Always fill with zeros.
      2. Never indicate overflow.
      3. Sign bit treated as any other bit.

   (c) Open Shift - Bits shifted out of the register are lost.

   (d) Closed Shift - End around, ring, or circular shift.

   (e) Double Length Shift

      When A & B are both shifted, they are treated as one register of 55 bits plus sign bit.

   (f) All left shifts in operand mode are floating shifts (shift and count).

2. The number of shifts is specified by the Operand Address field.

3. Multiply and divide can be performed in quarter, half, three-quarter, or full word length increments.

4. The block transfer command transfers a block of words from any track to any other track. The beginning address of the block is specified by the Operand Address field. The end sector of the block is contained in the C-register. Maximum block length is 128 words.

5. The Digital Input-Output commands can address several devices. These devices are specified by the Operand Address field. Typical devices are operator's control lights and switches, paper tape punches and readers, contact closures, and relay drivers.

6. The B, C, and D registers are each assigned a track address; thus these registers are addressable as memory cells. This feature provides the equivalent of the following commands:

B → A	C → B	A → C	B → D
C → A	D → B	A → D	C → D
D → A	A → B	B → C	A + B

TABLE I (Continued)

A + C	A $\oplus$ C	I - C	A = C
A + D	A $\oplus$ D	I - D	A = D
A - B	B $\rightarrow$ X	A x B	A $<$ B
A - C	C $\rightarrow$ X	A x C	A $<$ C
A - D	D $\rightarrow$ X	A x D	A $<$ D
A $\otimes$ B	B $\rightarrow$ I	A $\div$ B	A $>$ B
A $\otimes$ C	C $\rightarrow$ I	A $\div$ C	A $>$ C
A $\otimes$ D	D $\rightarrow$ I	A $\div$ D	A $>$ D
A $\oplus$ B	I - B	Jump on A = B	

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