27
10-13-82
JWC

(1)

9/16

SANDIA REPORT

SAND82-1744 • Unlimited Release • UC-63d

Printed August 1982

I. 5907

Dr. 911

A Microprocessor-Controlled Photovoltaic-Array Loading Unit

D. Farrell Russell

DO NOT MICROFILM
COVER

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-76DP00789

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

NOTICE: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, any agency thereof or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof or any of their contractors or subcontractors.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A04
Microfiche copy: A01

A Microprocessor-Controlled Photovoltaic-Array Loading Unit

D. Farrell Russell
Electromechanical Component Test Equipment
Division 2312
Sandia National Laboratories
Albuquerque, NM 87185

MASTER

Abstract

This report describes a microprocessor-controlled test system in operation at the Photovoltaics Advanced Systems Test Facility located at Sandia National Laboratories. The test system is designed to measure the total energy output of photovoltaic arrays. This report describes the theory, installation, operation, and calibration of the test system.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Acknowledgment

Significant contributions made by my associates are gratefully acknowledged:

A. E. Verardo - For contributing to the basic design concept and to the initial design of the transistor load bank.

Victor Lira - For preparing the mechanical design layout.

Contents

Introduction	7
System Description	8
Software Description	10
Installation	13
Operation	16
Calibration	18
APPENDIX A — Serial Communications Protocol	21
APPENDIX B — RS232 Communications Adapter Schematic	25
APPENDIX C — Software Listings	27
APPENDIX D — Front Panel Pictorial	51
APPENDIX E — Mechanical and Electrical Drawings	55

Figures

1 Microprocessor-Controlled Array Loading Unit	7
2 Array Loading Unit Block Diagram	9
3 Flow Chart of the Main Control Loop	11
4 Flow Chart of Serial Communications Driver	12
5 I-V Plot and Interrupt Service Routines	13
6 Safe Operating Area of ALU Loads	15
7 Load Operational Block Diagram	17

Tables

1 TB1 Terminal Block Connections	14
2 Display Parameters	17

A Microprocessor-Controlled Photovoltaic Array Loading Unit

Introduction

The Photovoltaics Advanced Systems Test Facility at Sandia National Laboratories evaluates the performances of various photovoltaic array designs. In evaluating the various designs, one useful parameter is a measure of the total energy output of each array over extended operating periods and known conditions, such as solar insolation, temperature, and tracking

parameters. The total energy output of an array is calculated by integrating the maximum instantaneous power output over the desired time period. Measurement of the total energy produced was the primary motivation for the development of the microprocessor-controlled array loading unit (ALU) described in this report. Figure 1 is a photograph of the ALU.

Figure 1. Microprocessor-Controlled Array Loading Unit

System Description

Figure 2 presents a block diagram of the ALU. In operation, the ALU provides a variable dc load for the array under test. The load is basically a bank of power transistors connected in parallel to provide up to 1kW of power dissipation. An analog feedback circuit controls the bank of transistors to maintain a specified voltage across the load. The feedback circuit may set the load voltage in a range from about 2 V (saturation voltage) to as much as 200 V with either manual operation or microprocessor control determining the setpoint. A switch selects either the manual or microprocessor-controlled (automatic) mode. In the manual mode, a dial sets the voltage across the load and consequently the voltage across the array under test. In the automatic mode, the microprocessor determines the voltage to be maintained by the load through the use of an 8-bit digital-to-analog converter (DAC). The DAC allows the microprocessor to load the array at its maximum power point.

In seeking the maximum power, the microprocessor uses its data acquisition capability to read the array current and voltage at a particular load voltage setting. It multiplies numbers corresponding to voltage and current, resulting in a calculated instantaneous power value. The microprocessor then outputs an incremental value to the DAC, and again measures the array current and voltage to obtain a power value at the new load voltage setting. It then compares the two sequential power values to determine the next value to be output to the DAC. Through the above method, the ALU can force the array voltage to seek and dither slightly about the maximum power point.

Time integration of the power values determines the total energy produced over the period of interest. Sequential addition of power values at uniform time interrupts is the actual scheme used in the microprocessor. A crystal-controlled clock generates a periodic interrupt to the microprocessor. At each interrupt, the microprocessor simply adds the current power value to the present energy output value. The energy value was scaled to units of kilowatt hours by choosing a clock period of 0.36 s and dividing the accumulated value by 10; thus

$$\frac{1 \text{ interrupt}}{0.36 \text{ s}} \times \frac{3600 \text{ s}}{1 \text{ h}} = 10,000 \frac{\text{interrupts}}{\text{h}}$$

results in 10,000 additions per hour and

$$\frac{\text{power (watts)} \times \text{hours} \times 10,000}{10} = 1 \text{ kWh}$$

Reset to zero is available by either a manually operated pushbutton switch or a computer-generated command over the serial link.

Another feature of the programmable load is its ability to characterize an array from a no-load, open circuit condition to essentially a short circuit condition. Again this is possible in either the manual or automatic mode. In the manual mode, a front-panel dial sweeps the load through its entire range. In the automatic mode, this capability is accessible over the serial communications link by a command sequence requesting I-V curve data. If the I-V request command is issued, the microprocessor sweeps the load through its entire range, taking data at 64 points. The microprocessor returns the current and voltage values at each point over the serial link as they are taken. After transmitting the last of the data, the microprocessor resumes seeking the maximum power point.

The microprocessor controls an 8 channel multiplexer and a 3½ digit, analog-to-digital converter (ADC) to read the array voltage, array current, and other essential parameters. A voltage in the range of 0 to 2 V represents each parameter. The microprocessor instructs the multiplexer to apply the desired parameter signal to the ADC. It then initiates an analog-to-digital conversion and inputs the resulting value for processing. The system is capable of performing up to 100 conversions per second.

An internal 3½ digit liquid crystal display (LCD) provides readout of various parameters under operator command. A rotary switch on the front panel selects the displayed parameter. The microprocessor reads the encoded switch position to determine which parameter value to output to the display.

The system is also capable of transferring various data values by way of a serial link to another computer for subsequent data processing. The serial link is designed so that several ALUs may share the same line. Each unit has its own address code that the computer must use for access. Only the properly addressed unit will respond with the requested data. For details of the required communications protocol, see Appendix A. Also, Appendix B provides a schematic of an adapter for connecting the serial link to an RS232 interface.

An ac line-operated, ±15 V, 100 mA, modular power supply provides all system power requirements. Onboard regulators supply ±5 V for the logic circuits. The ±15 V supply not only powers the ALU, but also serves as a trickle charger for two 12 V, 6 A·h sealed lead-acid batteries that provide backup power in case of line failure. Due to extensive use of CMOS circuitry, power requirements are typically less than 400 mW, allowing up to 200 h of battery operation.

Figure 2. Array Loading Unit Block Diagram

An internal relay connects the photovoltaic array to the ALU's load bank. The relay may be remotely switched to disconnect the ALU and allow other instruments to monitor and control the array.

Software Description

This section provides a brief description and flowcharts to aid in the understanding and possible user modification of the ALU software. The software is written in 1802 assembly language and resides in 1 K of ROM. No attempt is made at describing the assembly language which is defined in the RCA 1802 User's Manual.

The program consists of four basic parts: initialization, main control loop, serial communications driver, and interrupt service routine. The initialization portion defines and initializes program registers and essential variables. Appendix C contains a documented software listing (indicating 1802 register usage) and a map of system memory. The program stores variables in memory from the least significant digit to the most significant digit. The variables are in an unpacked, binary-coded-decimal, fixed-point format.

The main control loop is responsible for the maximum power point tracking, data display, and polling the serial communications link. Figure 3 provides a flow chart of the main control loop. The program initiates array current and voltage readings and multiplies the readings to obtain a calculated power value. The calculated power value determines a new load DAC adjustment based on the previous adjustment and power value. DAC adjustments are usually 1-bit steps but periodically they are increased to 2-bit steps. The increased step size provides a dither in the control signal to prevent limit cycles that often result from quantification.

The program then determines if an update of the display is required. Updates occur only once per eight passes of the main loop to prevent excessive display

flicker. If an update is to occur, the selector switch determines which parameter will be displayed. The program collects the required data and sends the information to the display.

The loop continues to adjust the load and update the display in this manner until it is either interrupted or receives a command over the serial communications link. The program must poll the serial port to determine if a command sequence has occurred. To prevent data loss, polling occurs at several locations within the main program loop.

When the main program loop detects a character on the serial communications port, it saves the present operating status and transfers control to the serial communications driver shown in Figure 4. The serial communications driver reads the data from the universal asynchronous receiver transmitter (UART) and checks the sequence against a defined protocol. If the sequence does not match the protocol or more than 2 s elapses between characters, the driver will return control to the main loop. The driver enters the main program at a point that restores the saved-loop operating status. If the command sequence is valid, the driver executes the command before returning to the main loop.

The command sequence specifies a parameter or parameters that the driver is to evaluate. The driver formats and transmits the required data. A lookup-table specifies the numbers of digits and the decimal position required to format each parameter value.

A crystal-controlled clock interrupts the program at periodic intervals to facilitate integration of the array power. Figure 5 indicates the procedure of the interrupt service routine. At each interrupt, the service routine adds the present power reading to a 10 digit accumulator containing the calculated energy value. The interrupts are transparent to the main program because the service routine saves the processor status upon entry and restores the status when returning to the interrupted program.

Figure 3. Flow Chart of the Main Control Loop

Figure 4. Flow Chart of Serial Communications Driver

Figure 5. I-V Plot and Interrupt Service Routines

Installation

Installation involves selecting the site, mounting the ALU, making the required connections, and setting the load control DAC range. Before installing the ALU, one must determine that the intended photovoltaic array will not exceed the load capabilities of the ALU. Figure 6 is a plot of the safe operating area (SOA) of load that may be used to determine compatibility.

Appendix D provides a pictorial of the ALU front panel, identifying the location of components that are referenced throughout the remaining portion of this report.

In selecting the site for the ALU, observe the following:

- 110 Vac power must be readily available.
- The ALU should be mounted as close as possible to the intended array to minimize voltage drops in the load lines.
- The ALU must be within 1500 ft of any system that is to communicate with the ALU over the serial interface.
- Adequate structural support must be provided.

User connections are made at terminal strip TB1 on the front panel of the ALU. Table 1 provides a list of the connections available at TB1. Note that some of the TB1 positions are used for internal connections and need only be verified by the user.

Table 1. TB1 Terminal Block Connections

Terminal No.	Polarity	Title	Description/Function
1 2	+ -	TRANSFER RELAY CONTROL	Optional - a contact closure between 1 and 2 causes the TRANSFER RELAY to switch the ARRAY from the internal load to the CURRENT BUS.
3 4	+ -	PV ARRAY	User installed - provides connection for the array to be tested.
5 6	+ -	CURRENT BUS	Optional - provides for instruments to be connected to the array. The array can be switched to the CURRENT BUS by providing a contact closure at terminals 1 and 2.
7 8	+ -	LOAD MAIN	Fabricator installed - provides for the transistor load modules to be connected. Both modules are connected in parallel.
9	N.A.	LOAD CONTROL	
10 11 12	+ Gnd -	BATTERY	Fabricator installed - provides for backup batteries; two 12-V lead-acid batteries in series. The junction is system ground.
13 14	+ -	SERIAL IN	Optional - provides for incoming serial data, whereby the ALU may receive commands.
15 16	+ -	SERIAL OUT	Optional - provides for outgoing serial data, whereby the ALU transmits requested data.
17 18		AC	Fabricator installed - provides for bringing 110 Vac power onboard.

Figure 6. Safe Operating Area of ALU Loads

At installation, you must adjust the load control DAC output range to obtain the optimum resolution during the maximum power tracking mode. Adjust the full-scale output voltage of the DAC to agree with the open circuit voltage of the intended array. Details of the adjustment and installation procedures are provided in the following outline:

1. Initial Checkout

- 1.1 Begin by placing front panel switches marked ARRAY, BATT, and AC in their OFF positions.
- 1.2 Check that the transistor load modules are connected to terminals 7, 8, and 9 of TB1. Both modules must be connected in parallel.
- 1.3 Check that the backup batteries are in place and properly connected to terminals 10, 11, and 12 of TB1. The batteries must be wired in series with the junction to terminal 11, positive side to 10, and negative side to 12.
- 1.4 Check the no-load voltage of both batteries. If either is below 12.6 V, then remove and recharge the battery until no-load voltage is ~13.2 V. Recharging may be performed by a current-limited, variable power supply set for ~14.8 V and a current limit of 0.6 A.
- 1.5 Check that terminals 19 and 20 of TB1 are connected to the ac source connector at the lower left-hand corner of the enclosure.

- 1.6 Check that all fuses are installed and of the proper rating.

2. Necessary Connections

- 2.1 Connect a power cord from the ac power connector to a 110-Vac power source.
- 2.2 Connect the photovoltaic array to terminals 3(+) and 4(-) of TB1, observing proper polarity.

3. Optional Connections

- 3.1 If serial communication with a computer system having an RS232 serial port is desired, establish transmit and receive buses. Use the RS232 to ALU adapter, described in Appendix D, and connect the computer system's RS232 interface cable to the connector on the adapter.
- 3.2 Connect terminals 13(+) and 14(-) of TB1 on the ALU to the adapter's transmit bus terminals observing proper polarity. NOTE: These lines are paralleled to all ALUs in operation.
- 3.3 Connect terminals 15(+) and 16(-) of TB1 to the adapter's receive buss terminals, observing proper polarity. These lines are also parallel to all ALUs.
- 3.4 Set a unit address code on the 7-bit DIP switch located on card B' of the ALU. This code must be unique to each ALU on the communication bus.

3.5 If it is desired to run tests on the array using other loads, connect them to the CURRENT BUS (terminals 5(+) and 6(-) on TB1); then switch them from the ALU to the external load by supplying a contact closure between terminals 1(-) and 2(+) of TB1 which actuates the TRANSFER RELAY within the ALU. NOTE: Transfer relay control is a 15-Vdc 10-mA source. External contact closures should be rated appropriately.

3.6 If temperature monitoring is desired, plug transistor probe into socket 15 of wire-wrap card A (far right). Attach probe end to suitable temperature monitoring point on the photovoltaic array.

4. Turnon and Setup

4.1 Operate the ac power switch to ON. The AC indicator lights.

4.2 Operate BATT ON/OFF switch to ON. The DISPLAY is activated.

4.3 Press and release the RESET μ P switch.

4.4 Connect a DVM to the test points marked V_{DAC} (socket 26, card C). Adjust R17 (RANGE ADJ.) until the DVM reads array open circuit voltage divided by 100 ($V_{oc}/100$). Example: If the array to be tested has an open circuit voltage of 62 V, then V_{DAC} should read 0.62 V (this sets the maximum voltage that the load will achieve during an I-V scan).

4.5 Operate ARRAY ON/OFF switch to ON.

4.6 Operate AUTO/MANUAL switch to AUTO.

4.7 Operate the SELECTOR switch to V_p . Display should now indicate maximum array power in watts.

Operation

The two basic modes of operation, manual or automatic, differ in the way in which the array loading is controlled. As the block diagram in Figure 7 shows, the load operates as a feedback system for which the control variable is the array voltage. The load is regulated so that the array voltage is proportional to the applied reference input. It is the reference input that distinguishes the different modes. In manual operation, the V_{MP} SET potentiometer provides the reference that allows the operator to control the array voltage. In the automatic mode, the reference is derived from a μ P-controlled DAC, thus the μ P can control the array voltage. An algorithm allows the μ P to regulate the array voltage to achieve maximum power output. Therefore in the auto mode, the system is operating about the maximum power point on the I-V curve of the array, and in manual mode the system operates about a set voltage point on the curve. The operating mode is selected by the front panel AUTO/MANUAL toggle switch.

In either mode, a $3\frac{1}{2}$ digit display and select switch allow the operator to view system parameters in real time. A list of parameters that may be selected is provided in Table 2. It is also possible for another computer to request the parameters to be transmitted over a serial communications link. For the required protocol, consult Appendix A.

Figure 7. Load Operational Block Diagram

Table 2. Display Parameters

Parameter	Switch Notation	Display Format
Array temperature	V_T	-XXX °C
Load voltage setpoint	V_{MP}	XXX.X Volts
Array voltage	V_A	XXX.X Volts
Array current	V_I	XX.XX Amps
Array power	V_P	XXXX Watts
Accumulated array energy	E	XXX.X kWh
Backup battery voltage	V_{BATT}	0XX.X Volts
Test point voltage	V_{TEST}	X.XXX Volts

Calibration

Adjustment potentiometers are provided for calibrating the ALU's ADC as well as the monitoring circuits for array voltage, current, and temperature. In practice, the ADC should be calibrated first. A zero and a gain adjust are provided and should be set so that the ADC reads in the range of 0 to 1.999 V. The voltage, current, and temperature monitoring circuits are also provided with zero and gain adjustments necessary for proper readings. The voltage monitor functions from 0 to 199.9 V; the array current monitor reads from 0 to 19.99 A; and the temperature probe from -20° to 120°C .

There are no calibration adjustments required for the power and energy readings that are derived by calculating the array voltage and current readings. However, the energy measurement does require an accurate time base. The time base is derived from the crystal clock and may be verified by measuring the period between pulses on the μP interrupt line (card C, pin F35). The period should be within 100 ms of 0.36 s.

The following procedures outline the calibration process for the ADC and monitoring circuitry. All components are referenced in Appendix E.

1. Equipment Needed for Calibration

- 1.1 HP6002A Power Supply or Equivalent
- 1.2 HP3465A Digital Multimeter or Equivalent
- 1.3 Fluke 3330B DC Calibrator Source or Equivalent

2. Turnon Procedures

- 2.1 Begin with switches in the following positions:

AC	OFF
ARRAY	OFF
BATT	OFF
AUTO/MAN	MAN
V_{MP}	≈ 1

- 2.2 Connect power cord to its ac source.
- 2.3 Operate ac power switch to ON. Verify that the ac indicator lights.
- 2.4 Operate BATT ON/OFF switch to ON. Verify that the DISPLAY is activated.
- 2.5 Operate RESET μP switch.

3. Analog-to-Digital Converter Calibration.

- 3.1 Operate FUNCTION switch to TEST.

- 3.2 Short TEST voltage input (card A, socket 26, pins 16 and 9).

- 3.3 Adjust R43 ZERO ADJ. (on card C) until display reads 001 and then back off until display reads 000.

- 3.4 Remove the short from TEST voltage input and apply a 1.900-V signal.

- 3.5 Adjust R42 GAIN ADJ. (on card C) until display reads 1.900.

4. Array Voltage Calibration

- 4.1 Place a short across ARRAY input terminals 3 and 4 of TB1.

- 4.2 Operate DISPLAY switch to VA.

- 4.3 Rotate V_{MP} SET control fully counterclockwise.

- 4.4 Operate ARRAY switch to ON.

- 4.5 Adjust VOLT ZERO ADJ. potentiometer (card A, socket 24, R53) to obtain a reading of 001 and continue to adjust until display just changes from 001 to 000.

- 4.6 Operate ARRAY switch to OFF.

- 4.7 Remove short from terminals 3 and 4 of TB1.

- 4.8 Set HP6002A power supply for current limit of ~ 0.1 A and voltage limit at maximum setting.

- 4.9 Connect power supply to ARRAY input terminals 3 and 4 of TB1.

- 4.10 Operate ARRAY switch to ON. Power supply should go into the current limit mode.

- 4.11 Connect DVM to read the voltage across terminals 3 and 4 of TB1.

- 4.12 Rotate V_{MP} SET to obtain a reading of ~ 48 V on the DVM.

- 4.13 Adjust VOLTAGE GAIN ADJ. potentiometer (card A, socket 5, R16) until the ALU display indicates the same as the DVM.

NOTE: As the potentiometer is adjusted, DVM reading should change and not the ALU display.

5. Array Current Calibration

- 5.1 With power supply still connected as in the voltage calibration procedure, insert a digital current meter capable of 10 A in the negative leg of the supply.

- 5.2 Rotate DISPLAY switch to VI.
- 5.3 Adjust the current limit on the supply to obtain a current reading of ~ 0.01 A.
- 5.4 Adjust CURR ZERO ADJ. potentiometer (card A, socket 24, R56) to obtain identical readings on ALU display and current meter.
- 5.5 Adjust current limit of power supply to obtain a current reading of ~ 10 A.
- 5.6 Adjust CURR GAIN ADJ. potentiometer (card A, socket 5, R15) to obtain identical readings on ALU display and current meter.
- 5.7 Repeat steps 5.3 through 5.6 until both settings are correct.
- 5.8 Operate ARRAY switch to OFF.
- 5.9 Remove power supply.
6. Temperature Calibration
 - 6.1 Operate DISPLAY selector to V_T .
 - 6.2 Immerse temperature probe end in a strained bath of ice water. NOTE: Controlled temperature chamber set at 0°C may be used.
 - 6.3 Adjust TEMP ZERO ADJ. potentiometer (card A, socket 12, R29) until display reads 001, then back off until display changes to 000.
 - 6.4 Remove temperature probe from ice water and place in an environment of known temperature. (Next to a laboratory thermometer will suffice.) If a temperature chamber is used, set temperature to $\sim 30^\circ\text{C}$.
 - 6.5 Allow display reading to stabilize. Then adjust TEMP GAIN ADJ. potentiometer (card A, socket 12, R28) until display reads the measured or set temperature surrounding the probe.
 - 6.7 Repeat 6.2 through 6.5 as necessary.

APPENDIX A

Serial Communications Protocol

A computer may request data from the ALU by observing the proper protocol. The requesting computer transmits a specific sequence of ASCII characters that the ALU recognizes as a command to return selected data. The ALU responds with the data in a predetermined format. Table A1 provides a summary of the available commands and associated data formats.

All transmissions are standard asynchronous format with 1 stop bit, no parity, and 8 bits per character. The transmission rate must be 300 baud.

The serial link is designed so that several ALUs may be connected to the same line. The computer selects the desired ALU by an address code within the command sequence. An address switch on each ALU determines the character required for access.

The command sequence consists of three ASCII characters: an STX, an ALU address code (determined by the address switch of the desired ALU), and a parameter code (see Table A1).

The ALU acknowledgment consists of the following ASCII sequence: an ACK, the ALU address code, the parameter code, a comma, the requested data (see Table A1), and an EOT character.

Table A1. Select Codes and Data Formats

Data Requested	Parameter Select Character	Returned Data ^{1,2} Format	Units
Array Temperature	0	-XXXC _R ³	°C
Load Setpoint	1	XXX.XC _R	Volts
Array Voltage	2	XXX.XC _R	Volts
Array Current	3	XX.XXC _R	Amps
Array Power	4	XXXXC _R	Watts
Test Voltage	5	X.XXXC _R	Volts
Battery Voltage	6	XXX.XC _R	Volts
Array Energy	7	XXXX.XXC _R	kWh
Reset Energy	8	0C _R	kWh
All Array Parameters	9	-XXX, XXX.X, XX.XX, XXXX, XXXX.XXC _R	— ⁴
I-V Sweep	A	C _R XX.XX, XXX.XC _R ⁵ XX.XX, XXX.XC _R	Amps, Volts

Notes:

1. X indicates a decimal digit
2. C_R indicates a carriage return
3. If not negative then a space will replace the minus sign
4. Units are the same as for individual parameters with the following sequence: temperature, voltage, current, power, energy
5. 64 current, voltage points are transmitted.

APPENDIX B

RS232 Communications Adapter Schematic

APPENDIX C

Software Listings

1/19/81

47F	TOP OF RAM	RRRRRR	A	N	N
	TRANSMIT BUFFER	R R	A A	NN	MM
		R R	A A	M M	M M
		RRRRRR	A A	M M	M M
441	SAVE	R R	AAAAAAA	M	M
440	D0	R R	A A	M	M
	D1 ARRAY	R R	A A	M	M
	D2 CURRENT				
	D3				
430	D0				
	D1 ARRAY				
	D2 VOLTAGE				
	D3				
438	D0				
	D1 PRESENT				
	D2 ARRAY				
	D3 POWER				
	D4				
	D5	BBBB	Y Y	TTTT	EEEE
431	D0	B B	Y Y	T	E
	D1 PREVIOUS	BBBB	Y	T	EEEE
	D2 ARRAY	B B	Y	T	E
	D3 POWER	BBBB	Y	T	EEEE
	D4				
	D5				
42A	D0				
	D1				
	ARRAY ENERGY				
	D9				
420	PROGRAM STACK				
3FF	LOOK-UP TABLE	RRRRRR	00000	N	N
		R R	0 0	NN	MM
		R R	0 0	M M	M M
	SUBROUTINES	RRRRRR	0 0	M M	M M
		R R	0 0	M	M
		R R	00000	M	M
	MAIN CONTROL		1 K K		
			1 K K		
			1 K K		
	INITIALIZATION	11111	K K		
000					

..

1802 REGISTER FILE USAGE

..

.. R0 - MAIN PROGRAM POINTER
 .. R1 - INTERRUPT SERVICE PROGRAM POINTER
 .. R2 - STACK POINTER
 .. R3 - SUBROUTINE CVP PROGRAM COUNTER
 .. R4 - SUBROUTINE INPUT PROGRAM COUNTER
 .. R5 - SUBROUTINE TRANS PROGRAM POINTER
 .. R6 - SUBROUTINE TMIT PROGRAM COUNTER
 .. R7 - TRANSMIT BUFFER DATA POINTER
 .. R8 - R8.0 - LOAD DAC CONTROL COUNTER
 .. - R8.1 - LOOP OPERATING STATUS BYTE
 .. R9 - GENERAL PURPOSE LOOP COUNTER
 .. RA - GENERAL PURPOSE DATA STORAGE AND TIMER
 .. RB - RB.0 - MULTIPLY LOOP COUNTER
 .. - RB.1 - ALU SELECT CODE STORAGE
 .. RC - LOOK-UP TABLE POINTER, VARIABLE POINTER
 .. RD - MULTIPLIER DATA POINTER
 .. RE - GENERAL PURPOSE DATA POINTER
 .. RF - GENERAL PURPOSE DATA POINTER
 ..

1FL	LOC	COSMAC CODE	LNNO	SOURCE LINE	81/01/19, 16.14.55.	DFR	1-19-81
0000	1	..	1	***** ARRAY LOADING UNIT DRIVER *****			
0000	2	..	2				
0000	3	..	3				
0000	4	..	4	THE FOLLOWING DRIVER ALLOWS THE ARRAY LOADING UNIT TO CONTINUELY LOAD			
0000	5	..	5	A PHOTOVOLTAIC ARRAY AT ITS MAXIMUM POWER POINT, THE ARRAY CURRENT AND			
0000	6	..	6	VOLTAGE ARE READ DIRECTLY FROM THE ARRAY AND MULTIPLIED TO OBTAIN POWER.			
0000	7	..	7	THE POWER IS MONITORED CONTINUELY AND THE LOAD ADJUSTED TO MAXIMIZE THE			
0000	8	..	8	POWER OUTPUT, THE POWER IS ALSO INTEGRATED BY REPETITIVE ADDITIONS TO			
0000	9	..	9	OBTAIN AN ENERGY VALUE, THERE IS A COMMUNICATION LINK PROVIDED FOR REMOTELY			
0000	10	..	10	INTEROGATING THE UNIT TO OBTAIN ARRAY PARAMETERS, AN ONBOARD DISPLAY IS			
0000	11	..	11	ALSO PROVIDED WITH A FUNCTION SWITCH TO SELECT THE DISPLAYED PARAMETER.			
0000	12	..	12				
0000	13	..	13				
0000	14	..	14	.. PORT AND REGISTER ASSIGNMENTS			
0000	15	MAIN = R0	15	.. ASSIGN R0 AS MAIN PROGRAM COUNTER			
0000	16	CVP = R3	16	.. ASSIGN R3 TO CVP SUBROUTINE			
0000	17	INPUT = R4	17	.. ASSIGN R4 TO INPUT SUBROUTINE			
0000	18	TRANS = R5	18	.. ASSIGN R5 TO TRANS SUBROUTINE			
0000	19	TMIT = R6	19	.. ASSIGN R6 TO TMIT SUBROUTINE			
0000	20	DAC = 4	20	.. ASSIGN PORT 4 TO DAC			
0000	21	UART = 7	21	.. ASSIGN PORT 7 TO THE UART			
0000	22	ADC1 = 1	22	.. ASSIGN PORT 1 TO ADC DIGITS 1 & 2			
0000	23	ADC2 = 2	23	.. ASSIGN PORT 2 TO ADC DIGITS 3 & 4			
0000	24	DISP1=1	24	.. ASSIGN PORT 1 TO DISPLAY DIGITS 1 & 2			
0000	25	DISP2 = 2	25	.. ASSIGN PORT 2 TO DISPLAY DIGITS 3 & 4			
0000	26	MUX = 3	26	.. ASSIGN PORT 3 TO ANALOG MULTIPLEXER			
0000	27	DEVCD = 3	27	.. ASSIGN PORT 3 TO DEVICE SELECT CODE SWITCH			
0000	28	PARAM = 4	28	.. ASSIGN PORT 4 TO PARAMETER SELECT SWITCH			
0000	29	..	29	***** INITIALIZATION *****			

0000	30	ORG 00	
0000 7100	31	DIS, 0	.. DISABLE INTERRUPTS
0002 F804	32	LDI A, 1<POW>	.. INITIALIZE STACK AND DATA POINTERS
0004 B2	33	PHI R2	.. TO RAM AREA
0005 B7	34	PHI R7	
0006 BC	35	PHI RC	
0007 BD	36	PHI RD	
0008 BE	37	PHI RE	
0009 BF	38	PHI RF	
000A F81A	39	LDI A, 0<INRPT>	.. INITIALIZE INTERRUPT ROUTINE POINTER
000C A1	40	PLO R1	
000D F802	41	LDI A, 1<INRPT>	
000F B1	42	PHI R1	
0010 F801	43	LDI A, 1<INPUB>	
0012 B4	44	PHI INPUT	
0013 F8A0	45	LDI A, 0<INPUB>	
0015 A4	46	PLO INPUT	
0016 F800	47	LDI A, 1<TRANB>	
0018 B5	48	PHI TRANS	
0019 F8EF	49	LDI A, 0<TRANB>	
001B A5	50	PLO TRANS	
001C F803	51	LDI A, 1<TMITB>	
001E B6	52	PHI TMIT	
001F F868	53	LDI A, 0<TMITB>	
0021 A6	54	PLO TMIT	
0022 F841	55	LDI A, 0<SAVE>	.. SET POINTER TO STORAGE AREA AND
0024 AF	56	PLO RF	.. INITIALIZE LOOP OPERATING POINT
0025 F8CF	57	LDI #CF	
0027 5F	58	STR RF	
0028 1F	59	INC RF	
0029 F820	60	LDI #20	
002B 5F	61	STR RF	
002C F820	62	LDI A, 0<SP>	.. INITIALIZE STACK POINTER
002E A2	63	PLO R2	
002F E0	64	SEX R0	
0030 7020	65	RET, #20	.. ENABLE INTERRUPTS ; SET X TO R2
0032 6B	66	INP DEVCD	.. GET DEVICE SELECT CODE AND
0033 BB	67	PHI RB	.. STORE IN RB, 1
0034 F818	68	LDI A, 0<CVPB>	
0036 A3	69	PLO CVP	
0037 F801	70	LDI A, 1<CVPB>	
0039 B3	71	PHI CVP	
003A F841	72	LDI A, 0<SAVE>	.. SET A POINTER TO STORAGE AREA AND
003C AF	73	PLO RF	.. RETRIEVE PREVIOUS LOOP OPERATING POINT
003D 4F	74	LDA RF	
003E B8	75	PHI R8	
003F 4F	76	LDA RF	
0040 A8	77	PLO R8	
0041 F880	78	LDI #80	
0043 A7	79	PLO R7	
0044 3E8B	80	BN3 REC	.. CHECK UART BUFFER FOR RECEIVED WORD
0046 D3	81	SEP CVP	.. CALL CVP ROUTINE TO INITIALIZE CURRENT,
0047	82		.. VOLTAGE, AND POWER VARIABLES.
0047	83	MAIN1:	.. MAIN LOOP ENTRY POINT:
0047	84	..	

0047	85	..	WITHIN THIS LOOP THE ARRAY MAXIMUM POWER OUTPUT IS TRACKED,
0047	86	..	THE DISPLAY IS UPDATED WITH THE PROPER PARAMETER, AND
0047	87	..	THE UART IS CONTINUELY POLLED FOR RECEIVED COMMANDS
0047	88	..	
0047 3EBB	89	BN3 REC	.. CHECK UART FOR RECEIVED WORD
0049 D3	90	SEP CVP	.. CALL CVP ROUTINE
004A 3EBB	91	BN3 REC	.. POLL UART AGAIN
004C F82B	92	COMP: LDI A.0(KW+1)	.. COMPARE PREVIOUS POWER READING WITH
004E AE	93	PLO RE	.. THE CURRENT POWER READING
004F F807	94	LDI #07	
0051 A9	95	PLO R9	
0052 EE	96	SEX RE	
0053 4F	97	COMP1: LDA RF	
0054 F5	98	SD	
0055 3B5E	99	BNF RIGHT	
0057 3ACC	100	BNZ WRONG	
0059 1E	101	INC RE	
005A 29	102	DEC R9	
005B 89	103	GLO R9	
005C 3A53	104	BNZ COMP1	
005E	105	..	GET HERE IF CURRENT POWER READING >= PREVIOUS
005E	106	..	POWER READING, INDICATING DAC IS BEING STEPPED IN THE PROPER DIRECTION.
005E 98	107	RIGHT: GHI R8	.. GET DAC CONTROL BYTE
005F FA40	108	ANI #40	.. MASK OFF INC\DEC BIT
0061 326E	109	BZ DECR	.. GO TO DECREMENT ROUTINE IF BIT=0
0063 87	110	GLO R7	.. GET LOOP CONTROL BYTE
0064 FE	111	SHL	.. SET DF WITH MSB
0065 88	112	GLO R8	.. GET DAC DATA BYTE
0066 C7	113	LSNF	.. ADD 1 OR 2 DEPENDING ON MSB OF LOOP CONTROL BYTE
0067 FC01	114	ADI #01	
0069 FC01	115	ADI #01	
006B A8	116	PLO R8	
006C 3077	117	BR INC1	
006E 87	118	DECR: GLO R7	
006F FE	119	SHL	
0070 88	120	GLO R8	
0071 C7	121	LSNF	.. SUBTRACT 1 OR 2 DEPENDING ON LOOP CONTROL BYTE
0072 FF01	122	SMI #01	
0074 FF01	123	SMI #01	
0076 A8	124	PLO R8	
0077 E2	125	INC1: SEX R2	.. PREPARE TO OUTPUT TO DAC
0078 52	126	STR R2	
0079 64	127	OUT DAC	.. OUTPUT NEW OPERATING POINT TO DAC
007A 22	128	DEC R2	
007B 87	129	GLO R7	.. ADJUST LOOP CONTROL BYTE, RESULTS IN DAC BEING
007C FE	130	SHL	.. INCREMENTED BY 2 FOR 8 TIMES AND INCREMENTED
007D 87	131	GLO R7	.. BY 1 FOR 64 TIMES
007E C7	132	LSNF	
007F FC0E	133	ADI #0E	
0081 FC02	134	ADI #02	
0083 A7	135	PLO R7	
0084	136	MAN:	.. HERE THE LOOP CONTROL BYTE IS ADJUSTED AND
0084	137	..	TESTED TO DETERMINE IF THE DISPLAY ROUTINE SHOULD BE
0084	138	..	EXECUTED ON THIS PASS. THE ADJUSTMENTS RESULT IN THE
0084	139	..	DISPLAY BEING UPDATED ON EVERY 8TH PASS

0084 98	140	GHI R8	
0085 FC02	141	ADI #02	
0087 B8	142	PHI R8	
0088 FA10	143	ANI #10	
008A 3247	144	BZ MAIN1	
008C 98	145	GHI R8	
008D FAE0	146	ANI #E0	
008F B8	147	PHI R8	
0090 6C	148	INP PARAM	.. GET PARAMETER TO BE DISPLAYED
0091 FD06	149	SDI #06	.. CHECK TO SEE IF ADC MUST BE CALLED
0093 32D2	150	BZ POWER	
0095 3BD7	151	BNF OTHER	
0097 F840	152	LDI A.0(CURR)	.. PREPARE TO ACTIVATE ADC
0099 AE	153	PLO RE	
009A F0	154	LDX	
009B B9	155	PHI R9	
009C 79	156	MARK	
009D D4	157	SEP INPUT	.. ACTIVATE ADC AND GET READING
009E 22	158	DEC R2	
009F 1E	159	INC RE	
00A0 4E	160	DSPLY: LDA RE	.. ENTER ROUTINE TO DISPLAY PREVIOUSLY INPUT
00A1 FE	161	SHL	.. PARAMETER IN LCD DISPLAY
00A2 FE	162	SHL	
00A3 FE	163	SHL	
00A4 FE	164	SHL	
00A5 C7	165	LSNF	
00A6 FC50	166	ADI #50	
00A8 52	167	STR R2	
00A9 4E	168	LDA RE	
00AA F4	169	ADD	
00AB 52	170	STR R2	
00AC 61	171	OUT DISP1	
00AD 22	172	DEC R2	
00AE 4E	173	LDA RE	
00AF FE	174	SHL	
00B0 FE	175	SHL	
00B1 FE	176	SHL	
00B2 FE	177	SHL	
00B3 52	178	STR R2	
00B4 4E	179	LDA RE	
00B5 F4	180	ADD	
00B6 52	181	STR R2	
00B7 62	182	OUT DISP2	
00B8 22	183	DEC R2	
00B9 3047	184	BR MAIN1	.. CONTINUE MAIN LOOP
00BB	185	.. GET HERE IF UART RECEIVE BUFFER HAS A WORD	
00BB F841	186	REC: LDI A.0(SAVE)	.. SAVE CURRENT LOOP OPERATING POINT
00BD AF	187	PLO RF	
00BE 98	188	GHI R8	
00BF 5F	189	STR RF	
00C0 1F	190	INC RF	
00C1 B8	191	GLO R8	
00C2 5F	192	STR RF	
00C3 F818	193	LDI A.0(CVPB)	
00C5 A3	194	PLO CVP	
00C6 F801	195	LDI A.1(CVPB)	

00C8 B3	196	PHI CVP	
00C9 C0024F	197	LBR REC10	.. GOTO RECEIVE ROUTINE
00CC 98	198	WRONG: GHI R8	.. GET HERE IF PREVIOUS POWER READING >
00CD FB40	199	XRI #40	.. CURRENT POWER. CHANGE LOOP DIRECTON BIT
00CF B8	200	PHI R8	
00D0 305E	201	BR RIGHT	
00D2 F832	202	POWER: LDI A.0(PREV+1)	.. GET HERE TO DISPLAY POWER
00D4 AE	203	PLO RE	
00D5 30A0	204	BR DSPLY	
00D7 FC01	205	OTHER: ADI #01	
00D9 32E9	206	BZ KWHR	.. BRANCH TO KWHR TO DISPLAY ENERGY
00DB F82A	207	LDI A.0(KW)	.. GET HERE TO RESET ENERGY READING
00DD AF	208	PLO RF	
00DE F809	209	LDI #09	
00E0 A9	210	PLO R9	
00E1 F800	211	LDI #00	
00E3 5F	212	STR RF	
00E4 2F	213	DEC RF	
00E5 29	214	DEC R9	
00E6 89	215	GLO R9	
00E7 3AE1	216	BNZ *-6	
00E9 F822	217	KWHR: LDI A.0(SP+2)	.. GET HERE TO DISPLAY ACCUMULATED ENERGY
00EB AE	218	PLO RE	
00EC 30A0	219	BR DSPLY	
00EE	220	..	
00EE	221	.. THE FOLLOWING ROUTINE TAKES A BCD PARAMETER POINTED TO BY RE.	
00EE	222	.. CONVERTS IT TO ASCII, INSERTS A DECIMAL POINT AND PACKS THE	
00EE	223	.. ASCII CHARACTERS IN THE TRANSMIT BUFFER.	
00EE	224	.. THE PROPER DECIMAL POSITION AND NUMBER OF DIGITS FOR A	
00EE	225	.. GIVEN PARAMETER ARE RETRIEVED FROM A LOOK-UP TABLE.	
00EE	226	.. THE PARAMETER NUMBER IS PASSED IN RC.0	
00EE	227	..	
00EE D0	228	TRANE: SEP MAIN	.. RETURN TO MAIN PROGRAM
00EF 8C	229	TRANB: GLO RC	.. GET PARAMETER #
00F0 FA0F	230	ANI #0F	
00F2 FE	231	SHL	.. MULTIPLY BY 2
00F3 FC7F	232	ADI A.0(TAB)	.. CREATE TABLE POINTER
00F5 AC	233	PLO RC	
00F6 F803	234	LDI A.1(TAB)	
00F8 BC	235	PHI RC	
00F9 4C	236	LDA RC	.. GET # OF DIGITS FROM TABLE AND
00FA A9	237	PLO R9	.. PUT IN R9.0
00FB 4C	238	LDA RC	.. GET DECIMAL POSITION INDICATOR
00FC 89	239	PHI R9	
00FD 4E	240	TRAN2: LDA RE	.. GET DIGIT
00FE FC30	241	ADI #30	.. CONVERT TO ASCII
0100 57	242	STR R7	.. STORE IN TRANSMIT BUFFER
0101 99	243	GHI R9	.. CHECK IF DECIMAL NEEDED
0102 FE	244	SHL	
0103 89	245	PHI R9	
0104 CB010B	246	LBNF TRAN1	
0107 F82E	247	LDI #2E	.. PUT DECIMAL IN IF NEEDED HERE
0109 17	248	INC R7	
010A 57	249	STR R7	
010B 17	250	TRAN1: INC R7	

010C 29	251	DEC R9	
010D 89	252	GLO R9	
010E CA00FD	253	LBNZ TRAN2	.. DO REMAINING DIGITS
0111 F804	254	LDI #04	.. POINT RC BACK INTO RAM AREA
0113 BC	255	PHI RC	
0114 C000EE	256	LBR TRANE	
0117	257	..	
0117	258	..THE FOLLOWING ROUTINE WILL INPUT THE ARRAY CURRENT AND VOLTAGE;	
0117	259	.. SAVE THE LAST POWER READING, AND MULTIPLY CURRENT AND VOLTAGE	
0117	260	.. TO ACHIEVE A NEW POWER READING.	
0117	261	..	
0117 D0	262	CVPEX: SEP MAIN	.. RETURN TO MAIN PROGRAM
0118 F840	263	CVPB: LDI A,0<CURR>	.. PREPARE TO INPUT CURRENT
011A AE	264	PLO RE	
011B F803	265	LDI #03	
011D 89	266	PHI R9	
011E 79	267	MARK	
011F D4	268	SEP INPUT	
0120 22	269	DEC R2	
0121 98	270	GHI R8	.. CHECK TO SEE IF CALLED BY RECEIVE ROUTINE
0122 FE	271	SHL	
0123 C7	272	LSHF	
0124 3E32	273	BN3 GOREC	.. POLL UART IF NOT CALLED BY RECEIVE
0126 F802	274	LDI #02	.. PREPARE TO INPUT VOLTAGE
0128 89	275	PHI R9	
0129 79	276	MARK	
012A D4	277	SEP INPUT	
012B 22	278	DEC R2	
012C 98	279	GHI R8	
012D FE	280	SHL	
012E 3B39	281	BNF ARUND	
0130 3639	282	B3 ARUND	
0132 F8BB	283	GOREC: LDI A,0<REC>	
0134 A0	284	PLO MAIN	
0135 F800	285	LDI A,1<REC>	
0137 B0	286	PHI MAIN	
0138 D0	287	SEP MAIN	
0139 F82B	288	ARUND: LDI A,0<PREV-6>	.. PREPARE TO MOVE LAST POWER READING
013B AF	289	PLO RF	
013C F832	290	LDI A,0<POW-6>	
013E AE	291	PLO RE	
013F F807	292	LDI #07	
0141 A9	293	PLO R9	
0142 0E	294	MOVE: LDN RE	.. MOVE LAST READING AND ZERO AREA FOR MULTIPLY ROUTINE
0143 5F	295	STR RF	
0144 F800	296	LDI #00	
0146 5E	297	STR RE	
0147 1F	298	INC RF	
0148 1E	299	INC RE	
0149 29	300	DEC R9	
014A 89	301	GLO R9	
014B 3A42	302	BNZ MOVE	
014D 2E	303	DEC RE	.. PREPARE FOR MULTIPLY ROUTINE
014E F840	304	LDI A,0<CURR>	
0150 AD	305	PLO RD	

0151 F83C	306	LDI A,0<VOLT>	
0153 AC	307	PLO RC	
0154 F804	308	MULT1: LDI #04	.. MULTIPLY CURRENT AND POWER
0156 A9	309	PLO R9	
0157 0D	310	MULT3: LDN RD	
0158 AB	311	PLO RB	
0159 3269	312	MULT2: BZ MULT1	
015B 3076	313	BR ADD	
015D 1E	314	MULT4: INC RE	
015E 1E	315	INC RE	
015F 1E	316	INC RE	
0160 1E	317	INC RE	
0161 1C	318	INC RC	
0162 1C	319	INC RC	
0163 1C	320	INC RC	
0164 1C	321	INC RC	
0165 2B	322	DEC RB	
0166 8B	323	GLO RB	
0167 3059	324	BR MULT2	
0169 29	325	MULT1: DEC R9	
016A 89	326	GLO R9	
016B 3217	327	BZ CVPEX	
016D 9B	328	GHI R8	
016E FE	329	SHL	
016F C7	330	LSNF	
0170 3E32	331	BN3 GOREC	
0172 2E	332	DEC RE	
0173 2D	333	DEC RD	
0174 3057	334	BR MULT3	
0176	335	..	
0176	336	.. THIS ROUTINE WILL ADD TWO 4 DIGIT BCD NUMBERS. ONE POINTED TO BY	
0176	337	.. RC IS ADDED TO ONE POINTED TO BY RE AND THE SUM IS STORED THERE.	
0176	338	..	
0176 89	339	ADD: GLO R9	.. SAVE CURRENT CONTENTS OF R9.0
0177 52	340	STR R2	
0178 F804	341	LDI 04	.. INITIALIZE DIGIT COUNTER
017A A9	342	PLO R9	
017B EE	343	SEX RE	
017C 0C	344	ADD2: LDN RC	
017D F4	345	ADD	
017E 5E	346	STR RE	
017F FD09	347	SDI #09	
0181 338E	348	BDF ADD1	
0183 F0	349	LDX	.. DO A DECIMAL ADJUST OPERATION ON THEBSUM
0184 FC06	350	ADI #06	
0186 FA0F	351	ANI #0F	
0188 73	352	STXD	
0189 F0	353	LDX	
018A FC01	354	ADI#01	
018C 5E	355	STR RE	
018D 3B	356	SKP	
018E 2E	357	ADD1: DEC RE	
018F 2C	358	DEC RC	
0190 29	359	DEC R9	
0191 89	360	GLO R9	

0192 3A7C	361	BNZ ADD2	.. ADD ANY REMAINING DIGITS
0194 E2	362	SEX R2	
0195 F0	363	LD	.. RESTORE R9.0
0196 A9	364	PLO R9	
0197 CC	365	LSIE	.. CHECK TO SEE IF ADD ENTERED FROM INTERRUPT ROUTINE
0198 309C	366	BR INTR3	
019A 305D	367	BR MULT4	.. RETURN TO MULTIPLY ROUTINE IF NOT INTERRUPT ROUTINE
019C C00234	368	INTR3: LBR INTR2	
019F	369	..	
019F	370	.. THIS ROUTINE WILL INPUT THE PARAMETER SPECIFIED BY R9.1 AND	
019F	371	.. STORE IN BCD FORMAT IN RAM POINTED TO BY RE.	
019F	372	..	
019F 70	373	INPEX: RET	
01A0 99	374	INPUB: GHI R9	.. OUTPUT PARAMETER # TO MULTIPLEXER
01A1 E2	375	SEX R2	
01A2 52	376	STR R2	
01A3 63	377	OUT MUX	
01A4 22	378	DEC R2	
01A5 7B	379	SEQ	.. START THE A/D CONVERTER
01A6 7A	380	REQ	
01A7 3CA7	381	BN1 *	.. WAIT FOR A/D TO FINISH
01A9 69	382	INP ADC1	.. INPUT DIGITS 1 & 2
01AA AA	383	PLO RA	
01AB EE	384	SEX RE	
01AC 8A	385	GLO RA	
01AD FA0F	386	ANI #0F	
01AF 73	387	STXD	
01B0 8A	388	GLO RA	
01B1 F6	389	SHR	
01B2 F6	390	SHR	
01B3 F6	391	SHR	
01B4 F6	392	SHR	
01B5 73	393	STXD	
01B6 E2	394	SEX R2	
01B7 6A	395	INP ADC2	.. INPUT DIGITS 3 & 4
01B8 AA	396	PLO RA	
01B9 99	397	GHI R9	
01BA FA0F	398	ANI #0F	
01BC 3ACC	399	BNZ SPLIT	
01BE 8A	400	GLO RA	
01BF FF03	401	SNI #03	
01C1 AA	402	PLO RA	
01C2 3BDB	403	BNF NEG	
01C4 FA08	404	ANI #08	
01C6 32CC	405	BZ SPLIT	
01C8 8A	406	GLO RA	
01C9 FF06	407	SNI #06	
01CB AA	408	PLO RA	
01CC EE	409	SPLIT: SEX RE	.. THIS ROUTINE WILL UNPACK THE INPUT DIGITS AND
01CD 8A	410	GLO RA	.. STORE THEM CONSECUTIVELY IN RAM POINTED TO BY RE
01CE FA0F	411	ANI #0F	
01D0 73	412	STXD	
01D1 8A	413	GLO RA	

01D2 F6	414	SHR	
01D3 F6	415	SHR	
01D4 F6	416	SHR	
01D5 F6	417	SHR	
01D6 73	418	STXD	
01D7 E2	419	SEX R2	
01D8 12	420	INC R2	
01D9 309F	421	BR INPEX	
01DB FBFF	422 NEG1:	XRI #FF	
01DD EE	423	SEX RE	
01DE 73	424	STXD	
01DF 69	425	INP ADC1	
01E0 3AE7	426	BNZ NEG1	
01E2 60	427	IRX	
01E3 F801	428	LDI #01	
01E5 F4	429	ADD	
01E6 73	430	STXD	
01E7 F8FD	431 NEG1:	LDI #FD	
01E9 5E	432	STR RE	
01EA 60	433	IRX	
01EB 60	434	IRX	
01EC 60	435	IRX	
01ED 69	436	INP ADC1	
01EE FD9A	437	SDI #9A	
01F0 AA	438	PLO RA	
01F1 FA0F	439	ANI #0F	
01F3 FD0A	440	SDI #0A	
01F5 3AFB	441	BNZ NEG2	
01F7 8A	442	GLO RA	
01F8 FC06	443	ADI #06	
01FA AA	444	PLO RA	
01FB 8A	445 NEG2:	GLO RA	
01FC FA0F	446	ANI #0F	
01FE 73	447	STXD	
01FF 8A	448	GLO RA	
0200 F6	449	SHR	
0201 F6	450	SHR	
0202 F6	451	SHR	
0203 F6	452	SHR	
0204 73	453	STXD	
0205 E2	454	SEX R2	
0206 12	455	INC R2	
0207 2E	456	DEC RE	
0208 2E	457	DEC RE	
0209 C0019F	458	LBR INPEX	
020C	459 ..		
020C	460 ..	THE INTERRUPT ROUTINE WILL ADD THE PREVIOUS POWER READING	
020C	461 ..	TO AN ACCUMULATOR ON EACH INTERRUPT. THIS SERVES TO INTEGRATE	
020C	462 ..	THE POWER TO ACHIEVE AN ENERGY VALUE IF THE INTERRUPTS ARE	
020C	463 ..	PERIODIC.	
020C	464 ..		
020C E2	465 RET1:	SEX R2	.. GET HERE TO RETURN FROM INTERRUPT
020D 12	466	INC R2	
020E 42	467	LDA R2	
020F A9	468	PLO R9	
0210 42	469	LDA R2	

0211 BC	470	PHI RC	
0212 42	471	LDA R2	
0213 AC	472	PLO RC	
0214 42	473	LDA R2	
0215 AE	474	PLO RE	
0216 42	475	LDA R2	
0217 7E	476	SHLC	
0218 42	477	LDA R2	
0219 70	478	RET	
021A 22	479 INRPT:	DEC R2	.. ENTRY POINT FOR INTERRUPTS
021B 78	480	SAV	
021C 22	481	DEC R2	
021D 73	482	STXD	
021E 76	483	SHRC	
021F 73	484	STXD	
0220 8E	485	GLO RE	
0221 73	486	STXD	
0222 8C	487	GLO RC	
0223 73	488	STXD	
0224 9C	489	GHI RC	
0225 73	490	STXD	
0226 89	491	GLO R9	
0227 73	492	STXD	
0228 F804	493	LDI #04	
022A BC	494	PHI RC	
022B F82E	495	LDI A,0(PREV-3)	
022D AC	496	PLO RC	
022E F82A	497	LDI A,0(KW)	
0230 AE	498	PLO RE	
0231 C00176	499	LBR ADD	
0234 F805	500 INTR2:	LDI #05	
0236 A9	501	PLO R9	
0237 EE	502	SEX RE	
0238 F0	503	LDX	
0239 FD09	504 INTR1:	SDI #09	
023B C3020C	505	LBDF RETI	
023E F0	506	LDX	
023F FC06	507	ADI #06	
0241 FA0F	508	ANI #0F	
0243 73	509	STXD	
0244 29	510	DEC R9	
0245 89	511	GLO R9	
0246 C2020C	512	LBZ RETI	
0249 F0	513	LDX	
024A FC01	514	ADI 01	
024C 5E	515	STR RE	
024D 3039	516	BR INTR1	
024F	517	..	
024F	518	.. THE RECEIVE ROUTINE READS DATA FROM THE UART AND CHECKS IT AGAINST	
024F	519	.. A CERTAIN PROTOCOL. IF THE COMMAND SEQUENCE IS PROPER THEN THE	
024F	520	.. COMMAND IS EXECUTED AND AN ACKNOWLEDGEMENT IS TRANSMITTED.	
024F	521	.. THE COMMAND SEQUENCE CONSIST OF THE FOLLOWING ASCII CHARACTERS:	
024F	522	.. STX (#02),DEVICE SELECT(ANY VALID ASCII),PARAMETER SELECT(#30-#3A)	
024F	523	..	
024F 6F	524 REC10:	INP UART	.. INPUT RECEIVED WORD

0250 FD02	525	SDI #2	.. IS IT AN STX CHARACTER
0252 CA002C	526	LBNZ MAIN2	.. RETURN IF NOT
0255 98	527	GHI R8	
0256 FB80	528	XRI #80	
0258 B8	529	PHI R8	
0259 F843	530	LDI A,0(TBUFF)	.. INITIALIZE TRANSMIT BUFFER POINTER
025B A7	531	PLO R7	
025C E7	532	SEX R7	.. LET R(X) BE TRANSMIT BUFFER POINTER
025D FB06	533	LDI #06	.. PUT AN ACKNOWLEDGE CHARACTER IN BUFFER
025F 57	534	STR R7	
0260 60	535	IRX	
0261 F8FF	536	LDI #FF	.. THE FOLLOWING IS A DELAY ROUTINE WHICH
0263 BA	537	PHI RA	.. SETS THE AMOUNT OF TIME ALLOWED FOR
0264 AA	538	PLO RA	.. THE NEXT CHARACTER IN THE SEQUENCE TO
0265 3E71	539 DELY1:	BN3 CONT1	.. BE RECEIVED BEFORE RETURNING.
0267 2A	540	DEC RA	
0268 9A	541	GHI RA	
0269 3A65	542	BNZ DELY1	
026B 8A	543	GLO RA	
026C 3A65	544	BNZ DELY1	
026E C0002C	545	LBR MAIN2	
0271 6F	546 CONT1:	INP UART	.. GET SECOND CHARACTER OF SEQUENCE HERE
0272 9B	547	GHI RB	.. COMPARE WITH UNITS SELECT CODE
0273 F5	548	SD	
0274 CA002C	549	LBNZ MAIN2	.. RETURN TO MAIN LOOP IF NOT FOR THIS UNIT
0277 60	550	IRX	.. INCREMENT BUFFER POINTER; SAVES COPY OF SELECT CODE
0278 F8FF	551	LDI #FF	.. WAIT FOR NEXT CHARACTER AS BEFORE
027A BA	552	PHI RA	
027B AA	553	PLO RA	
027C 3E88	554 DELY2:	BN3 CONT2	
027E 2A	555	DEC RA	
027F 9A	556	GHI RA	
0280 3A7C	557	BNZ DELY2	
0282 8A	558	GLO RA	
0283 3A7C	559	BNZ DELY2	
0285 C0002C	560	LBR MAIN2	
0288 6F	561 CONT2:	INP UART	.. GET THIRD CHARACTER OF SEQUENCE HERE
0289 60	562	IRX	.. SAVE COPY IN TRANSMIT BUFFER
028A F82C	563	LDI #2C	.. PUT A COMMA IN TRANSMIT BUFFER
028C 73	564	STXD	
028D F836	565	LDI #36	.. COMPARE WITH AN ASCII 6
028F F5	566	SD	.. IF LESS THAN SIX THEN...
0290 3BEA	567	BNF SING	.. GOTO ROUTINE FOR READING THE A/D CONVERTER
0292 C20303	568	LBZ POW1	.. IF = 6 THEN SEND BACK POWER
0295 FF01	569	SMI #01	
0297 C2030C	570	LBZ KWHRT	.. IF = 7 ,THEN TRANSMIT ENERGY
029A FF01	571	SMI #01	
029C C20315	572	LBZ KWRST	.. IF = 8 THEN RESET ENERGY ACCUMULATOR
029F FF01	573	SMI #01	
02A1 C20329	574	LBZ ALL	.. IF = 8 ,THEN TRANSMIT ALL PARAMETERS
02A4	575	..	
02A4	576	.. GET HERE IF AN I-V CURVE IS REQUESTED. THIS ROUTINE WILL TRANSMIT	
02A4	577	.. 64 DATA POINTS ALONG THE OPERATING CURVE OF THE ARRAY BY SWEEPING	
02A4	578	.. THE DAC OUTPUT FROM MIN TO MAX AND TAKING THE CURRENT AND VOLTAGE	
02A4	579	.. READINGS AT VARIOUS POINTS. THE CURRENT AND VOLTAGE READINGS ARE	


```

02A4      580 .. FORMATED AND PACKED IN THE TRANSMIT BUFFER FOR TRANSMISSION. READINGS
02A4      581 .. FOR ONE POINT ARE TRANSMITTED THEN READINGS FOR THE NEXT ARE TAKEN.
02A4 60   582      IRX
02A5 60   583      IRX
02A6 F80D 584      LDI #0D
02A8 57   585      STR R7
02A9 F800 586      LDI #00      .. INITIALIZE DAC COUNTER TO 0 FOR FIRST POINT
02AB A8   587      PLO R8
02AC 60   588 REC5:  IRX
02AD 88   589      GLO R8      .. SET DAC OUTPUT TO NEXT POINT OF CURVE
02AE 57   590      STR R7
02AF 64   591      OUT DAC
02B0 D6   592      SEP TMIT      .. TRANSMIT PREVIOUS POINT READINGS OR...
02B1      593      .. ACKNOWLEDGE SEQUENCE IF FIRST POINT
02B1 D3   594      SEP CVP
02B2 E7   595      SEX R7      .. TAKE READINGS AND PUT IN TRANSMIT BUFFER
02B3 F843 596      LDI A.0(TBUFF)
02B5 A7   597      PLO R7
02B6 F83D 598      LDI A.0(VOLT+1)
02B8 AE   599      PLO RE
02B9 F803 600      LDI #03
02BB AC   601      PLO RC
02BC D5   602      SEP TRANS      .. TRANSFER CURRENT READING TO BUFFER
02BD F82C 603      LDI #2C
02BF 57   604      STR R7
02C0 17   605      INC R7
02C1 F802 606      LDI #02
02C3 AC   607      PLO RC
02C4 F839 608      LDI A.0(POW+1)
02C6 AE   609      PLO RE
02C7 D5   610      SEP TRANS      .. TRANSFER VOLTAGE READING TO BUFFER
02C8 F80D 611      LDI #0D
02CA 57   612      STR R7      .. PUT A CARRIAGE RETURN IN BUFFER
02CB 18   613      INC R8      .. INCREMENT DAC COUNTER TO NEXT POINT
02CC 18   614      INC R8
02CD 88   615      GLO R8
02CE 32E0 616      BZ LAST
02D0 FFC0 617      SMI #C0
02D2 33AC 618      BDF REC5
02D4 18   619      INC R8
02D5 18   620      INC R8
02D6 FC40 621      ADI #40
02D8 33AC 622      BDF REC5
02DA 18   623      INC R8
02DB 18   624      INC R8
02DC 18   625      INC R8
02DD 18   626      INC R8
02DE 30AC 627      BR REC5
02E0 D6   628 LAST: SEP TMIT      .. TRANSMIT LAST POINT READINGS
02E1 F804 629      LDI #04      .. TRANSMIT AN EOT CHARACTER TO SIGNIFY LAST POINT
02E3 57   630      STR R7
02E4 37E4 631      B4 *
02E6 67   632      OUT UART
02E7 C002C 633      LBR MAIN2
02EA 72   634 SING: LDXA      .. GET HERE TO TRANSMIT A PARAMETER WHICH REQUIRES

```

02EB B9	635	PHI R9	.. THE AND CONVERTER TO BE CALLED
02EC AC	636	PLO RC	
02ED F840	637	LDI A.0(CURR)	
02EF AE	638	PLO RE	
02F0 79	639	MARK	
02F1 D4	640	SEP INPUT	
02F2 22	641	DEC R2	
02F3 17	642	INC R7	
02F4 1E	643	INC RE	
02F5 D5	644 REC1:	SEP TRANS	.. TRANSFER PARAMETER TO BUFFER
02F6 F80D	645 REC2:	LDI #0D	.. PUT A CARRIAGE RETURN IN BUFFER
02F8 57	646	STR R7	
02F9 D6	647	SEP TMIT	.. TRANSMIT THE BUFFER
02FA F804	648	LDI #04	.. TRANSMIT AN EOT CHARACTER TO SIGNIFY END
02FC 57	649	STR R7	
02FD 37FD	650	B4 *	
02FF 67	651	OUT UART	
0300 C0002C	652	LBR MAIN2	
0303 72	653 POW1:	LDXA	.. GET HERE TO TRANSMIT POWER
0304 AC	654	PLO RC	
0305 60	655	IRX	
0306 F82B	656	LDI A.0(KW+1)	
0308 AE	657	PLO RE	
0309 C002F5	658	LBR REC1	
030C 72	659 KWHRT:	LDXA	.. GET HERE TO TRANSMIT THE ENERGY ACCUMULATOR
030D AC	660	PLO RC	
030E 60	661	IRX	
030F F822	662	LDI A.0(SP+2) &	0311 AE 663 PLO RE
0312 C002F5	664	LBR REC1	
0315 60	665 KWRST:	IRX	.. GET HERE TO RESET THE ENERGY ACCUMULATOR
0316 60	666	IRX	
0317 F82A	667	LDI A.0(KW)	
0319 AF	668	PLO RF	
031A F809	669	LDI #09	.. SET DIGIT COUNTER TO 9
031C A9	670	PLO R9	
031D F800	671 REST:	LDI #00	
031F 5F	672	STR RF	.. ZERO DIGIT
0320 2F	673	DEC RF	
0321 29	674	DEC R9	
0322 89	675	GLO R9	
0323 CA031D	676	LBNZ REST	.. GO BACK FOR REMAINING DIGITS
0326 C002F6	677	LBR REC2	
0329 60	678 ALL:	IRX	.. GET HERE TO TRANSMIT ALL ARRAY PARAMETERS
032A F800	679	LDI #00	
032C B9	680	PHI R9	
032D AC	681	PLO RC	
032E F840	682	LDI A.0(CURR)	
0330 AE	683	PLO RE	
0331 79	684	MARK	
0332 D4	685	SEP INPUT	.. GET ARRAY TEMPERATURE
0333 22	686	DEC R2	
0334 17	687	INC R7	
0335 1E	688	INC RE	
0336 D5	689	SEP TRANS	.. TRANSFER TO BUFFER
0337 F82C	690	LDI #2C	
0339 57	691	STR R7	

033A 17	692	INC R7	
033B D3	693	SEP CVP	.. GET THE CURRENT,VOLTAGE,AND POWER
033C E7	694	SEX R7	
033D F83D	695	LDI A.0<VOLT +1>	
033F AE	696	PLO RE	
0340 F803	697	LDI #03	
0342 AC	698	PLO RC	
0343 D5	699	SEP TRANS	.. TRANSFER THE CURRENT TO THE TRANSMIT BUFFER
0344 F82C	700	LDI #2C	
0346 57	701	STR R7	
0347 17	702	INC R7	
0348 F802	703	LDI #02	
034A AC	704	PLO RC	
034B F839	705	LDI A.0<POW+1>	
034D AE	706	PLO RE	
034E D5	707	SEP TRANS	.. TRANSFER THE VOLTAGE READING
034F F82C	708	LDI #2C	
0351 57	709	STR R7	
0352 17	710	INC R7	
0353 F806	711	LDI #06	
0355 AC	712	PLO RC	
0356 F832	713	LDI A.0<PREV+1>	
0358 AE	714	PLO RE	
0359 D5	715	SEP TRANS	.. TRANSFER THE POWER READING
035A F82C	716	LDI #2C	
035C 57	717	STR R7	
035D 17	718	INC R7	
035E F807	719	LDI #07	.. PREPARE TO TRANSMIT ENERGY READING
0360 AC	720	PLO RC	
0361 F822	721	LDI A.0<SP+2>	
0363 AE	722	PLO RE	
0364 C002F5	723	LBR RECT	
0367	724	..	
0367	725	.. THIS ROUTINE TRANSMITS THE CONTENTS OF THE TRANSMIT BUFFER UNTIL	
0367	726	.. A CARRIAGE RETURN CHARACTER (#0D) IS FOUND. IT THEN TRANSMITS THE	
0367	727	.. CARRIAGE RETURN CHARACTER AND RETURNS TO CALLER.	
0367	728	..	
0367 D0	729	TNITE: SEP MAIN	.. RETURN TO MAIN PROGRAM
0368 F843	730	TNITB: LDI A.0<TBUFF>	.. INITIALIZE BUFFER POINTER
036A A7	731	PLO R7	
036B F87F	732	LDI #7F	
036D 8A	733	PHI RA	
036E 2A	734	NULL: DEC RA	
036F 9A	735	GHI RA	
0370 3A6E	736	BNZ NULL	
0372 3772	737	TNIT1: B4 *	.. WAIT UNTIL UART IS READY
0374 67	738	OUT UART	.. TRANSMIT CHARACTER
0375 F0	739	LDX	.. GET NEXT CHARACTER
0376 FD0D	740	SDI #0D	.. IS IT A CARRIAGE RETURN?
0378 3A72	741	BNZ TNIT1	.. CONTINUE IF NOT
037A 377A	742	B4 *	.. SEND CARRIAGE RETURN
037C 67	743	OUT UART	
037D 3067	744	BR TNITE	
037F	745	..	
037F	746	.. THE FOLLOWING TABLE IS USED BY THE TRANSFER ROUTINE. EACH PARAMETER	

```

037F      747 .. HAS A TWO BYTE ENTRY. THE FIRST OF WHICH SPECIFIES THE NUMBER OF
037F      748 .. DIGITS TO BE TRANSFERED, THE SECOND LOCATES THE DECIMAL POSITION.
037F      749 ..
037F 0420  750 TAB:   DC#0420
0381 0420  751      DC #0420
0383 0420  752      DC #0420
0385 0440  753      DC #0440
0387 0420  754      DC #0420
0389 0420  755      DC #0420
038B 0610  756      DC #0610
038D 0608  757      DC #0608
038F      758 ..
038F      759      .. STORAGE ALLOCATIONS
0420      760      ORG #420
042A      761 SP:   ORG * + 10
0431      762 KW:   ORG **7
0438      763 PREV: ORG **7
043C      764 POW:  ORG **4
0440      765 VOLT: ORG **4
0441      766 CURR: ORG **1
0443      767 SAVE: ORG **2
0443      768 TBUFF: ORG *
0443      769      END

```

1 REGISTER REFERENCES

R0																				
+	15	64	228	262	284	286	287	729												
R1																				
+	40	42																		
R2																				
+	33	63	125	126	128	158	167	170	172	178	181	183	269	278	340	362	375	376	378	394
+	419	420	454	455	465	466	467	469	471	473	475	477	479	481	641	686				
R3																				
+	16	69	71	81	90	194	196	594	693											
R4																				
+	17	44	46	157	268	277	640	685												
R5																				
+	18	48	50	602	610	644	689	699	707	715										
R6																				
+	19	52	54	592	628	647														
R7																				
+	34	79	110	118	129	131	135	242	248	249	250	531	532	534	585	590	595	597	604	605
+	612	630	642	646	649	687	691	692	694	701	702	709	710	717	718	731				
R8																				
+	75	77	107	112	116	120	124	140	142	145	147	188	191	198	200	270	279	328	527	529

+	587	589	613	614	615	619	620	623	624	625	626										
R9																					
+	95	102	103	155	210	214	215	237	239	243	245	251	252	266	275	293	300	301	309	325	
+	326	339	342	359	360	364	374	397	468	491	501	510	511	635	670	674	675	680			
RA																					
+	383	385	388	396	400	402	406	408	410	413	438	442	444	445	448	537	538	540	541	543	
+	552	553	555	556	558	733	734	735													
RB																					
+	67	311	322	323	547																
RC																					
+	35	229	233	235	236	238	255	307	318	319	320	321	344	358	470	472	487	489	494	496	
+	601	607	636	654	660	681	698	704	712	720											
RD																					
+	36	305	310	333																	
RE																					
+	37	93	96	101	153	159	160	168	173	179	203	218	240	264	291	294	297	299	303	314	
+	315	316	317	332	343	346	355	357	384	409	423	432	456	457	474	485	498	502	515	599	
+	609	638	643	657	663	683	688	696	706	714	722										
RF																					
+	38	56	58	59	61	73	74	76	97	187	189	190	192	208	212	213	289	295	298	668	
+	672	673																			

1NAME	VALUE	DEFINED	REFERENCES
-------	-------	---------	------------

+ADC1	0001	22	
+			382 425 436

+ADC2	0002	23	
+			395

+ADD1	018E	357	
+			348

+ADD2	017C	344	
+			361

+ADD	0176	339	
+			313 499

+ALL	0329	678	
+			574

+ARUND	0139	288																	
+			281	282															
+COMP1	0053	97																	
+			104																
+COMP	004C	92																	
+CONT1	0271	546																	
+			539																
+CONT2	0288	561																	
+			554																
+CURR	0440	766																	
+			152	263	304	637	682												
+CVPB	0118	263																	
+			68	70	193	195													
+CVPEX	0117	262																	
+			327																
+CVP	0003	16																	
+			69	71	81	90	194	196	594	693									
+DAC	0004	20																	
+			127	591															
+DECR	006E	118																	
+			109																
+DELY1	0265	539																	
+			542	544															
+DELY2	027C	554																	
+			557	559															
+DEVCD	0003	27																	
+			66																
+DISP1	0001	24																	
+			171																
+DISP2	0002	25																	
+			182																
+DSPLY	00A0	160																	
+			204	219															
+GOREC	0132	283																	
+			273	331															
+INC1	0077	125																	
+			117																

+INPEX	019F	373							
+			421	458					
+INPUB	01A0	374							
+			43	45					
+INPUT	0004	17							
+			44	46	157	268	277	640	685
+INRPT	021A	479							
+			39	41					
+INTR1	0239	504							
+			516						
+INTR2	0234	500							
+			368						
+INTR3	019C	368							
+			366						
+KWHRT	030C	659							
+			570						
+KWHR	00E9	217							
+			206						
+KWRST	0315	665							
+			572						
+KW	042A	762							
+			92	207	497	656	667		
+LAST	02E0	628							
+			616						
+MAIN1	0047	83							
+			144	184					
+MAIN2	002C	62							
+			526	545	549	560	633	652	
+MAIN	0000	15							
+			228	262	284	286	287	729	
+MAN	0084	136							
+MOVE	0142	294							
+			302						
+MULT1	0169	325							
+			312						
+MUL72	0159	312							

[illegible]

+R5	0005	0																							
+			18	18																					
+R6	0006	0																							
+			19	19																					
+R7	0007	0																							
+			34	79	110	118	129	131	135	242	248	249	250	531	532	534	595	590	595	597	604	605			
+			612	630	642	646	649	687	691	692	694	701	702	709	710	717	718	731							
+R8	0008	0																							
+			75	77	107	112	116	120	124	140	142	145	147	188	191	198	200	270	279	328	527	529			
+			587	589	613	614	615	619	620	623	624	625	626												
+R9	0009	0																							
+			95	102	103	155	210	214	215	237	239	243	245	251	252	266	275	293	300	301	309	325			
+			326	339	342	359	360	364	374	397	468	491	501	510	511	635	670	674	675	680					
+SAVE	0441	767																							
+			55	72	186																				
+SING	02EA	634																							
+			567																						
+SPLIT	01CC	409																							
+			399	405																					
+SP	0420	761																							
+			62	217	662	721																			
+TAB	037F	750																							
+			232	234																					
+TBUFF	0443	768																							
+			530	596	730																				
+TMITB	0368	730																							
+			51	53																					
+TMITE	0367	729																							
+			744																						
+TNIT1	0372	737																							
+			741																						
+TNIT	0006	19																							
+			52	54	592	628	647																		
+TRANB	00EF	229																							
+			47	49																					
+TRANE	00EE	228																							

[illegible]

READY.

APPENDIX D

Front Panel Pictorial

①	RESET μ P	Resets the microprocessor circuitry.
②	RESET E	Resets the accumulated energy value to zero. Accumulations begin when the switch is released.
③	AUTO/MANUAL	Selects the mode of operation for the electronic load. In the AUTO mode the μ P controls the load and seeks the maximum power point. In MANUAL mode the load is controlled by the V_{MP} SET potentiometer.
④	V_{MP} SET	When in MANUAL mode, allows the operator to select the voltage set point for load operation.
⑤	ARRAY ON/OFF	Disconnects the photovoltaic array from the electronic load when in the OFF position.
⑥	BATT ON/OFF	When in the OFF position, disconnects batteries and power from the ALU circuitry. Batteries remain connected to the internal battery charging circuits in the OFF position.
⑦	AC ON/OFF	Supplies 110-Vac power to the battery charging circuits when in the ON position.
⑧	AC Indicator	Indicates when ac power is applied.
⑨	AC Fuse	Protects against overloads on the ac power line.
⑩	DC Fuses	Protects against overloads on the dc power lines.
⑪	DISPLAY	3½ digit liquid crystal display for viewing the selected parameter value.
⑫	SELECT Switch	Selects the desired parameter to be displayed on the front panel DISPLAY.
⑬	AC Power Supply	Supplies battery charging circuits.
⑭	TB1	Terminal strip for external connections.
⑮	Card C	Microprocessor card and support circuitry.
⑯	Card B	Digital interface circuitry.
⑰	Card A	Load control and analog circuitry.
⑱	DEVICE ADDRESS Switch	Sets the identity code for serial communications link.

APPENDIX E

Mechanical and Electrical Drawings

<u>Dwg. No.</u>	<u>Name</u>	<u>Page</u>
T-71712	Array Loading Unit Assembly (Sheets 1 through 8)	56
T-89001	Transistor Load Assembly	64
339226	Printed Wiring Assembly (Sheets 1 and 2)	65

- ▲ MATCH-DRILL TWO .3125 18 UNC-28 HOLES IN ITEM 4 TO CORRESPOND TO MOUNTING PINS INSIDE BOX, ITEM 21.
- ▲ MATCH-DRILL FOUR .190 (10) 24 UNC-2A HOLES IN ITEM 4 AND THRU THE HEAT-SINKS OF THE TRANSISTOR LOAD ASSY., ITEM 8.
- ▲ WELD AND INSPECT PER 9912117-00, CLASS 11, USING ERAC43 ELECTRODES OR RODS PER AWS A5.10-69.

NOTES:

1. ITEM 21, PIN A-24 82408 ALLP AND ITEM 22, PIN A-VE34 MAY BE PURCHASED FROM HOFFMAN ENGR. CO., DIV. OF FEDERAL CARTRIDGE CORP., 9TH AND TYLER ST., ANOKA, MN. 55303.
2. ITEM 23, PIN BVH8W MAY BE PURCHASED FROM DEFLECTO CORP.
3. ITEM 24 PIN F315000-M5 (P3302C) MAY BE PURCHASED FROM FED-MOGUL CORP., SOUTHFIELD, MI 48034.

ITEM 1
 MATL: SEE CALLOUTS
 SCALE: FULL
 NOTE: SILVER SOLDER BACK GRILL
 TO FRAME PER 9913001.
 LEAVE FRONT GRILL LOOSE.

ITEM 4
 MAT'L: ALUM. SHEET .064 THK
 6061-T6 PER QQ-A-250/11
 SCALE: FULL

ITEM 3
 MATL: ALUM. ROUND, 6061-T651
 PER QQ-A-225/8
 SCALE: 2/1

Hand-drawn technical drawing of a mechanical part, likely a shaft or tube, with various dimensions and features. The drawing shows a long cylindrical component with a central section of length 11.095 ± .005. The total length is 20.00 ± .03. The left end has a flange with a central hole of diameter .750 ± .010 and a thickness of .250 ± .010. The right end has a flange with a central hole of diameter .375 THRU and a thickness of .368 THRU. The central section has a diameter of .200 THRU and a length of 11.095 ± .005. There are two sets of dimensions for the central section: 1.370 ± .010 and 1.095 ± .005. The drawing includes various geometric symbols and dimension lines.

NOTES:

USE THIS DIMENSION FOR PRINT INSPECTION MEASUREMENT ONLY. DO NOT USE PRINTS MORE THAN .100 INCH OUT-OF-SCALE FOR DRILLING TEMPLATES.

11. PAINT ITEM 9 HEWLETT PACKARD GRAY.
12. MARK REFERENCE DESIGNATIONS IN DASHED BOXES PER 9919100 CLASS A-1.A ON FARSIDE. CHARACTER SIZE OPTIONAL (1.187 REFI). LOCATE APPROXIMATELY AS SHOWN.

13. MARK REFERENCE DESIGNATIONS IN SOLID BOXES PER 9919100 CLASS E-2, BLACK FILL, METHOD OPTIONAL, CHARACTER SIZE OPTIONAL 1,187 REF. EXCEPT DESIGNATIONS FOR S1 ARE .156 REF.1. LOCATE APPROXIMATELY AS SHOWN. 8F SURE VOLTAGE SUBDESIGNATIONS ARE SLIGHTLY LOWER THAN THE V.

14. MARK LINES AROUND 51 PER 9919100 CLASS
E-2, BLACK FILL, METHOD OPTIONAL,
THICKNESS OPTIONAL.

15. DO NOT MARK DESIGNATIONS APPEARING IN
BRACKETS AND DIMENSIONS APPEARING WITHIN
OUTLINE OF VIEWS ON THE PART.

INSTALL AUTOMATIC ITEM 22
PER MANUFACTURER'S INSTRUCTIONS.

HOLE TABLE		
DESIG	DESCRIPTION	RE
A	Ø.103/.093	8
B	Ø.135/.125	6
C	Ø.160/.150	7
D	Ø.318/.308 ±.02" 1" C SINK	2
E	Ø.166/.156	1
F	2.166/1.56 DIMPLE FARSIDE	3
G	2.195/1.185	6

HOLE TABLE		
DESIG	DESCRIPTION	REQ
H	Ø.260/.250	2
J	Ø.385/.375	3
K	Ø.478/.468	4
L	SEE FIG. 1	3
M		12
N	.260/.250 R	2
P	.1885/.1875 .760/.750

NOTES: SCHEMATIC

20. UNLESS OTHERWISE SPECIFIED ALL RESISTANCE VALUES ARE IN OHMS.
21. UNLESS OTHERWISE SPECIFIED ALL CAPACITANCE VALUES ARE IN MICROFARADS.
22. INDICATES SCREWDRIVER CONTROL.
23. COMPONENT SPECIFICATIONS ARE AT ENGINEER'S DISCRETION.

SEE CARD C, SHEET 7

1. COLOR CODE:

2. TERMINAL AREA SIZES: .062HS, .075.

3. PATH WIDTHS: .015.

4. MINIMUM CLEARANCE BETWEEN ADJACENT, CONDUCTIVE PATTERNS, AND BETWEEN CONDUCTIVE PATTERNS AND THE BOARD EDGES IS .015.

5. (•) INDICATES PIN 1 OF I.C.'S.

Do Not
Microfilm Distr.

DISTRIBUTION:

A. D. Little, Inc
Acorn Park
Cambridge, MA 02140
Attn: W. P. Teagan

Acurex Corp
Aerotherm Group
485 Clyde Ave
Mountain View, CA 94042
Attn: D. Rafinejad

Albuquerque Operations Office (3)
US Department of Energy
Albuquerque, NM 87185
Attn: J. A. Morley
E. A. Walker
D. C. Graves

Applied Solar Energy Corp
15251 E. Don Julian Rd
PO Box 1212
City of Industry, CA 91749
Attn: K. Ling
T. Brawley

Arizona Public Service Co.
411 North Central Ave.
Phoenix, AZ 85036
Attn: J. McGuirk

Arizona State University
College of Engineering
Tempe, AZ 85281
Attn: C. E. Backus

Battelle-Columbus Laboratories
505 King Ave.
Columbus, OH 43201
Attn: D. C. Carmichael

Clemson University
College of Engineering
Clemson, SC 29631
Attn: J. W. Lathrop

Congressional Research Service
Library of Congress
Washington, DC 20540
Attn: H. Bullis

US Department of Energy (2)
Division of Photovoltaic Energy Systems
Forestal Bldg
1000 Independence Ave. SW
Washington, DC 20585
Attn: A. D. Krantz
M. B. Prince

DSET
PO Box 195
Phoenix, AZ 85029
Attn: G. A. Zerlaut

Electric Power Research Institute
PO Box 10412
Palo Alto, CA 94303
Attn: F. Goodman

E-Systems, Inc
Energy Technology Center
PO Box 226118
Dallas, TX 75222
Attn: M. O'Neill

General Electric Co. (2)
PO Box 8661
Philadelphia, PA 19101
Attn: R. C. Hodge
N. F. Shepard, Jr.

Jet Propulsion Laboratory (2)
4800 Oak Grove Dr
Pasadena, CA 91103
Attn: W. Callaghan
R. Ferber

Martin Marietta Corp (2)
Denver Division
PO Box 179
Denver, CO 80201
Attn: R. E. Hein

Microwave Associates, Inc
108 Turquoise Ave.
Balboa Island, CA 92622
Attn: S. Deem

MIT-Energy Laboratory
E38-411
Cambridge, MA 02139
Attn: R. Tabors

DISTRIBUTION (cont):

MIT-Lincoln Laboratory
PO Box 73
Lexington, MA 02173
Attn: M. Pope

Monegon, Ltd
4 Professional DR
Suite 130
Gaithersburg, MD 20760
Attn: H. L. Macomber

Motorola, Inc
Government Electronics Division
8201 E. McDowell Rd
Scottsdale, AZ 85252
Attn: R. Sanders

Naval Civil Engineering Lab
Fort Hueneme, CA 93042
Attn: G. Watson, Code L-63

New Mexico State University
New Mexico Solar Energy Institute
PO Box 3SOL
Las Cruces, NM 88003
Attn: H. S. Zwibel

Oak Ridge National Laboratory
PO Box X
Oak Ridge, TN 37830
Attn: S. Kaplan

RCA Corp
David Sarnoff Research Center
PO Box 432
Princeton, NJ 08540
Attn: P. J. McGinley

Research Triangle Institute
PO Box 12194
Research Triangle Park, NC 27709
Attn: R. M. Burger

Solar Kinetics, Inc
PO Box 47045
Dallas, TX 75247
Attn: G. Hutchison

Solar Energy Research Institute (3)
1617 Cole Blvd
Golden, CO 80401
Attn: G. Nuss
Library (2)

Solarex Corp
1335 Piccard Dr
Rockville, MD 20850
Attn: R. C. Hamilton

Texas Tech University
Center for Energy Research
Lubbock, TX 79409
Attn: W. M. Marcy

The Aerospace Corp
PO Box 92957
Los Angeles, CA 90009
Attn: S. Leonard

The BDM Corp
Technology Applications Center
2600 Yale Blvd, SE
Albuquerque, NM 87106
Attn: W. R. Kauffman

University of Texas at El Paso
Department of Metallurgical Engineering
El Paso, TX 79968
Attn: S. Stafford

Varian Associates, Inc
611 Hansen Way
Palo Alto, CA 94303
Attn: H. J. R. Maget

2312	J. K. S. Walter
2312	D. F. Russell (5)
2312	A. E. Verardo
9700	E. H. Beckner
9720	D. G. Schuler
9721	J. F. Banas
9721	H. J. Gerwin (4)
9721	D. A. Pritchard
9723	E. L. Burgess
9724	E. C. Boes
8214	M. A. Pound
3141	L. J. Erickson (5)
3151	W. L. Garner (3)
3154-3	C. H. Dalin (25)

For DOE/TIC (Unlimited Release)