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DATA ACQUISITION SYSTEM FOR THE HAMILTON
STANDARD W2 ELECTRON BEAM WELDER

James Hopwood
Model Shops and Inspection Division 8423
Sandia Laboratories, Livermore

ABSTRACT

A data acquisition system has been designed which will perform on-line weld-parameter sampling. It is a microprocessor-based program controller and calculator. The parameters sampled are beam current, accelerating voltage, focus-coil current, workpiece rpm, and filament voltage. Sampling in analog form occurs in pre-selected angular-rotation increments from 1 to 9 degrees. There are three data printout options: A, all data displayed; B, only out-of-tolerance values displayed; and C, differences between nominal and sampled values in excess of preselected error bands displayed. A magnetic tape cart-ridge unit allows long-term data storage and easy retrieval.

This report is a manual for system operation. It also describes the design--logic principles, circuitry, and programming--in detail.

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Introduction

The precision of the Hamilton Standard Electron Beam Welder is dependent upon five parameters: beam current, accelerating voltage, focus-coil current, workpiece rpm, and filament voltage. Experience has shown that there are often fluctuations in one or more parameters during a weld and that this can affect weld quality. It was for the purpose of monitoring these fluctuations that a data acquisition system was designed.

The system is a microprocessor-based program controller and calculator. On-line sampling in analog form of all five parameters occurs in preselected angular-rotation increments from 1 to 9 degrees. If 1-degree increments are selected, sampling will occur for each degree of workpiece rotation up to a maximum of 3 revolutions. For 9-degree increments, 27 revolutions are the maximum.

Each sampling is converted to a 3-digit binary coded decimal (BCD) and stored in a 16K x 4-bit word on-board read/write memory. After the welding operation, the operator selects one of three output format options, labeled A, B, and C. The stored data are then read from memory, calculations performed, and the appropriate output transmitted to a Texas Instruments Model 733 data terminal. If option A has been chosen, all acquired data are printed in columnar format. If option B has been chosen, the measured values are compared with nominal and error-band values which the operator has entered via the data terminal prior to the welding operation and only those measured parameters which are outside the error band are printed. If option C has been chosen, the measured values are, as for B, compared with nominal and error-band values, but now the amount that each parameter falls outside the error band is printed. The latter two options permit a quick view of the weld parameters so that the welding engineer can correlate perturbations in the weld with fluctuations in parameters.

To check system operation, there is a compact welder simulation unit which can be readily substituted and used to enter known parameter and error-band values into the system.

An additional storage medium is provided. A magnetic tape cartridge system manufactured by Tri-Data Corporation will record the stored data for future comparison and possibly manipulation and plotting by a computer.

System Operation

Figure 1 is a photograph of the complete data acquisition system. Figure 2 shows the central unit, which samples the data and performs the required calculations. It fits in a standard 19-inch rack and is 6 inches high.

Depressing the START button prompts the program to ask the operator (through the terminal printout) for nominal parameter values, error-band values, and the workpiece rotation angle between each data sample. The operator first sees

TYPE NOMINAL

RPM =

on the printout. The response must be in the form XX.X. Similar requests for nominal values of high voltage (HV), beam current (BC), focus current (FC), and filament voltage (FIL) then follow. After the operation response to "FIL", the program prompts the terminal to write

TYPE ERROR BAND

RPM =

Upon receiving a response in the form X.X, the program requests the remaining error-band values. The final request is

STEP = ,

in response to which the operator types any integer from 1 to 9, corresponding to the number of degrees between each data sample. The program then prompts the data terminal to print the abbreviation of each parameter followed by a summary of the nominal and error-band values in the same columnar format. Figure 3 shows an example of the entire printout discussed thus far.

If at any time thereafter it is desired to change the operator-selected inputs, activating RESET followed by START will return the program to the interrogation sequence.

Next, the program waits for a signal from the shaft encoder. Data acquisition and storage in the on-board read/write memory occur after the workpiece has rotated through each commanded increment.

Depressing the STOP button after the welding operation is completed (or, sooner, whenever welder parameter information is desired) followed by activating the PRINT switch causes the program to ask for the print option: A, B, or C. If A is chosen, all data are printed in the same format as the summary of nominal (operator-selected) values immediately above. If B is chosen, only out-of-tolerance data are printed and each value is labeled since there is no fixed format.

Figure 1. Complete Data Acquisition System for the Hamilton Standard Electron Beam Welder.
(Top to bottom: Texas Instruments Model 733 Data Terminal Central Controller and Calculator, Tri-Data Corporation Magnetic Tape Cartridge Unit, and Welder Simulation Unit)

Figure 2a. Front View of Central Processing and Control Unit

Figure 2b. Rear View of the Same (Cables from the data terminal and magnetic tape unit attach at J_2 and J_3 , respectively. Lines from the welder, or simulation unit, attach to the TB1 array.)


```

TYPE NOMINAL
RPM=02.0
HV=90.0
DC=31.0
FC=42.0
FIL=97.0
TYPE ERROR BAND
RPM=0.2
HV=1.0
DC=1.0
FC=1.0
FIL=1.5
STEP=1
DEG  RPM  HV  DC  FC  FIL
    02.0 90.0 31.0 42.0 97.0
    0.2  1.0  1.0  1.0  1.5

```

Figure 3. Sample Printout Showing Operator-Selected Nominal and Error-Band Parameter Values Followed by the Summary of the Same

If C is chosen, the terminal prints the magnitude and sign of the parameter fluctuations where they exceed operator-selected error-band values, again in the same format as the summary of nominal values. Examples are shown in Figure 4. Note that if the step command is 1 (degree), the numbers in the left-most column are truly the degrees of angular travel. For any other step command $X = 2, \dots, 9$, the number of degrees of angular travel is found by multiplying by X . Since the RAM has a storage capacity for 1088 data points, the number of complete revolutions is given by $1088X/360$ rounded down to the nearest integer.

After 1088 lines are printed, the word END is printed and the program jumps to its initial state. Activation of PRINT allows a different print option for the same data.

Activating the RESET switch permits the operator to interrupt one print option before it is completed and, after activating PRINT, choose a new option.

When the system power is switched off, the data are lost. If it is desired to save the data, activation of the LP switch (load point) causes the tape in the magnetic cartridge unit to advance to a reflective marker which indicates the beginning of the tape. When this has occurred, activation of STORE causes the data to be recorded.

Loading data that are on tape back into the central unit is accomplished activating LP followed by READ MAG TAPE.

If the operator wishes to verify correct system operation, the welder simulation unit can be used to feed definite parameter values into the central unit. Its operation is self-evident from front-panel controls.

DEG	RPM	HV	DC	FC	FIL
02.0	90.0	31.0	42.0	97.0	
0.2	1.0	1.0	1.0	1.5	

TYPE FORMAT CODE A

001	02.0	91.0	29.7	40.9	97.0
002	02.1	91.0	29.7	40.9	97.0
003	02.0	91.0	29.7	40.9	97.0
004	02.0	91.0	29.7	40.9	97.0
005	02.0	91.0	29.7	40.9	97.0
006	02.0	91.0	29.7	41.0	97.0
007	02.0	91.0	29.7	40.9	97.0
008	02.0	91.0	29.7	40.9	97.0
009	02.0	91.0	29.7	40.9	97.0
010	02.0	91.0	29.7	40.9	97.0
011	02.0	91.0	29.7	41.0	97.0
012	02.0	91.0	29.7	40.9	97.0
013	02.0	91.0	29.7	40.9	97.0
014	02.0	91.0	29.7	40.9	97.0

TYPE FORMAT CODE B

001	DC=29.7	FC=40.9
002	BC=29.7	FC=40.9
003	BC=29.7	FC=40.9
004	BC=29.7	FC=40.9
005	BC=29.7	FC=40.9
006	BC=29.7	FC=40.9
007	BC=29.7	FC=40.9
008	BC=29.7	FC=40.9
009	BC=29.7	FC=40.9
010	BC=29.7	FC=40.9
011	BC=29.7	FC=40.9
012	BC=29.7	FC=40.9

TYPE FORMAT CODE C

001	-0.00	+0.300	+0.100
002	-0.00	+0.300	+0.100
003	-0.00	+0.300	+0.100
004	-0.00	+0.300	+0.100
005	-0.00	+0.300	+0.100
006	-0.00	+0.300	+0.00
007	-0.00	+0.300	+0.100
008	-0.00	+0.300	+0.100
009	-0.00	+0.300	+0.100
010	-0.00	+0.300	+0.100
011	-0.00	+0.300	+0.00
012	-0.00	+0.300	+0.100

Figure 4. Sample Printout Illustrating Options A, B, and C

Overall Central Unit Design

The entire system is contained on 20 printed-circuit cards. Three cards encompass the programmed logic system (PLS 443) containing the microprocessor and stored program. These were purchased from Pro-Log Corporation of Monterey, California. The remaining 17 cards were designed and fabricated in-house. Four of these cards contain the analog-to-digital converters and operational amplifiers which interface and condition the analog signals from the welder prior to their input to the A-to-D converter. This conditioning includes (1) buffering to prevent loading of the welder, (2) filtering to remove the 60-cycle and 180-cycle ripple component present in the welder circuitry due to the high-voltage power supply and 3-phase motor-generator, and (3) amplification to bring the signal within the working range of the converter (0-10 V). The four cards to the left of the PLS contain the 16K x 4-bit RAM which stores all measured parameter data acquired during the previous weld. One card contains the National Semiconductor 57109 floating-point arithmetic unit (FPAR) and associated circuitry, which performs the arithmetic operation and gives the microprocessor system great calculating power.* The remaining eight cards contain the logic circuitry necessary to interface to the magnetic tape unit, data terminal, front-panel switches, input-data multiplexers, and miscellaneous control circuitry.

Figure 5 is a simplified schematic of the beam current and focus coil circuitry within the welder showing the modifications which permit parameter sampling. To measure the beam current, the circuit is split at wire #420 at 61 TB, and a 100-ohm precision resistor inserted. The voltage developed across the resistor is used to measure the beam current. For example, 4 V corresponds to 40 mA. This voltage also drives a digital voltmeter mounted within the operator's console.

To measure the accelerating voltage the circuit is split at wire #421 at 61 TB, and a 750-ohm precision resistor inserted. By inserting this resistor in the 75-megohm 2-MA bleeder string, the voltage developed across the resistor becomes directly proportional to the accelerating voltage. For example, 1.5 V (resistor) corresponds to 150 kV (accelerating voltage).

The focus coil current is measured by means of a 1-ohm precision resistor between wire #224 and #225 in the focus-coil power supply. Thus 1 amp corresponds to 1 volt.

* For complete details on the FPAR see D. C. Macmillan, "A Floating Point Arithmetic Unit for Pro-Log Based Control Systems," Sandia Laboratories Report SAND77-8041, 1977.

Figure 5. Parameter Sampling Locations in Welder Circuitry

Figure 6 is a block diagram of the data acquisition system. The program is stored in read-only memories (ROMs) within the program logic system. A total of 16 Intel 1702 ROMs contain almost 4,000 instructions. The PLS has 8 ports; 2 are wired for input and 6 for output.

A large amount of data must pass into the microprocessor through inport 0. To accomplish this, a series of 3 cascaded multiplexers are wired to the data sources. The program selects specific data by first activating the appropriate multiplexer address lines and then reading inport 0.

Prior to reading in parameter values, the program issues a Start Conversion command. The analog data are converted to an equivalent BCD number in 17 microseconds. The program then immediately reads the BCD data and stores them in the read/write memory. The FPAR (which performs all calculations), read/write memory, magnetic tape, and data terminal are addressed at appropriate times by command lines from the output ports.

The Texas Instrument Model 733 terminal sends and receives characters at a 300 cps baud rate and prints data in 1 of 3 formats as explained previously.

Logic and Circuit Details

Parameter Measurement Circuitry

Figures 7-10 show the detail schematic of the high voltage, beam current, focus current, and filament voltage measurement and signal conditioning circuits, respectively. The first stage is an operational amplifier connected in a differential configuration to act as a buffer between the data acquisition system and the welder circuit from which the sampling is made. A differential form is necessary because the location of the parameter sampling is above Earth ground and, also, it is necessary to prevent loading of the welder circuitry. The output of the buffer enters a Sallen-Key unity-gain, low-pass filter to remove the 60- and 180-cycle ripple present in the welder beam current circuitry. The filter output is a ripple-free dc voltage which is applied to an amplifier with a gain sufficient to bring the voltage level to the working range of the analog/digital converter. The high voltage and focus current measurement circuit require a gain of 10 whereas the beam current circuit has a gain of 1. The filament voltage measurement circuitry is unique and will be explained later.

The analog/digital converter requires an input voltage of 0 to +10 V. After conversion, the output is a 3-digit BCD representation of the analog input. After receiving a Start/Convert signal, conversion is complete in 17 microseconds. The converter is Model #ADC-L12D2B2 and is manufactured by Datel Corporation.

Figure 6. Block Diagram--Data Acquisition Sy

Figure 6. Block Diagram--Data Acquisition System

Figure 7. High Volt

Figure 7. High Voltage Measurement Circuit

Age Measurement Circuit

Figure 8. Beam

Figure 8. Beam Current Measurement Circuit

Figure 9. Foci

Figure 9. Focus Current Measurement Circuit

Figure 10. Filament Voltage Measurement

Figure 10. Filament Voltage Measurement Circuit

Filament Voltage Measurement Circuitry--The degree of heat of the electron beam gun filament is directly related to the position of an auto-transformer mounted in the operator's console. This transformer is supplied with 100 volts ac. The filament measurement circuitry (Figure 10) samples the voltage at the center tap of the auto-transformer. Any change in the ac supply to the filament is thus detected.

The measurement circuit consists of 2 operational amplifiers, U4 and U5. U4 receives the reference phase which sets the point at which the voltage from the tapped transformer is sampled. The voltage divider, consisting of a 10k ohm and 1k ohm resistor, supply a voltage to the input of the reference amplifier. The point at which the amplifier conducts is set by adjusting the 20k ohm potentiometer connected to the inverting input of U4. The input to the other amplifier U5 is also from a voltage divider connected to the slider of the auto-transformer. Diodes are connected at the output of each amplifier to clip the negative going half of the ac cycle. When U4 conducts it causes a Start/Convert signal, converting the voltage appearing at U5 output. In this manner the same angular part of the ac cycle is sampled each time.

Encoder RPM Logic

The purpose of the encoder RPM logic is to sense the presence of output signals from the encoder and to convert the time between encoder signals to a digital number. To obtain the RPM, the digital number, stored in a 3-stage decade counter, is processed by the microprocessor system by its taking the reciprocal of the number and multiplying by 1000.

A 4-bit binary counter is connected to receive the encoder output signal. (See Figure 11.) It counts down from 4, and when it reaches 0 the one-shot U1-A triggers, reloading the 4 back into the counter. This division is necessary because the fixture used to hold the workpiece has a 4-to-1 gear reduction from the mounting location of the encoder.

When the counter has reached 0, triggering one-shot U-1A, flip-flop U3 is toggled, enabling the 500 kHz oscillator which is made up of gate U4, resistors R3 and R4, and capacitor C5. The oscillator is connected to the input of a 74C195 4-stage shift register.

The output of one-shot U1-A triggers one-shot U1-B which is connected to the shift/load input of the 74C195. Bit 1 (pin 4) is connected to 10 V (logic 1). Because of the 5-microsecond delay effected by one-shot U1-A, the shift/load signal arrives 0.5 microseconds after the first transition of the clock. The clock signal now shifts a logical 1 progressively through on each clock signal. When shifted to the bit 2 position, a load pulse is generated, loading the state of each decade counter U6, U7, and U8 into the 3-stage storage registers U9, U10, and U11. When shifted the fourth time, another clock pulse is generated which loads all zero's in U6, U7, and U8--effectively a resetting action.

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Registers U9, U10, and U11 now contain the number of counts allowed to enter the 3-stage counter between 2 encoder signals.

The clock oscillator operating the counter is made up of U12, R1, R2, and C2. The frequency of oscillation is 6 kHz (166.6 microseconds period). This frequency causes the number in the counter to be inversely proportional to the time between the encoder's signals. For example, if the encoder is turning at 10 RPM and an output signal occurs each degree of rotation, then

$$\frac{\text{RPM} \cdot 360}{60} = \frac{\text{signals}}{\text{sec}} \longrightarrow \frac{3600}{60} = 60 ;$$

$$\frac{1}{\text{signal/sec}} = \text{Period} \longrightarrow \frac{1}{60} = 0.0166 \text{ sec} ;$$

$$\frac{\text{Period}}{\text{Clock Period}} = \text{Count in Register} \longrightarrow \frac{166 \times 10^{-4}}{166 \times 10^{-6}} = 100.$$

The counter is an inverse function of the time between encoder signals. To linearize the curve, the microprocessor and FPAR combination finds the reciprocal as follows (see Figure 12):

$$\frac{1}{100} \times 1000 = 10 \text{ RPM}.$$

The minimum RPM is 1. If it is lower, the 3-stage counter will overflow. Maximum RPM is 30. This limitation is due to the time needed for the microprocessor to fetch and store parameter values before returning to detect another encoder signal.

Send Memory Data to Terminal

This mode of operation fetches data from the read/write memory, performs calculations if necessary, and send these data to the Texas Instrument Model 733 terminal for printout. A schematic diagram is shown in Figure 13.

The program, through output 7, initializes the memory address register (see Figure 14). The 12 address lines A-0 through A-11 select 2 of 4000 locations in memory to be interrogated. To address higher order locations, the appropriate chip enable (CE) line is activated. Since the memory is composed of 4 printed circuit cards, or pages, each page contains 4K of memory. CE1

Figure 12. Counter-Encoder Signal Relationship (X) and Linearized Result (1/X)

Figure 13

Figure 13. Send Memory Data to Terminal

Send Memory Data to Terminal

3

Figure 14. Address Register and Switch Circuits

Figure 15. RAM Data Select

After all addressing is completed, the program pulses the $\overline{CE}$ line, placing data on the D27 lines, and then reads inport 0 into the CPU accumulator. If no mathematical operation is to be performed, the data character is placed on the broadside inputs of the parallel-to-serial shift register through outputs 2 and 6. The shift/load line is activated; then the clock to output 1 begins to shift the character to the terminal at a 300 CPS baud rate.

Write Memory Data to Magnetic Tape

The procedure previously described for sending data to the terminal is identical for this mode of operation, except that now the magnetic tape unit receives the memory data for storage. Refer to Figure 16. Data to be stored are placed on lines DB-1 through DB-8 from outputs 2 and 6. When the read/write clock (RWCL) signal from the tape unit is received through MPX-3 and inport 0, indicating that the tape unit is ready to receive a character, signal WXFR from output 7 first writes the character onto the tape, signal WSTC (write-start) then starts the tape unit, and finally WSPC (write-stop) stops it when data transfer is complete.

Read Input Characters From Data Terminal

In this mode of operation the program enters a wait state until a character is received from the terminal. Refer to Figure 17. When the operator strikes a key, the terminal begins to transmit an 11-bit ASCII coded character word at 300 cps baud rate to the system circuitry (1 start bit, 8 data bits, 2 stop bits). The first bit (start bit) is detected by the microprocessor which responds by issuing clock pulses from output 1 to shift the character word into the serial-to-parallel shift register. After shifting is complete, lines b-2 through b-8 contain the ASCII coded character; b-1 is ignored since it is the start bit and not part of the coded character. The ASCII coded character is contained on data lines D20 and D21 wired to data multiplexer 2. When MPX-2 and MPX-3 are addressed by the program through outputs 6 and 7, D20 and D21 (which represent the alpha-numeric character) are passed to inport 0 and fetched by the microprocessor. The program then branches to perform some action, or if necessary, enter another wait state for the next start bit.

Figure 18 is a detailed schematic of the serial-to-parallel shift register (74164) which receives the ASCII code alpha-numeric character from the data terminal through the LM1489A bipolar to unipolar convertor. The start bit (bit 1) is detected by the program through U8 connected to inport 4. The parallel-to-serial shift register (74166A) receives a character from outputs 4 and 5. The shift/load and clock respectively load the character and then shift it to the terminal through the LM1488A converter at 300 cps baud rate.

Read Data From Tape and Reload to Memory

In this mode of operation the tape unit becomes the source of data. Refer to Figure 19. The microprocessor issues a read-start (RSTC) signal which places

Figure 16.

Figure 16. Write Memory Data to Magnetic Tape

Write Memory Data to Magnetic Tape

Figure 17. Read Input Characters From Term

e 17. Read Input Characters From Terminal

Figure 18. Data Terminal Input and Output Shift Registers

Figure 19. Read Data From Tape and Relo

19. Read Data From Tape and Reload to Memory

the tape unit in the read mode. The tape unit then issues an RWCL indicating that a character is ready to be read. The program, upon detecting the RWCL, responds by acquiring the data on lines D26 and D27 by addressing the MPX-3 multiplexer and inputting the character through input 0. The program then operates to write the character in the read/write memory. Addressing takes place as described previously, but now the WE (write enable) is actuated before the $\overline{CE}$, thereby effecting a write operation. Tape interrogation and memory writing continue until the full 16K locations have been filled.

Data Acquisition and Storage

The schematic is shown in Figure 20. Upon receiving a flag at input 4 from the shaft encoder located on the workpiece within the weld chamber, the program issues the Convert signal from output 1 which causes the analog-to-digital converters to convert the analog signal present at its input to an equivalent 4-bit BCD code (12 lines) in 17 microseconds. The program then operates to acquire these data and store them in the read/write memory. To achieve this, the 3 cascaded multiplexers MPS-1, MPX-2, and MPX-3 are addressed to first pass the high-voltage least significant digit (LSD) into input 0, store this in memory, and then read and store the second digit of high voltage. This sequence is repeated until all parameters are read and stored in the order shown in Figure 20. Characters are stored by addressing the appropriate locations, then activating the $\overline{CE}$ and WE lines as described previously. All input and output ports which are required are shown in Figure 20. Encoder flag detection and parameter storing continues until the memory is full (16K) or the Stop switch is pushed by the operator.

Read Memory and Process Data With FPAR

After parameter data acquisition has been achieved, the operator activates the Print switch, causing the program to ask for a print format code operation (A, B, or C). If option A is selected the program simply interrogates the memory and passes the characters to the terminal in column form. If B or C format code is selected the operation becomes complex since the measured data are compared with nominal and error-band input values. The results of this comparison determine what is sent to the terminal.

The FPAR (National Semiconductor Model 57109) is used to perform all calculations in making the determinations. Figure 21 is a schematic of the FPAR and peripheral control circuitry.

Functional instructions to the FPAR are through the 2-bit Op code I-5 and I-6 from output 3 (see Figure 22). Output characters and the Ready-out (RDYO) and Ready-in (RDYI) lines are directed to the microprocessor to multiplexers 2 and 3 when properly addressed by the program to outputs 6 and 7. Data input to the FPAR is from output 2.

Figure 20. Data Acquisition and Storage

Figure 20. Data Acquisition and Storage

Figure 21. Schematic for FPAR

Figure 22. Read Memory and Process Data

e 22. Read Memory and Process Data With FPAR

When Reset is activated, the programs enter a subroutine called CALRDY which initializes the FPAR by first manipulating the hold line and waiting for certain timing relationships between RDYI and RDY0. A series of 3 commands is then entered: a master clear Op code, followed by an error-clear Op code, and ending with an Op code which has the FPAR accept input in scientific notation. Eight digits, sign, exponent, and exponent sign must be presented to the FPAR in a fixed format (Figure 23a). Figure 23 is a map of the RAM register located within the programmed logic system. It is used during programming for temporary storage of nominal and error-band input values, FPAR input and output numbers, and other miscellaneous storage. The RAM register 0 is always used as input to the FPAR. Prior to an entry function for arithmetic operation, the 12 digits are first arranged in a correct format under program control. After an operation, the result is removed by the output subroutine and placed in RAM register 1 in the format and location shown in Figure 23b; however, the number in the FPAR is retained. Because of timing constraints the number is placed as the FPAR offers it in register 1. Other subroutines then unscramble register 1 contents before moving them to other locations.

Registers 2 and 3 in Figure 23a show the locations where nominal parameter values (entered by the operator prior to the weld) are stored. Values remain until there is a manual reset, they are changed by the operator, or until power is removed. RAM register number 1 (Figure 23b) shows the location of error-band values in register 0. Register 2 contains the number of degrees and is incremented prior to each line of printout. This is the 3-digit number which is printed first.

The programming for the mathematical operation in comparison decisions is shown in detail in the flow chart in Appendix B.

Read/Write Memory

The Read/Write 16K x 4-bit word memory is composed of 4 printed circuit cards, each containing 4K x 4-bit words (1 page). In addition to the memory, page 1 contains a data multiplexer. The output line from each page is wired to input lines on the multiplexer. In this way the program, through address lines RDS-1 and RDS-2, selects the page to be interrogated. Gates U6, U7, and U8 interface the memory address register (see Figure 15) and memory address lines A0-A11 which select any one location of the 4K of memory. After addressing a memory location, the program can read the memory contents by issuing a CE (chip enable) signal. The duration of CE is about 20 microseconds. When the program performs a write operation, data are placed on Din-1 through Din-4, the WE (write enable) line is activated, the CE line is pulsed, and finally the WE is deactivated.

The memory is manufactured by Mostek Corporation with MOS technology. Each unit is packaged in a 16-pin dual in-line configuration and contains 4K x 1-bit capacity. Four such units are mounted on one page to effect the 4K x 4-bit storage capacity.

REGISTER CHARACTER																STATUS CHAR.						
0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	0	1	2	3			
OUTPUT FROM FPDR																8	4	2	1	REG 0	TO FPAR	
					TENS	UNITS	SIGN		D1	D2	D3	D4	D5	D6	D7	D8	SIGN	REGB	REGF			
INPUT TO FPDR																8	4	2	1	REG 1	FROM FPAR	
D1	SIGN	D2	D3	D4	D5	D6	D7	D8	SIGN	TENS	ONES						STEW					
NOMINAL VALUES																8	4	2	1	REG 2		
RPM				HV				BC								CODE						
D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12											
1	2	3	4	1	2	3	4	1	2	3	4											
NOMINAL VALUES																8	4	2	1	REG 3		
FOCUS				FLA																		
D1	D2	D3	D4	D5	D6	D7	D8															
1	2	3	4	1	2	3	4															

Figure 23a. Intel 4002-1 RAM Register Map #0

REGISTER CHARACTER																STATUS CHAR,				
0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	0	1	2	3	
ERROR BAND INPUT VALUES																8	REG 0			
RPM			HV			BC			FC			FIL								
D 1	D P	D 2	D 1	D P	D 2	D 1	D P	D 3	D L	D P	D 2	D 1	D P	D 2						
																8	REG 1			
																4				
																2				
																1				
DEG																8	REG 2			
L S	D 2	M S	D																	
SAVE DATA																8	REG 3			
D 1	D 2	D 3																		

Figure 23b. Intel 4002-1 RAM Register Map #1

Address Register and Switch Circuit

Blocks U-4, U-5, and U-6 in Figure 14 are 3 each, 4-bit binary storage registers used for addressing the read/write memory. The address is placed in the register by the microprocessor by first placing the address at output 7 lines and then activating the appropriate load line L1, L2, or L3 through output 6. Thus the program has the capability of randomly selecting any location within memory.

All front-panel switches are connected to de-bouncing circuits and then to a flip-flop. The Q outputs from the flip-flops are wired to multiplexers, which eventually enter the microprocessor where their active state is detected and appropriate action is taken by the program to perform the commanded function.

Magnetic Tape-Unit Data and Control Circuit

Data to be written onto magnetic tape are first placed at lines DBT-1 through DBT-4 from the microprocessor output 3 (see Figure 24). Since only numeric characters are stored, more than 4 lines are unnecessary. Therefore, DBT-5 through DBT-8 are wired to a permanent logic 0. Data lines from the tape unit are used for both input and output, depending on the status of RM (read mode) and WM (write mode) signal lines. These two lines are used to place the 4126 gates in either a high Z (open switch) state or low Z (closed switch) state. For example, when the tape unit is in the write mode the WM lines go to 0 V, effectively opening circuit U-1. RM is at 5 V, allowing data to pass through gate U3 to be written onto tape.

The right side of Figure 24 shows the signals and corresponding connector pin numbers which pass to and from the magnetic tape unit and microprocessor. The read-write clock (RWC1) signal is applied to a flip-flop because its duration is too short to be detected by the microprocessor. The flip-flop stores the RWCL signal until the microprocessor has time to detect its presence at input 0, after which the program resets the flip-flop from output 5.

Microprocessor Port Assignments

Figure 25 shows all input and output ports of the programmed logic system. All data and control lines associated with each port are shown. Because of the many modes of operation associated with the complete operation, some ports have multiple functions. For example, output 2 supplies data to the tape unit, data terminal, and RAM. This is possible because only 1 unit is activated at any time. A unit being addressed receives the data whereas the other cannot since its control lines are deactivated. This scheme permits multiple operation without increasing the number of ports.

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Figure 24. Magnetic Tape Unit Data and Control Circuit

Figure 25. Microprocessor Port Assignme

Figure 25. Microprocessor Port Assignments

APPENDIX A--MISCELLANEOUS DRAWINGS AND DIAGRAMS

Calibrator

A schematic for the calibrator is shown in Figure A-1. This calibrator permits simulation of parameters for a functional test of the data acquisition system. A connector mounted on the rear of the unit receives the cable from the system which normally connects to the welder. On the front panel of the calibrator there is one potentiometer each for the high voltage, beam current, and focus current. To allow a parameter to be set accurately, a three-way selector switch is used to display, on a front panel digital voltmeter, the value being adjusted.

The simulated filament voltage is fixed at 97.0 V. For the workpiece RPM, a crystal-controlled oscillator supplies a simulated encoder signal. The fixed frequency is equivalent to a constant 2.1 RPM.

Encoder

Figure A-2 is a schematic of the encoder power supply and interface. The encoder, which is attached to the fixture holding the part to be welded, puts out 360 pulses per complete revolution. It is a type 82H360 manufactured by Dynapar Corporation. Noise transients generated by high-voltage discharges within the welding chamber can be transmitted to the data acquisition system electronics and damage components. To prevent this, an optical isolator is interposed between the encoder signal output at the input to the system. Also, the encoder is powered by a dedicated power supply.

Figure A-1. Data Acquisition Calibrator

Figure A-2. Encoder Power Supply and Interface

Figure A-3. Diagram of the Cable Between the Connector Mounted on the Welder (for Parameter Sampling) and the Terminal Strip Mounted on the Rear of the Data Acquisition System

Figure A-4. Wiring Diagram Between Mag Tape Unit and DAS

Figure A-5. Mechan Data A

[illegible]

Figure A-5. (continued)

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5. (continued)

APPENDIX B--PROGRAM FLOW CHART

INSTRUCTIONS, OF DATA ACQUISITION PROGRAM

BEGINNING OF DATA ACQUISITION PROGRAM

3

ROUTE FROM READING CHARACTERS FROM TERMINAL

RIGHTING OF PRINT PROGRAM

PRINT OUT MEASURED DATA 4

OF PRINT PROGRAM

PRINTS OUT MEASURED DATA WHICH IS OUT OF ERROR BAND

CPB-8

PRINTS ALL DATA TO TERMINAL

APPENDIX C--DETAILED SCHEMATICS

Electron Beam Welder Data Acquisition System

Electron Beam Welder Data Acquisition System