MODEL TC01

STAND ALONE DIGITAL TEMPERATURE CONTROLLER
USER MANUAL

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FOURTH EDITION

Sun Electronic Systems, Inc. Tel: **321-383-9400** Email: **sales@sunelectronics.com**

LIMITED WARRANTY INFORMATION
TCO1 TEMPERATURE CONTROLLERS

SUN ELECTRONIC SYSTEMS, INC warrants this product to the original purchaser to be free from defects in material and workmanship and to operate within applicable specifications for a period of two (2) years from the date of shipment provided it is used under normal operating conditions. This warranty does not apply to sealed assemblies which have been opened or to any item which has been repaired or altered without SUN SYSTEMS authorization.

Risk of loss or damage to product shall pass to the customer upon delivery by SUN SYSTEMS to the carrier at SUN SYSTEMS premises.

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Contents

SECTION I - GENERAL INFORMATION

1-1 INTRODUCTION

CONGRATULATIONS ON YOUR PURCHASE OF THE TC01 TEMPERATURE CONTROLLER

Your new temperature controller was manufactured under stringent quality control procedures to insure trouble-free operation for many years. If you should encounter difficulties with the use or operation of your controller, contact Sun Electronic Systems' customer service department at (321)383-9400.

As with all Sun Electronic Systems' products, we would appreciate any comments that you may have regarding your evaluation and application for this equipment. Please address your comments to:

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This manual contains user information for the TC01 microprocessor controlled temperature controller and is divided into five sections which provide information as follows:

SECTION I, GENERAL INFORMATION.
Contains the TC01 description and specifications as well as option descriptions. SUN markets the TC01 directly to end-users and also through OEM channels.

SECTION II, INSTALLATION/PRELIMINARY CHECKOUT.
Contains information relative to receiving inspections, preparation for use, and, if installation is required, how to proceed.

SECTION III, OPERATION.
Contains operating instructions for the TC01 series.

SECTION IV, USER ADJUSTMENTS.
Contains information on adjustments and modifications that may be made in the field.

SECTION V, REPAIR/PARTS REPLACEMENT.
Contains information on repair and warranty policy.

1-1.1 EARLIER VERSION COMPATIBILITY

This latest version of the TC01 controller presents a significant increase in controller capability. New temperature probe support, and performance features provide greater flexibility and greater performance/price ratio to the end-user. This section will serve to summarize the increased capability for those that have used the earlier versions.

PROCESS WIRING CHANGES

The Line wiring and load connection to the new TC01 is the same as far as location and function at the 8 pos screw terminal. The fusing of this new TC01 has changed. See figure 3 for a schematic of the line interface. The fusing of this new TC01 are; The cool output, the TC01 line transformer, and the switched line output are now all protected by one fuse. In the previous versions there was a fuse for the line transformer, a fuse for the cool output, and no fusing on the switched line output. The only change the user should notice is, if your system requires more than 4 amps total from the cool output and the switched line output, then you will need to run a line powered relay from the TC01 switched line output. That relay will then provide the high current switched line to your system.

A new input has been added for a TTL level failsafe input. The new failsafe input can be configured for pos/neg true level via a jumper on the CPU PC board. When the failsafe input is active, the heat and cool outputs are automatically turned off. The default active level is low.

COMMANDS THAT HAVE CHANGED

An effort was made to have the new version TC01 as compatible as possible with earlier versions. One command has changed and a new command has been added;

Command:	OPT	Remote command to determine TC01 configuration.
Changes:		The OPT command now provides more information.
Command:	INIT	Remote command to configure TC01.
Changes:		A new command.

SEE RS232 or GPIB detailed command description section.

ADDED COMMANDS

Table 3-4 summarizes the commands available for the TC01. commands and features that have been added since the last manual are proceeded with a plus (+) sign.

1-2 INITIAL INSPECTION

Inspect the shipping container for obvious damage. If the shipping container or cushioning material is damaged then a written note (on the bill of lading) of the damage should be made while the delivery person is still on the premises. This documents damage to the shipping company should a claim need to be made. Save any damaged carton or cushioning material until the temperature controller has been checked mechanically and electrically. The contents of the shipment should be checked against the packing slip. Procedures for checking the mechanical and electrical operation are given in SECTION III — OPERATION.

1-2.1 LOST OR DAMAGED EQUIPMENT

The goods described on your packing slip were delivered to the transportation company at Sun Electronic Systems' premised in complete and good condition. If any of the goods called for on the packing slip are short or damaged, you must file a claim WITH THE TRANSPORTATION COMPANY FOR THE AMOUNT OF THE DAMAGE AND/OR LOSS.

If any of the goods called for on your packing slip are short or damaged at the time of delivery, ACCEPT THEM, but insist that the freight agent make a damaged or short notation on your freight bill or express receipt and sign it.

If any concealed loss or damage is discovered, notify your local freight agent or express agent AT ONCE and request him to make an inspection. This is absolutely necessary. Unless you do this, the transportation company will not consider your claim for loss or damage valid. If the agent refuses to make an inspection, you should draw up an affidavit to the effect that you notified him on a certain date and that he failed to make the necessary inspection.

If you have ascertained that the extent of the damage renders the controller inoperative call Sun Electronic Systems for an RMA number (see paragraph 1.9, RETURN OF MERCHANDISE) and return the controller. We will repair or replace the controller, as necessary, and bill you for the cost. This new invoice will then be part of your claim for reimbursement from the transportation company. This, together with other papers, will properly support your claim.

1-2.2 UPS SHIPMENTS

The claims adjustment procedure for UPS shipments varies somewhat from the procedure listed above for regular motor and air freight shipments. If your equipment was shipped via UPS and sustained either damage or loss, the UPS representative in your area must initiate the claim by inspecting the goods and assigning a freight claim number to the damage equipment. The representative will attach a "Call Tag" to the outside of the equipment box which will be your authorization to return the merchandise to our factory for claim adjustment. Upon receipt of this damaged equipment, we will perform the necessary repairs, process the appropriate paperwork with UPS and return the equipment to you. Please allow time for processing of any type claim. Normal time for proper processing of a UPS claim in 15-30 working days.

Remember, it is extremely important that you do not give the transportation company a clear receipt if damage or shortages are evident upon delivery. It is equally important that you call for an inspection if the loss or damage is discovered later. DO NOT, UNDER ANY CIRCUMSTANCES, ORDER THE TRANSPORTATION COMPANY TO RETURN SHIPMENT TO OUR FACTORY OR REFUSE SHIPMENT UNLESS WE HAVE AUTHORIZED SUCH RETURN.

1-3 TC01 SPECIFICATIONS

TABLE 1-1

Set Temperature Range	-199 to +315 deg C
Absolute error over temp range	+/- 1 deg C
Temperature Control	+/- .2 deg C
Long term stability	+/- .25 deg C
Repeatability	+/- .1 deg C
Resolution	.1 deg C
Temperature control technique	PID algorithm - Pulse width modulation at .5 HZ
Temperature display resolution	.1 deg C below 200 deg C 1 deg C 200 deg C and above
Time at temperature range (soak time)	1 to 1800 minutes(hour) & continuous
Time at temperature resolution	.1 minute(hour)
Number of scan set temps	10
Number of scan set times	10
Number of 'Cycles'	1-1800 & infinite
Compressor Auxiliary Output w/Compressor time-out	TTL open collector + pullup
Auxiliary Output #2	TTL open collector + pullup
Auxiliary Input	TTL level input + pullup
Failsafe Input	TTL input with pullup. Active low default. Level configurable
Local control	Via 16 key keyboard
Remote control	IEEE-488 bus and RS232-C (*)
Controller power requirement	2 watts, 110 volts 50/60 HZ 220 volts jumper selectable
Cooling solenoid control	1 amp 240 volts max @ zero cross
Heater control	15 amps 240 volts max @ zero cross
Size	23 cm H x 12 cm W x 11.5 cm D 9"H x 4.75" W x 4.5"D
OPTIONS:	see Section 1.7

(*); 1200, 2400, 4800, & 9600 Baud available for RS232-C. Baud Rate adjustable by user. 9600 Baud default. — see Paragraph 4-3

1-4 SAFETY CONSIDERATIONS

1-4.1 OPERATION

AC power supplied to the temperature controllers must be in accordance with SECTION II — INSTALLATION. The installation instructions allow connection to either 110 volt or 240 volt systems.

Section 2-3 — INSTALLATION contains information on how to determine whether a particular TC01 is wired for 110 or 220 volts.

WARNING!

Any interruption of the protective (grounding) power conductor, inside or outside of the system to which the TC01 is installed (including the wall outlet), or disconnection of the protective earth terminal, could be dangerous. The controller and associated user system should only be plugged into a properly installed grounded outlet. The TC01 must be mounted in the users equipment in such a manner that the operator is protected from coming into contact with any dangerous voltages.

1-4.2 INSTALLATION

Although the TC01 series of temperature controllers have been designed in accordance with accepted safety standards, the information, cautions, and warnings in this manual must be followed to ensure safe operation. Installation, if any, should be performed only by qualified personnel. All user adjustments are described in SECTION IV — USER ADJUSTMENTS.

1-5 CONTROLLERS COVERED BY THIS MANUAL

The contents of the manual apply to controllers with the serial number prefixes listed under SERIAL NUMBERS on title page iii.

1-6 TC01 DESCRIPTION

1-6.1 GENERAL DESCRIPTION

The TC01 temperature controller offers the following features to allow for local front panel control, as well as remote computer control, of the users temperature chamber system.

- Set and read the chamber set temperature
- Set the amount of time the chamber should remain at the set temperature (1 to 180 minutes or indefinitely)
- Read the remaining time at temperature
- Read the chamber temperature
- Set and read any of 10 scan temperatures
- Set and read any of 10 scan times
- Start the scan mode or the cycle mode
- Enable/disable Compressor and auxiliary outputs
- Reset the controller to power up conditions (TEMP = 25c TIME = infinity, single temperature mode)
- Gives an audio and visual indication when the time at temperature expires and if in remote mode, generates and interrupt (SRQ for IEEE-488 and ASCII “I” character for RS232)
- Local control keyboard can be enabled or disabled via IEEE-488 bus commands.

1-6.2 BLOCK DIAGRAM DESCRIPTION

As shown in Figure 1, the microprocessor (uP) unit is the heart of the system which controls all actions of the controller. The uP contains three types of memory. It has ROM for program storage, RAM for variables, and EEPROM for storage of seldom changed variables that are retained during power down.

The timer generates interrupts to the microprocessor which are derived from the crystal oscillator system clock. These interrupts are used in timing the pulse width modulated heat and cool times, time at temperature timing, watchdog timing, and display timing. The heater driver and the cooling valve driver are optically coupled triacs that switch the heater and the cooling valve to the power line. The heater and cooling outputs are synchronized to the zero crossing of the power line to reduce electrical noise.

The temperature measurement circuitry provides the necessary interface to scale the output of the temperature probe and to convert its analog output to a digital number which can be used by the microprocessor in its control program. The chamber temperature is always measured with a resolution of 0.1 deg C.

The keyboard logic provides the interface to the 16 key keyboard. The actual encoding is performed by the microprocessor. The display logic interfaces the microprocessor to the LED displays. The displays consist of a 3 1/2 digit, seven segment display which normally displays the chamber temperature and can be instructed to display the remaining time at temperature, the current set temperature, any of the 10 scan temperatures or scan times, etc. There are also five LED indicators that show whether or not: the chamber requires heating or cooling; the controller has been set to the remote mode; the chamber temperature is currently being displayed; and if the time at temperature has expired. An audio indication is also generated when a timeout occurs. Below 200 C, the display resolution is .1 C. Above 200 C, the display resolution is 1 deg C.

The asynchronous serial interface provides a remote RS232-C interface to the controller in order to allow remote control in almost any digital system.

The IEEE-488 (GPIB) interface allows remote control via the IEEE-488 standard bus. Due to its higher speed of operation and increased capabilities, the IEEE-488 interface is best suited for remote control when feasible. When the controller is controlled via the IEEE-488 bus, a command is supported which allows ASCII characters to be input via the IEEE-488 bus and sent out via the RS232-C bus. This extra feature can be used to control another RS232-C compatible device. For example, a CRT terminal could be connected to provide operator information from the system controller, or an RS232-C compatible switching device could be used to control measurements.

Two auxiliary outputs (open collector TTL) are available to control external events. The AUX1 (compressor control) is special in that it has an automatic time-out feature useful when the TC01 is incorporated into compressor-cooled chambers. Both outputs are under GPIB/RS232 control. A one-bit input port is available and can be read under RS232 or GPIB control. Finally a failsafe input is provided to inform the TC01 that an external device has detected an error condition. The TC01 will turn off the heat and cool outputs in response to the failsafe input.

1-6.3 FAILSAFE FEATURES

Several features have been designed into the TC01 that provide a measure of protection against damaging or unusual controller operation conditions. While these failsafes features provide the user with a first level failsafe, the controller cannot detect all failure modes and therefore your chamber must have an independent failsafe mechanism.

FUSES

Two fuses are located on the power supply board (board furthest from front panel) that protect against damaging loads. Refer to figure 3 for reference. F2 is a 15 amp fuse that is in series with the heating Triac. F1 is a 5 amp fuse in series with the TC01 power transformer input, the cool Triac circuit, and the switched line output.

WATCHDOG TIMER

This hardware within the TC01 protects against microprocessor malfunction or other form of loss-of-program-control. This hardware is accessed by the processor and associated software approximately every second. If a malfunction occurs and said hardware is not accessed, the watch-dog circuitry takes control and provides an orderly shutdown of the TC01. Heat, cool, Aux#1, and Aux#2 outputs are automatically disabled and the TC01 is put into an “OFF” state. This condition cannot be reset by any bus or keyboard command. The TC01 must be turned off in order to reset. If some permanent hardware malfunction is present, the watch-dog circuitry will again shut down the

TC01 upon power-up. In this latter case, the TC01 will most likely require factory service. See Section 1-8 and 1-9 for further information on repair and return of merchandise.

SHORTED/OPEN PROBE

The TC01 controller contains built-in circuitry to detect the two most common temperature probe failure modes. If a controller temperature probe fails, i.e. becomes a high or low resistance, the controller will automatically disable the heat and cool outputs within 30 seconds of the probe failure.

UPPER TEMPERATURE LIMIT (UTL)

The TC01 can be programmed via the RS232 or GPIB to alert the user when some user-selected Upper Temperature Limit (UTL) has been exceeded. This feature is useful to protect equipment that may be damaged at some temperature lower than the TC01/Chamber maximum capability. As an example, if it is known that a plastic housing will start to deform at 105c, a UTL can be set to be 90c. If any command is entered that subsequently attempts to raise the chamber temperature above this UTL, a 'command error" will be generated. If the measured chamber temperature should exceed the current UTL then the TC01 responds with an ASCII character ('O') or a GPIB interrupt (Hex 47). Additionally, the heat output will automatically be disabled until the chamber temperature falls below the UTL. The Special Commands to accomplish the UTL function are further described in Section 3-3.4 RS232 Special Group and Section 3-4.4 GPIB Commands: Special.

BUS TIME-OUT

The processing of some GPIB commands by the TC01 require waiting for a response from the GPIB system controller. For example, the GPIB system controller may write to the TC01: sends ASCII "T". This "T" character is interpreted by the TC01 to mean "please send the current chamber temperature." If a "READ" statement is not incorporated into the system controller program, the TC01 would be waiting forever to transmit the chamber temperature. This lock-up condition is averted by the Bus Time-Out feature. If the TC01 is locked-up waiting for some system controller response, it will only wait approximately 5 seconds and generate an interrupt (Hex 4F) that alerts the controller that a bus time-out has occurred. The interrupt handling routine in the calculator then processes this information and can alert the operator as to the problem.

CHAMBER FAILSAFE

The ultimate failsafe against high temperature damage is provided by the independent failsafe mechanism, usually a bimetal sensor, found in most all temperature and environmental chambers. This failsafe mechanism is an independent check on reckless system operation and should be known to be in proper operation condition. The TC01 provides for a TTL level failsafe input signal that will cause all TC01 outputs to turn off. The active level of the failsafe input is jumper selectable. The default failsafe active level is low. The users failsafe circuitry must provide for an independent interruption of the heater circuit to protect against TC01 heat triac failure in the on condition. Triac failure is very rare but still possible.

1-7 OPTIONS

1-7.1 220 volt 50/60 Hz OPERATION - OPTION 00

Option 00 allows the TC01 to be powered by a 220 volt 50/60 Hz source. Factory installed jumpers connect two power transformer windings either in parallel (for 110 volt operation) or in series (for 220 volt operation). The correct jumpers were factory installed per the original customer order. Section 2.3 contains information on how to determine whether a particular TC01 is wired for a 110 volt or a 220 volt source.

1-7.2 PROBE TYPES SUPPORTED

The TC01 can be ordered to operate with the following temperature probes; RTD 100 ohm platinum 3 wire (.385 or .392 alpha) or J or K or T type thermocouple. With the new INIT command the user can now change probe type in the field.

1-7.3 TIME SET IN HOURS - OPTION 07

Some applications require very long ‘soak times’ approaching thousands of hours. For these applications, option 07 will allow local and remote programming to be set in the units of hours. Set resolution is .1 hour. With the new INIT command the user can now change the time units in the field.

1-8 REPAIR

Due to the rather elaborate test system required, field repair of the TC01 may not be feasible for some failures. Sun Electronic Systems maintains a full service department that will attempt to resolve any problems first by telephone and subsequently by repair of the controller.

1-9 RETURN OF MERCHANDISE

When calling for return of a controller, the Customer Service Department will issue a Return Material Authorization (RMA) number which will be valid for a period of 30 days.

Any equipment returned to Sun Electronic Systems without an RMA number will result in repair delay.

After securing an RMA number from the Customer Service Department, return the specified controller to Sun Electronic Systems, freight prepaid, at the address below. NOTE: The RMA number must be plainly marked and visible on your shipping label to insure proper routing at Sun's Receiving Department.

Customer Service Department
Sun Electronic Systems, Inc.
1845 Shepard Drive
Titusville, FL 32780

The Customer Service Department can give you an estimate of the time it should take to process and repair your controller. Turnaround time for repair varies depending on workloads and parts availability but normally your controller will be repaired and returned to you within 2 working days of receipt.
Be sure a declared value equal to the price of the unit is shown on the Bill of Lading, Express Receipt or Air Freight Bill, whichever is applicable. Risk of loss or damage to Sun equipment during the time it is in transit either to or from Sun's facilities is your sole responsibility. A declared value must be placed on your Bill of Lading to insure substantiation of your freight claim if shipping damage or loss is incurred.

All equipment returned to Sun Electronic Systems must be freight prepaid. Equipment not prepaid on arrival at Sun's Receiving Department cannot be accepted. Upon repair to the defective equipment, it will be returned to you F.O.B. the factory in Titusville, FL via UPS or equivalent ground transportation unless you specify otherwise.

SECTION II - INSTALLATION / PRELIMINARY CHECKOUT

This section provides reference for installation of the standalone version. For those who have purchased a chamber/TC01 combination it is only necessary to supply the proper AC line voltage to the chamber/TC01 combination as given on the chamber data plate on its rear panel.

2-1 CONNECTOR DETAIL

The TC01 contains several cables that are used for I/O. This section serves as a reference for proper connection to the various male/female connectors on the controller.

I/O Cable

A 26 conductor flat cable serves as interconnect for RS232 and GPIB I/O. One end connects to the TC01 CPU board (board with LED display) and the other to a small PC board that has RS232 and GPIB connectors mounted to it (the remote board).

Temperature Probe

The TC01 uses a 4 pin screw terminal to connect the temperature probe. The header is located at the bottom of the CPU board (board with LED display). The connector is polarized and can easily be mated in only one way. See figure 3 for probe wiring.

Auxiliary Outputs/Inputs [for standalone controller]

The TC01 provides 2 TTL level outputs AUX1 and AUX2 that the user may control. It also has one TTL level input AUXIN that the user can read. Lastly a failsafe TTL level input is provided. All of these signals are available on a 8 position small green screw header located at the top of the power supply board (board with line transformer). See figure 3 for wiring.

Power Input and process connection [for standalone controller]

Figure 3 provides the schematic for the TC01 line and process connection. All line and line powered process (chamber) connections are to the large 8 position screw terminal located on the bottom of the power supply board (top board that has line transformer). Pin 1 and 3 are the input / output for the heater. Pin 2 provides triac switched line hot for the cooling device. Pin 4 is connected to line neutral (ph B) and pin 6 is for line hot (ph A) input. Pin 7 provides line hot when the TC01 controller's power switch is on, and is limited to approximately 4 amp. Finally pin 8 provides a ground point to the TC01 ground. Note: The TC01 controller that is supplied as the controller in Sun's model EC0x chambers, has a different power / process interface.

Installation of the TC01 into your system may require custom metalwork on the host system. For these cases, figures 5 and 6 give sufficient detail to install the TC01 in a panel.

2-2 INSTALLATION INSTRUCTIONS

The chamber interface circuitry of the TC01 is flexible enough to accommodate practically any temperature chamber. The factors involved in the retrofit are discussed below. The schematic in figure 3 should be used as a guide.

MAXIMUM POWER CONTROLLED

The HEAT triac circuit of the TC01 (pos 1 & 3, fig 3) can drive a 100 to 240 VAC 15 AMP max load. The COOL triac circuit (pos 2) can drive a 100 to 240 VAC 2 AMP load. The switched line hot output (pos 7) provides the line voltage that is on position 6 when the TC01 power switch in on. The total load current used by the cool output and the switched line output should not exceed 4 AMP. To boost the switched line output current capability you can add a relay that is controlled by the TC01 switched line output.

COOL OUTPUT SENSE

The sense of the cool output, as shipped from the factory, is such that when cooling is required the cool output will provide line hot on position 2 of the 8 pos screw terminal. If an inversion is required by your system (when cooling is required the cool, output at pos 2, needs to be off) then the COOLPOL jumper on the CPU board (board with LED display) must be jumpered. The jumper is located below the uP socket.

LINE VOLTAGE SELECTION

The TC01 was designed to operate with 100-120 VAC or 200-240 VAC line power. There are 3 solder jumpers located on the power supply board (top board with line transformer) that are used to set the TC01 line voltage. For 110 VAC operation, solder in wire jumpers in J2 & J3 and remove jumper from J1. For 220 VAC operation, solder in a wire jumper in J1 and J2 & J3 must be open.

AUXILIARY I/O

The TC01 provides 2 TTL open collector auxiliary outputs. AUX 1 is, by default, used to turn on/off the compressor, if required. One auxiliary TTL level input with integral pull up to +5V and a TTL level failsafe input with integral pull up. All 4 signals are provided to a small 8 position screw header that is located at the top right side of the power supply board. Figure 3 provides the pin connection information. The failsafe input provides for an external input that will cause the TC01 to turn off its heat and cool outputs. The active polarity of the failsafe input in by default low level and can be changed to high level active state by jumpering the FS POL jumper on the CPU (board with LED display) board. NOTE: while the failsafe input causes the TC01 to turn off its outputs, the users failsafe circuitry must provide for an independent interruption of the heater circuit to protect against TC01 heat triac failure in the on condition. Triac failure is very rare but still possible. The same is true for cooling if it poses a potential hazard.

MOUNTING THE CONTROLLER

To mechanically mount the TC01 controller into your system you may need to cut panel openings for the controller and the remote I/O assembly. Figure 5 and 6 provide cutout dimensions.

2-3 PRELIMINARY CHECKOUT

The following procedure allows checking basic control function of the TC01. Data entry is via the 16 key keyboard. At this time refer to the TC01 command summary, TABLE 3-4.

Enable the Heat and Cool toggle switches to the 'ON' position. Apply power to the system by switching the power switch to the 'ON' position. In TABLE 3-4 note the column "Keyboard/DISPLAY". This column summarizes keystroke entry for the various functions supported by the TC01. With TABLE 3-4 as a reference, input the following sequences and note the controller response.

KEYSTROKE	CONTROLLER RESPONSE
C	Rest Controller (Clear) the GPIB address is displayed for a few seconds Time is set to Infinity (1999) Temp is set to 25c
50 TEMP	Set Chamber to 50c
5 TIME	Set Time at Temp = 5 minutes

At this point, Heat will be enabled and chamber temperature will rise. At any time, 'TEMP' or 'TIME' keys can be depressed to give status.

TEMP	Chamber SET Temp Displayed
TIME *	Remaining Time at 50c
C	Reset Controller (Clear) stop controlling temperature, display GPIB address Time = Infinity Temp = 25c

* In 5 minutes, after reaching the set temp, the controller will 'Time-Out' and sound the audible alarm. Depress 'C' to clear the controller back to time = Infinity and Temp = 25c.

If the controller is operating properly, continue on to Section III - OPERATION for more detailed information.

SECTION III - OPERATION

3-1 FRONT PANEL CONTROLS/STATUS

The Heat switch and Cool switch are located on either side of the main power switch. The function of the Heat (Cool) switch is to disable application of power to the heaters (cooling solenoid) when in the “off” position. The TC01 microprocessor system continues to make heat or cool decisions independent of the switch settings but actual power is applied only if the hear/cool switches are in the ‘on’ position. This feature allows the operator to manually override the heat/cool decisions of the TC01.

After power-up and/or after a reset command, the heat and cool outputs are disabled. Setting the single mode ‘set temp’ or starting the ‘scan mode’ will enable the heat and cool outputs automatically. Control of heat and cool outputs is also provided by the ‘ON’ and ‘OFF’ commands via the RS232 port, or IEEE-488 bus.

The 3 1/2 digit numeric display indicates Temperature or Time depending upon previous keystrokes. The display will default to indicating Chamber temperature when no key is pressed and 3 seconds have elapsed. Set Temperature and Set Time are displayed when the “Temp” key and “Time” key are depressed, respectively.

Five LEDs offer status information on the TC01. The left side of the front panel contains the Heat and Cool LEDs. When power is going to the heater and the cooling circuit the LED will be on.

From left to right, three red LEDs above the main display are labeled “Box Temp”, “REM”, and “TIME OUT” respectively. Activation of the Box Temp LED indicates that the numerals on the display are indicating Chamber Temperature. The “REM” LED will activate when the TC01 is in the “Remote” mode. Remote mode is current when information is being transferred via either the RS232 or IEEE-488 bus. The “TIME OUT” LED will activate when the Temperature Chamber has been at the Set Temperature for the required amount of time. Simultaneously, an audio indication will sound. The buzzer can be reset by depressing the “time” or “temp” or “C” (clear) key on the keyboard or by setting any controller temp/time function. (For any key to have effect, the keyboard must not have been “locked out” by an IEEE-488 lockout command. See section 3-4.3, #10.)

Slightly below the 16 key keyboard are two holes with attending large panhead screws that are unlabeled. These holes provide access to calibration pots that are used to calibrate the TC01. Details are given in SECTION IV- User Adjustments.

3-2 LOCAL KEYBOARD CONTROL

The following commands are provided by the local keyboard, assuming the controller has not been instructed via and IEEE-488 interface command to 'lock out' local control. Any invalid data or any command error immediately causes the display to read '0.0' with no action taken by the controller

CONVENTIONS:

1. "n" or "m" refers to any numeric key (a single keystroke)
2. "-" refers to the minus key - (Keyboard Layout 1)
   "**#**" refers to the minus key # (Keyboard Layout 2)
3. Items enclosed in parentheses are optional. Thus n(n(n)) means that at least one numeric key has to be depressed. Two additional numeric keystrokes are optional.
4. "A => B" is read as "A is equal to or greater than B"
5. All temperatures referred to are in the units of "degrees centigrade".
6. Keystrokes are noted as a sequence of numbers and words that define each entry. "n(n(n)) TEMP" means "press 1,2, or 3 numeric keys, then press the TEMP key." "SCAN TEMP m" means "press the key marked 'SCAN TEMP' followed by a numeric entry." BOLD type in the examples indicates keystrokes.

3-2.1 KEYBOARD COMMANDS: SINGLE TEMPERATURE MODE

(See Command Summary, TABLE 3-4)

<u>1. To SET the CHAMBER TEMPERATURE</u>

(-) n(n(n)) TEMP where -184 <= (-)n(n(n)) <= UTL (Keyboard Layout 1)
(#) n(n(n)) TEMP where -184 <= (#)n(n(n)) <= UTL (Keyboard Layout 2)

A) If the controller was in the Scan Mode before this command, the Scan Mode is terminated and the Single Temp Mode is initiated.

B) UTL is the user-settable limit temperature. UTL can only be set <= PLIMIT. PLIMIT is the highest temperature allowed or 315ºC.

C) Fractional temperatures can be entered using the - key as a decimal point once a digit has been entered.

D) Setting the temperature enables the Heat and Cool outputs with Heat/Cool switch override.

E) A temperature < -184 or > UTL is ignored and no action will be initiated by the controller.

F) EXAMPLES:

Keyboard Layout 1:

50 TEMP	sets the chamber to +50ºC
-38.5 TEMP	sets the chamber to -38.5ºC
-200 TEMP	is ignored

Keyboard Layout 2:

50 TEMP	sets the chamber to +50ºC
#38.5 TEMP	sets the chamber to -38.5ºC
#200 TEMP	is ignored

2. To SET the TIME-AT-TEMPERATURE (Soak Time)

n(n(n(n))) TIME where 0 <= n(n(n(n))) <= 1999

A) A time < 0 or > 1999 is ignored and no action is taken by the controller.

B) A time > 1800 and <= 1999 sets the time to infinity.

C) Time is interpreted as Minutes unless changed to Hours using INIT Command

D) EXAMPLES:

10 TIME	sets the soak time to 10 minutes
1981 TIME	sets the soak time to infinity
-10 TIME	is ignored (Keyboard Layout 1)
#10 TIME	is ignored (Keyboard Layout 2)

3. To DISPLAY the CHAMBER TEMPERATURE

No action is required to display the chamber temperature since the chamber temperature is normally displayed, unless the controller has been instructed to display another parameter. If so instructed, the controller will once again display the chamber temperature 3 seconds after the instruction.

4. To DISPLAY the SET TEMPERATURE

TEMP

The chamber set temperature will be displayed for 3 seconds.

5. To DISPLAY remaining time at temperature

TIME

The remaining Time-At-Temperature will be displayed for 3 second.
Time is interpreted as Minutes unless changed to Hours using INIT command

3-2.2 KEYBOARD COMMANDS: SCAN MODE

(See Command Summary TABLE 3-4 and TABLE 3-5)

1. To SET/DELETE a SCAN TEMPERATURE

Keyboard Layout 1:	
(-)n(n(n)) SCAN TEMP m	where -184 <= (-)n(n(n)) <= UTL and where 0 <= m <=9
Keyboard Layout 2:	
(#)n(n(n)) SCAN TEMP m	where -184 <= (#)n(n(n)) <= UTL and where 0 <= m <=9

A) A temperature of < -184 or > UTL is ignored and no action will be initiated by the controller.

B) UTL is the user-settable limit temperature. UTL can only be set <= PLIMIT. PLIMIT is the highest temperature allowed or 315ºC.

C) - SCAN TEMP m will delete Scan Temp and Scan Time m (Keyboard 1)
SCAN TEMP m will delete Scan Temp and Scan Time m (Keyboard 2)

D) Fractional temperatures can be entered using the - key as a decimal point once a digit has been entered.

E) Scan Temps can be assigned in any order. However, Scan Temps will be executed in ascending order.

F) EXAMPLES:

Keyboard Layout 1:

-30 SCANTEMP 3	sets Scan Temp #3
50 SCANTEMP 0	sets Scan Temp #0
100 SCANTEMP 8	sets Scan Temp #8

The previous sequence will execute +50ºC first, -30ºC second, and 100ºC third.

- SCANTEMP 3	deletes Scan Temp #3.
150 SCANTEMP 8	changes Scan Temp #8

Keyboard Layout 2:

#30 SCANTEMP 3	sets Scan Temp #3
50 SCANTEMP 0	sets Scan Temp #0
100 SCANTEMP 8	sets Scan Temp #8

The previous sequence will execute +50ºC first, -30ºC second, and 100ºC third.

#SCANTEMP 3	deletes Scan Temp #3.
150 SCANTEMP 8	changes Scan Temp #8

G) A Scan Temp entered without a corresponding Scan Time is ignored at execution time.

2. To SET/DELETE a SCAN TIME

n(n(n(n))) SCAN TIME m where 0 < n(n(n(n))) <= 1999

A) A time < 0 or > 1999 is ignored and no action is initiated by the controller.

B) A time > 1800 and <= 1999 sets the time to infinity.

C) -SCAN TIME m will delete Scan Temp and Scan Time m. (Keyboard Layout 1)
#SCAN TIME m will delete Scan Temp and Scan Time m. (Keyboard Layout 2)

D) Scan Times can be assigned in any order. They, along with their corresponding Scan Temp, will be executed in ascending order.

E) Time is interpreted as Minutes unless changed to Hours using INIT Command

F) EXAMPLES:

Keyboard Layout 1:
10 SCANTIME 3 sets Scan Time #3
82 SCANTIME 0 sets Scan Time #0
100 SCANTIME 8 sets Scan Time #8

The soak time at the first executed temperature will be 82 minutes, at the second temperature 10 minutes, and at the third temperature 100 minutes.

- SCANTIME 3 deletes Scan Time #3
55 SCANTIME 8 changes Scan Time #8

Keyboard Layout 2:
10 SCANTIME 3 sets Scan Time #3
82 SCANTIME 0 sets Scan Time #0
100 SCANTIME 8 sets Scan Time #8

The soak time at the first executed temperature will be 82 minutes, at the second temperature 10 minutes, and at the third temperature 100 minutes.

SCANTIME 3 deletes Scan Time #3
55 SCANTIME 8 changes Scan Time #8

G) A Scan Time entered without a corresponding Scan Temp is ignored at execution time.

3. To SET the number of 'CYCLES' for the SCAN MODE

n(n(n(n))) SCAN TIME - where 0 <= n(n(n(n))) <= 1999 (Keyboard 1)
n(n(n(n))) SCAN TIME # where 0 <= n(n(n(n))) <= 1999 (Keyboard 2)

An input > 1800 and <= 1999 sets the number of cycles to infinity.

4. To DISPLAY a SCAN TEMPERATURE

SCAN TEMP m where 0<= m <=9

Scan Temperature m will be displayed for 3 seconds.

5. To DISPLAY a SCAN TIME

SCAN TIME m

Scan Time m will be displayed for 3 seconds.

6. To DISPLAY the CURRENT CYCLE NUMBER

SCAN TIME – (Keyboard Layout 1)
SCAN TIME # (Keyboard Layout 2)

Note: '1' will be displayed during the first cycle or loop, '2' will be displayed during the second, etc. The scan will terminate automatically after the cycle where the current cycle number equals the number of cycles 'to do'. When the Scan Mode is terminated, the Heat and Cool outputs are disabled,

the ‘SET TEMP’ is set for 25ºC and the Time-At-Temperature is set to infinity, and the number of cycles "TO-DO" is set to infinity. If the Scan Mode hasn’t started, or has been stopped (See command #11, this section) then this command displays the original number of cycles set.

7. To DISPLAY the CHAMBER TEMPERATURE

No action is required to display the chamber temperature since the chamber temperature is normally displayed, unless the controller has been instructed to display another parameter. Is so instructed, the controller will once again display the chamber temperature 3 seconds after the instruction.

8. To DISPLAY the CURRENT SCAN TEMPERATURE

TEMP

The Set Temperature will be displayed for 3 seconds.

9. To DISPLAY REMAINING TIME at the CURRENT TEMPERATURE

TIME

The remaining Time-At-Temperature will be displayed for 3 seconds.

10. To START the SCAN MODE

SCAN TEMP SCAN TIME

Starting the Scan Mode without any valid Scan Temp/Scan Time data programmed will cause a ‘COMMAND ERROR’ response.

11. To STOP the SCAN MODE

SCAN TIME SCAN TEMP

Stopping the Scan Mode disables the Heat and Cool outputs, and disables the Time-Out function. Upon restarting, execution begins at the FIRST valid Scan Time/Temp of the "LOOP" or "CYCLE" in which it was stopped. Execution does NOT continue at the Scan Time/Temp at which the Scan was stopped.

3-2.3 KEYBOARD COMMANDS: CONTROL GROUP

to RESET (clear) the CONTROLLER

C (Keyboard Layout 1)
* (Keyboard Layout 2)

The controller is reset to power up conditions:

1) Single Temp mode
2) All scan temperature and time cleared
3) Set temperature equal to 25 degrees
4) Time-at-temperature equal to infinity
5) # of cycles equal to infinity
6) Compressor and auxiliary outputs disabled
7) Heat/Cool outputs disables
8) RS232-C echo disabled
9) IEEE-488 address displayed for 3 seconds
10) Local control enabled
11) PID coefficients and period unchanged
12) Scan interrupts are disabled
13) UTL = PLIMIT
14) Deviation limit checking disabled

3-2.4 TIME-OUT INDICATIONS

SINGLE TEMPERATURE MODE

When the desired soak time (time-at-temperature) has been reached, the operator is alerted to this fact in two ways. First, the 'TIME-OUT' LED located on the front panel is turned 'ON'. Secondly, a continuous tone is emitted from a transducer located on the TC01 power supply board. The LED and audio indication will continue until a TIME or TEMP key is pressed. Alternately, the controller may be RESET by depressing the 'C' (clear) key. Note that when RESET, all SCAN temps and times are cleared and the Single Temp mode is entered. See 3-2.3.

SCAN MODE

The TC01 Scan Mode allows a maximum of 10 segments (0 through 9) to be programmed through the keyboard. Each segment is described by a Temperature and a Soak Time (time-at-temperature). One minute before any particular Soak Time is compete, an audible indication will start and continue for the remaining one minute. This time-out is distinguished from the single temp mode time-out mentioned above in that the sound is 'ON' for 1 second and 'OFF' for 1 second. At the end of the 1 minute on/off period, the audible indication is automatically turned 'OFF'. The TC01 then moved on to the next Scan segment. This one minute "warning" can be used to alert an operator to start taking data or measurements during the final minute of the programmed soak time. If a number of cycles have been programmed, the above sequence is repeated for each cycle. At the end of the last soak time of the last cycle, a continuous tome is emitted until a TIME or TEMP key is pressed. Alternately, the controller can be RESET by depressing 'C' (clear) on the keyboard. Note that when RESET, all SCAN temps and times are cleared and the single temp mode is entered. See 3-2.3

3-3 RS232 - C REMOTE CONTROL

CONVENTIONS/COMMENTS:

1. “n” or “m” refers to any numeric character 0 through 9.
2. Items enclosed in parentheses “( )” are optional. Thus n(n(n(n))) means that at least one numeric character has to be sent. One or two additional numeric characters to the left of a decimal and one character after a decimal is allowed.
3. All times referred to are in the unit of minutes or hours.
4. All temperatures referred to are in the unit of “degrees centigrade.”
5. Commands sent to the controller and data sent from the controller are in the form of “ASCII character strings”. Commands sent to the controller are masked to 7 bits and may contain space characters (blanks).
6. The RS232 encoding format used for Windows is: Baud Rate: 9600, Data: 8 Bits, Parity: None, Flow Control: None, Stop Bits: 1 (Note: Older equipment with serial numbers below C1508, Baud Rate = 2400)
7. Data sent from controller are followed by carriage return and line feed characters as line terminator.
8. See TABLE 3-1 for RS232-C CONTACT ASSIGNMENTS and WIRING DIAGRAM.
9. The command processor software ignores leading zero’s and trailing digits on all numeric data received. For example, -0000025.32c will set the single mode temperature to -25.3c.
10. BOLD type in the Terminal Examples indicates keystrokes required from the terminal keyboard.
11. When a ‘dumb terminal’ is used for the RS232 interface, any TC01 output will automatically be displayed on the terminal. When using a computer, any TC01 output must be read through some form of ‘INPUT’ or READ’ statement- usually a part of an application program written in a language such as BASIC.
12. Computer examples are written in BASIC. In these BASIC statements, the variables X, Y, and A$ are assumed to be defined somewhere else in the BASIC program and contain the proper values for desired results. The BASIC program statements: PRINT#1 and INPUT#1 are assumed to output RS232 data to the TC01 and input RS232 data from the TC01, respectively.

3-3.1 RS232 COMMANDS: SINGLE TEMPERATURE MODE

(See Command Summary TABLE 3-4 and TABLE 3-5)

1. to SET the CHAMBER TEMPERATURE
   (-)n(n(n(.(n)))C where -100 <= (-)n(n(n.(n))) <= UTL

   A) If the controller was in the scan mode before this command, the scan mode is terminated and the single temp mode is initiated.

   B) UTL is the user-settable limit temperature. UTL can only be set <= 315.

   C) Setting the temperature enables the heat and cool outputs, with heat cool switch override.

   D) A temperature < -100 or > UTL is ignored and no action will be initiated by the controller.

   E) TERMINAL EXAMPLES:
   50C sets the chamber to +50.0C
   -38.2C sets the chamber to -38.2C
   -108C is ignored

F) COMPUTER EXAMPLES: PRINT#1,”-38.2C” or PRINT#1,X,”C”

2. to SET the TIME-AT-TEMPERATURE (Soak Time)

   n(n(n(n)))M where 0 < n(n(n(n))) <= 1999

   A) A time < 0 or > 1999 is ignored and no action is initiated by the controller.

   B) A time between 1800 and 1999 sets the time to infinity.

   C) TERMINAL EXAMPLES: 10M sets the soak time to 10 minutes
   1981M sets the soak time to infinity
   -10M is ignored

   D) COMPUTER EXAMPLES: PRINT#1,”10M” or PRINT#1,X”M”

3. to SET the DEVIATION LIMIT and ENABLE DEVIATION INTERRUPT

   EDIn(n(n(.(n)))) where 0 <= n(n(n(.(n)))) <= UTL

   A) The allowed temperature deviation before generating a deviation interrupt is +/- the set value around the target chamber set temperature.

   B) The deviation checking is automatically disabled during transitions between chamber temperature set points and begins once the chamber temperature is within the deviation limits of the set temperature.

   C) The deviation limit will be checked each time a new heat/cool period is calculated (once every 2 seconds, default).

   D) TERMINAL EXAMPLE: EDI5.3 enables interrupt and set limit to +/- 5.3c

   E) COMPUTER EXAMPLE: PRINT#1,”EDI5.3" or PRINT#1,”EDI”,X

4. to READ the CHAMBER TEMPERATURE

   T

   A) The resolution of the temperature reading read over the interface is .1 degree centigrade.

   B) The front panel LED display will display to .1 deg up to 199.9 deg. At temperatures >200 deg, the display resolution is 1 deg.

   C) TERMINAL EXAMPLE: T chamber temp is displayed on terminal
   D) COMPUTER EXAMPLE: PRINT#1,”T” output command to TC01
   INPUT#1, X read chamber temperature

5. to READ the SET TEMPERATURE

   C

   A) The resolution of the temperature reading read over the interface is .1 degree centigrade.

   B) The front panel LED display will display to .1 deg up to 199.9 deg. At temperatures > 200 deg, the display resolution is 1 deg.

   C) TERMINAL EXAMPLE: C outputs Set Temp to terminal

   D) COMPUTER EXAMPLE: PRINT#1,"C" outputs command to TC01
   INPUT#1, X read Set Temp

6. to READ the REMAINING TIME at the CURRENT TEMPERATURE

   M

   A) Time is interpreted as minutes unless hours was selected by the INIT command. OPT can be used to determine time setting.

   B) TERMINAL EXAMPLE: M outputs Time to terminal

   C) COMPUTER EXAMPLE: PRINT#1,"M" output command to TC01
   INPUT#1, X read Time

3-3.2 RS232 COMMANDS: SCAN MODE

(See Command Summary TABLE 3-4 and TABLE 3-5)

1. to SET/DELETE a SCAN TEMPERATURE

   (-)n(n(n.(n))))Am where -100.0 <= (-)n(n(n(.(n)))) <= UTL and 0 <= m <= 9

   A) A temperature < -100 or > UTL is ignored and no action is initiated by the controller.

   B) UTL is the user-settable limit temperature. UTL can only be set <= PLIMIT. PLIMIT is the highest temperature allowed or 315 deg C.

   C) -Am will delete scan temperature and time m.

   D) Scan Temps can be assigned in any order. Scan Temps will be executed in ascending order.

   E) The resolution of the temperature set of the interface is .1 deg. The LED display will only display to .1 degree up to 199.9 deg. At temperatures >200 deg, the display resolution is 1 deg.

F) TERMINAL EXAMPLES: -30A3 sets Scan Temp #3 to -30 C
50.2A0 sets Scan Temp #0 to +50.2 C
100.5A8 sets Scan Temp #8 to +100.5 C

The above sequence will be executed +50.2 C first, -30.0 C second, and +100.5 C third.

-A3 deletes Scan Temp #3

With Scan Temp #3 deleted, execution will start with +50.2 C and end with +100.5 C.

150.5Ab sets Scan Temp #8 to +150.5 C

Note that the new Scan Temp of 150.5 writes over the old one of 100.5.

G) COMPUTER EXAMPLES: PRINT#1,"-30A3" or PRINT#1,X,"A",Y

2. to SET/DELETE a SCAN TIME

A) A time < 0 or > 1999 is ignored and no action is initiated by the controller.

B) A time between 1800 and 1999 sets the time to infinity.

C) -Bm will delete scan temperature and time m.

D) Scan Times can be assigned in any order. They, along with their corresponding Scan Temp, will be executed in ascending order.

E) TERMINAL EXAMPLES: 10B3 sets Scan Time #3 to 10 minutes
82B0 sets Scan Time #0 to 82 minutes
100B8 sets Scan Time #8 to 100 minutes

The soak-time at the first executed temperature will be 82 minutes, at the second temperature, 10 minutes, and at the third temperature, 100 minutes.

F) COMPUTER EXAMPLES: PRINT#1,"10B3" or PRINT#1,X,"B",Y

3. TO SET THE NUMBER OF 'CYCLES' OR 'LOOPS' FOR THE SCAN MODE

n(n(n(n)))B- where 1 <= n(n(n(n))) <= 1999

A) An input >1800 and <= 1999 sets the number of cycles to infinity.

B) The number of cycles that have been set can only be displayed before the Scan sequence has started. (see #7 below) or, once the scan sequence has been started, by stopping the scan sequence and executing command #7 below. See command #12, this section.

C) TERMINAL EXAMPLES: 124B- sets the number of cycles to 124

D) COMPUTER EXAMPLES: PRINT#1,"125B-" or PRINT#1,X,"B-"

4. to SET the DEVIATION LIMIT and ENABLE DEVIATION INTERRUPTS

   EDIn(n(n(.(n))) where 0 <= n(n(n.(n)))) <= UTL

   A) The allowed temperature deviation before generating a deviation interrupt is +/- the set value around the target chamber set temperature.

   B) The deviation checking is automatically disabled during transitions between chamber temperature set points and begins once the chamber temperature is within the deviation limits of the set temperature.

   C) The deviation limit will be checking each time a new heat/cool period is calculated (once every 2 seconds, default).

   D) TERMINAL EXAMPLES: EDI5.3 enables interrupt and sets limit to ± 5.3C

   E) COMPUTER EXAMPLES: PRINT#1,"EDI5.3" or PRINT#1,EDI",X

5. to READ a SCAN TEMPERATURE

   Am where 0 <= m <= 9

   A) The resolution of the temperature measurement of the interface is .1 deg. The LED display will only display to .1 degree up to 199.9 deg. At temperatures > 200 deg, the display resolution is 1 deg.

   B) TERMINAL EXAMPLES: A3 causes TC01 to output Scan Temp #3

   C) COMPUTER EXAMPLES: PRINT#1,"A3" outputs command to TC01
   INPUT#1,X reads Scan Temp #3
   or PRINT#1,"B",Y
   INPUT#1,X

6. TO READ THE CURRENT CYCLE NUMBER

   B-

   A) '1' will be displayed during the first cycle or loop, '2' will be displayed during the second, etc. The scan will terminate automatically after the cycle where the current cycle number equals the number of cycles 'to do'. When the scan mode is terminated, the heat and cool outputs are disabled, the 'set temp' is set for 25 deg., the time at temperature is set to infinity, and the number of cycles 'to do' is set to infinity. If the Scan Mode hasn't started, or has been stopped (see #11, this section), then this command displays the original number of cycles set.

   B) TERMINAL EXAMPLES: B- reads current cycle number

   C) COMPUTER EXAMPLES: PRINT#1,"B-" INPUT#1,X

7. to READ the CURRENT CHAMBER TEMPERATURE

   T

   A) The resolution of the temperature measurement of the interface is .1 deg. The LED display will only display to .1 deg up to 199.9 deg. At temperatures > 200 deg, the display resolution is 1 deg.

   B) TERMINAL EXAMPLES: T causes TC01 output current Temp

   C) COMPUTER EXAMPLES: PRINT#1,"T" INPUT#1,X

8. to READ the CURRENT SCAN TEMPERATURE

   C

   A) See 8 A) above

   B) TERMINAL EXAMPLES: C causes TC01 to output current Scan Temp

   C) COMPUTER EXAMPLES: PRINT#1,"C" INPUT#1,X

9. to Read REMAINING TIME at CURRENT TEMPERATURE

   M

   A) Time is interrupted as minutes unless hours was selected by the INIT command then it is in hours.

   B) TERMINAL EXAMPLES: C causes TC01 to output remaining time

   C) COMPUTER EXAMPLES: PRINT#1, "M" outputs commands to TC01
   INPUT#1, X reads Time

10. to START the SCAN MODE

    AB

    A) Starting the Scan Mode without any valid Scan Temp/Scan Time data programmed will cause a 'command error' response.

    B) TERMINAL EXAMPLES: PRINT#1,"AB" starts Scan Mode or PRINT#1,A$

11. to STOP the SCAN MODE

    BA

    A) Heat and Cool outputs are disabled; the time-outs function is turned off. Upon restarting, execution beings at the FIRST valid Scan Temp/Time data of the 'loop' or 'cycle' in which it was stopped. It does NOT continue at the scan data at which the Scan was stopped.

    B) TERMINAL EXAMPLES: BA stops scan mode

C) COMPUTER EXAMPLES: PRINT#1,"BA" stops Scan Mode

3-3.3 RS232 COMMANDS: CONTROL GROUP

1. to RESET (clear) the CONTROLLER

   R

   The controller is rest to power up conditions:
   1) Single Temp Mode
   2) All scan temperatures and times cleared
   3) Set temperature equal to 25 degrees
   4) Time-at-temperature equal to infinity
   5) # of cycles equal to infinity
   6) Compressor and auxiliary outputs disabled
   7) Heat/Cool outputs disabled
   8) RS232-C echo disabled
   9) IEEE-488 address displayed for 3 seconds
   10) Local control enabled
   11) PID coefficients unchanged
   12) Scan interrupts are disabled
   13) UTL =PLIMIT
   14) Deviation limit checking disabled

2. to ENABLE LOCAL CONTROL of the CONTROLLER

   Pressing a local keyboard key returns the controller to local mode. There is no local lockout function supported for the RS232-C bus.

3. to ENABLE REMOTE CONTROL
   The controller is automatically set in the remote mode whenever it receives a character over the RS232-C bus.

4. to ENABLE RS232 ECHO mode

   H

   A) The default mode is 'no echo' of characters that come in the RS232 port.

   B) This command sets the controller in the 'echo mode' which causes any character input to the RS232 port to be echoed back out to the RS232 port.

   C) To re-enter the 'no echo' mode, the controller must be RESET. Note that RESET will clear all SCAN times and temps and controller will enter single temp mode.

   D) TERMINAL EXAMPLES: H enables RS232 Echo

   E) COMPUTER EXAMPLES: PRINT#1,"H" enables RS232 Echo

5. to ENABLE the HEAT and COOL OUTPUTS

   ON

   A) Setting the single mode ‘set temp’ or starting the ‘scan mode’ also automatically enables the heat and cool outputs.

   B) TERMINAL EXAMPLES: ON enables Heat/Cool outputs

   C) COMPUTER EXAMPLES: PRINT#1,”ON” or PRINT#1,A$

6. to ENABLE the AUXILIARY #1 OUTPUT

   OUT1ON

   A) This auxiliary output is typically used for compressor control in mechanically cooled temperature chambers. At power up, the TC01 sets a status bit that instructs it to use the AUX #1 output for compressor control. The TC01 will automatically turn the compressor ON when one of the following conditions is met:

      1) When the SET temperature <= 40 deg C and heat/cool outputs enabled.

      2) When the TC01 is in the scan mode and the next scan set temperature is less than the current scan set temp and the time remaining at the current is < 1 minute and heat/cool outputs enabled.

      3) Whenever cooling is required (and has been required for > 1 minute) regardless of the current set temperature value and heat/cool outputs enabled.

      4) If a new set temp < the current set temp in the single temp mode.

   B) The TC01 will automatically turn the compressor OFF when:

      1) The SET temperature > 40 deg C and cooling has not been required for a period of 1 minute and not in the last minute of a scan temp point.

      2) The TC01 has received an OFF command or whenever the heat/cool outputs are disabled.

         The TC01 will always perform the above automatic compressor control unless it receives an “OUT1ON” or an “OUT1OFF” command. Once it receives either, the automatic compressor control is disabled until the TC01 is RESET. Once disabled, the user can enable or disable this output (via “OUT1ON” or “OUT1OFF”) at will to control whatever external event desired, including any compressor. The auxiliary output consists of an open collector output plus a 5 volt/270 ohm current source which can be used to drive opto coupler circuits. See Figure 3B for the auxiliary output interface.

   C) TERMINAL EXAMPLES: OUT1ON enables Aux#1 output

   D) COMPUTER EXAMPLES: PRINT#1,”OUT1ON” or PRINT#1,A$

7. to ENABLE the AUXILIARY #2 OUTPUT

   OUT2ON

   A) This auxiliary output is not used by any TC01 internal function. The default condition is off.

   B) TERMINAL EXAMPLES: OUT2ON enables Aux#2 output

   C) COMPUTER EXAMPLES: PRINT#1,"OUT2ON" or PRINT#1,A$

8. to ENABLE SCAN MODE INTERRUPTS

   ESI

   A) While the RS232 port does not experience or deliver 'interrupts' as such, this command allows the TC01 to output the various characters that signify end-of-soak-times as discussed in Section 3-3.5.

   B) TERMINAL EXAMPLES: ESI enables Scan Mode Interrupts

   C) COMPUTER EXAMPLES: PRINT#1,"ESI" or PRINT#1,A$

9. to ENABLE DEVIATION INTERRUPTS

   See section 3-3.2, #4.

10. to DISABLE LOCAL KEYBOARD CONTROL

    There is no command to disable local control from the RS232 port. See IEEE-488 command on local lockout.

11. to DISABLE RS232 ECHO

    R

    A) Note that this is a reset command which will also reset most other controller parameters. See COMMAND 1 of the section.

    B) TERMINAL EXAMPLES: R will disable Echo and Reset TC01

    C) COMPUTER EXAMPLES: PRINT#1,"R" or PRINT#1,A$

12. to DISABLE the HEAT and COOL OUTPUTS

    OFF

    A) TERMINAL EXAMPLES: OFF disables Heat/Cool outputs

    B) COMPUTER EXAMPLES: PRINT#1,"OFF" or PRINT#1,A$

13. to DISABLE THE AUXILIARY #1 OUTPUT

    OUT1OFF

    A) See discussion in this section at command #6.

    B) TERMINAL EXAMPLES: OUT1OFF disables Aux#1 output

    C) COMPUTER EXAMPLES: PRINT#1,"OUT1OFF" or PRINT#1,A$

14. to DISABLE the AUXILIARY #2 OUTPUT

    OUT2OFF

    A) TERMINAL EXAMPLE : OUT2OFF disables Aux #2 output

    B) COMPUTER EXAMPLE : PRINT#1,"OUT2OFF" or PRINT#1,A$

15. to DISABLE SCAN MODE INTERRUPTS

    DSI

    A) See discussion at command #8, Enable Cycle Interrupts.

    B) TERMINAL EXAMPLE: DSI disables Scan Mode Interrupts

    C) COMPUTER EXAMPLE: PRINT#1,"DSI" or PRINT#1,A$

16. to DISABLE the DEVIATION INTERRUPT

    DDI

    A) See discussion at Section 3-3.2 #4.

    B) TERMINAL EXAMPLE : DDI disables deviation interrupts

    C) COMPUTER EXAMPLE : PRINT#1,"DDI" or PRINT#1,A$

3-3.4 RS232 SPECIAL GROUP

1. PID COEFFICIENT CHANGE
   Modification of the PID coefficients used in the TC01 algorithm is not generally recommended for the casual user. The standard TC01 PID coefficients have been chosen to provide a good compromise between fast settling time and good overshoot characteristics. However, for those who wish to optimize the TC01 transient or steady state response for their particular application, an application note (part # 680008) has been written to assist in the PID coefficient changes. See our web home page at www.sunelectronics.com.

   The TC01 controller calculates the amount of heating or cooling required to maintain the chamber temperature at the set temperature using a 3 mode proportional, integral, derivative servo equation. There is a weighing coefficient for each of the three

components of the control equation. At power up, the TC01 reads the default PID coefficients from its EEPROM memory and will use these coefficients unless they are changed, by the user, using this command. Once changed, the TC01 will continue to use the new coefficient until changed by another command or until the TC01 is powered off. Therefore, if other than the default coefficients are to be used, they must be set each time the TC01 is powered on. A new command “INIT” has been added to allow permanent changes to be made by the user.

to SET PID WEIGHING COEFFICIENTS

PID= (-)n, (-)n, (-)n where 0 < n < 9

A) The above values of ‘n’ are interpreted as exponents of 2. Therefore each multiplier has a range of 2^(-9) to 2^(+9).

B) The first value is the ‘proportional coefficient.’ multiplier. The second value is the ‘integral coefficient’ multiplier. The third value is the ‘derivative coefficient’ multiplier.

C) TERMINAL EXAMPLE:

PID=0, -3,4 sets the proportional coefficient to one since 2^(0) = 1,
sets the integral coefficient. to 2^(-3) = .125,
sets the derivative coefficient. to 2^(4) = 16

D) COMPUTER EXAMPLE:

```
PRINT#1,”PID=0,-3,4"
PRINT#1,”PID=”,X,”,”,Y,”,”,Z
```

to READ the CURRENT PID COEFFICIENTS

PID?

A) The three multipliers will be sent, each followed by CR LF

B) TERMINAL EXAMPLE: PID?

C) COMPUTER EXAMPLE:

```
PRINT#1"PID?”
INPUT#1,P$
INPUT#1,I$
INPUT#1,D$
```

2. OUTPUT THE INSTALLED OPTIONS

OPT

The OPT command allows the user to determine the type of unit that he is talking to, the type of probe, and the units of time that have been selected. Upon receiving the OPT command the TC01 will send an ASCII string containing “TC01, probe type, time units “. The substring TC01 informs the user that he is talking to a TC01. The probe type substring provides info on the type of temperature sensor that the TC01 is configured for. The substring time units will be MIN when minutes selected or HRS for hours time selection.

3. OUPUT AUXILIARY INPUT STATE

   IN1

   A) The value returned is 0 if the input is a TTL logic low, and 1 if the input is a logic high.

   B) See figure 3 for the AUXIN wiring.

   C) TERMINAL EXAMPLE : IN1 causes TC01 to output State

   D) COMPUTER EXAMPLE : PRINT#1,”IN1" or PRINT#1,A$

4. to SET UPPER TEMPERATURE LIMIT (UTL)

   (-)n(n(n(.(n))))UTL where -100 <= (-)n(n(n(.(n)))) <= PLIMIT

   A) UTL may be set to any value between -100 and PLIMIT inclusive. The value of PLIMIT is 315 deg C.

   B) UTL is set equal to PLIMIT at power up.

   C) TERMINAL EXAMPLE : 100.0UTL sets the UTL to 100.0 C

   D) COMPUTER EXAMPLE : PRINT#1,”UTL” or PRINT#1.A$

5. INIT TC01 OPERATING MODES

   INITn,p,i,d,M or H,C

   The INIT command allows the user to change most TC01 modes. The INIT command is a remote only command. The parameters that it changes are stored in EEPROM such that the information is saved with power off.

   n is a digit between 1 and 7 and selects the temperature probe type as follows;

   1= RTD 3 wire 100 ohm .385 alpha
   2= RTD 3 wire 100 ohm .392 alpha
   3= J thermocouple
   4= K thermocouple
   5= T thermocouple

   , data separator

   p allows permanent change to the PID P coefficient

   , data separator

   i allows permanent change to the PID I coefficient

   , data separator

   d allows permanent change to the PID D coefficient

, data separator

M to set time units to minutes or H for hours units

, data separator

finally always send C character

3-3.5 TIME-OUT/PROBLEM INDICATIONS

TIME-OUT INDICATIONS — SINGLE TEMPERATURE MODE

When the desired soak time (time-at-temperature) has been reached, the operator is alerted to this fact in three ways. Firstly, the 'TIME-OUT' LED located on the front panel is turned 'ON'. Secondly, a continuous tone is emitted from a transducer located on the TC01 power supply board. Thirdly, an ASCII 'I' is sent by the TC01 to the host RS232 device. The LED and audio indication will continue until a TIME or TEMP key is pressed. Alternately, the controller may be RESET by sending a RESET command (see Section 3-3.3) or by depressing the 'C' key on the TC01 keyboard. Note that all SCAN temps are cleared by the RESET command.

TIME-OUT INDICATIONS — SCAN MODE

Time-out bus and port indications may be ENABLED or DISABLED per commands in 3-3.3. The default condition is that Time-Out Indications are DISABLED. Audio (buzzer) and visual (LED) indicators are always enabled and may never be disabled.

The TC01 SCAN mode allows a maximum of 10 segments to be programmed through the RS232 port. Each segment is described by a temperature and a soak-time (time-at-temperature). Additionally, the scan mode sequence chosen by the user can be programmed to be automatically repeated any number of times up to a total of 1800 'cycles'. Thus we may define several types of 'time-outs' that would be useful to the user.

The first to consider is a time-out indication at the end of each soak time point within the temperature scan sequence. Another type would be a time-out signifying completion of the last soak time in a scan sequence. Since the scan sequence can be cycled, yet another time-out indication would be to alert that all cycles programmed have been completed.

The TC01 outputs three different ASCII characters for each of the three distinct time-outs (assuming time-out indications are ENABLED). The table below describes said characters. The characters are sent out 1 minute before completion of time-out.

TIME-OUT TYPE	ASCII CHARACTER SENT
SOAK TIME COMPLETE	P
CYCLE ('LOOP') COMPLETED	L
END OF TOTAL RUN	E

PROBLEM INDICATORS

Three problem indicators have been incorporated into the TC01.

PROBLEM TYPE	ASCII CHARACTER SENT
Deviation Limit Exceeded (when enabled)	D
Chamber Temp Exceeds UTL (automatically disables heat/cool)	O
Command Error	CMD ERROR!!

TABLE 3-1 RS232-C Contact Assignments & Wiring Diagram

CONTACT	SIGNAL LINE
1	GROUND
2	TRANSMIT DATA
3	RECEIVE DATA
7	SIGNAL GROUND
20	DATA TERMINAL READY

To communicate over the RS232 bus, a cable constructed with a male DB25 connector on the TC01 controller and a female DB9 connector on PC end and wired as follows is required:

TC01 CONTROLLER (DB25 Male) Pin#		COMPUTER (DB9 Female) Pin#
(2) TxD	_____	RxD (2)
(3) RxD	_____	TxD (3)
(7) GND	_____	GND (5)

For TC01 Controllers with serial number C1508 or later, use the following settings to communicate through Windows:

Connect using desired COM port
Bits per second: 9600
Data bits: 8
Parity: NONE
Stop bits: 1
Flow Control: NONE
CAPS LOCK ON FOR TCO1

**Note: If you are running Windows and operating a TC01 Controller with a serial number prior to C1508 you will need to use the following settings:

Connect using desired COM port
Bits per second: 2400
Data bits: 8
Parity: NONE
Stop bits: 1
Flow Control: NONE
CAPS LOCK ON FOR TC01

If your computer is using a DB25 Male connector instead of the DB9, the wiring connections are as follows.

TC01 CONTROLLER (DB25 Male) Pin#		COMPUTER (DB25 Female) Pin#
(2) TxD	_____	RxD (3)
(3) RxD	_____	TxD (2)
(7) GND	_____	GND (7)

3-4 IEEE-488 REMOTE CONTROL

CONVENTIONS:

1. “n” or “m” refers to any numeric character 0 through 9
2. Items enclosed in parentheses “( )” are optional. Thus n(n(n(.(n)))) means that at least one numeric character has to be sent. Optionally, one or two additional characters to the left of a decimal are allowed and one character after the decimal is allowed.
3. The sample 9825 commands assume that the calculator’s IEEE-488 interface card is set to select code 7; and that the temperature controller’s address has been set to binary 3.
4. Blanks, or space char, are ignored.
5. “X” and “Y” are variables assumed to be defined elsewhere in the controlling program.
6. See table 3-2 for IEEE-488 CONTACT ASSIGNMENTS
7. See table 3-3 for IEEE-488 BUS ADDRESS SWITCH SETTINGS
8. The command processor software ignores leading zero’s and trailing digits on all numeric data received. For example: -0000025.321000 C will set the signal mode temperature to -25.3 deg.

3-4.1 GPIB COMMANDS: SINGLE TEMPERATURE MODE

(See Command Summary TABLE 3-4 and TABLE 3-5)

1. to SET the CHAMBER TEMPERATURE

   (-)n(n(n(.(n))))C where -100.0 <= (-)n(n(n(.(n)))) <= UTL

   A) If the controller was in the scan mode before this command, the scan mode is terminated and the single temp mode is initiated.

   B) UTL is the user-settable limit temperature. UTL can only be set <= PLIMIT. PLIMIT is the highest temperature allowed for the TC01 and is 315 deg C.

   C) Setting the temperature enables the heat and cool outputs with heat cool switch override.

   D) A temperature < -100 or > UTL is ignored and no action will be initiated by the controller.

   E) Sample GPIB commands write 703,”50.2C” assume controller id=7, TC01 device address = 03, string=”50.2C” sets the chamber temperature to +50.2 deg C

2. to SET the TIME-AT-TEMPERATURE (Soak Time)
   n(n(n(n)))M where 0 <= n(n(n(n))) <= 1999

   A) A time < 0 or > 1999 is ignored and no action is initiated by the controller.

   B) A time between 1800 and 1999 sets the time to infinity.

   C) Time is interpreted as minutes unless the HR option is installed whereby time is interpreted as hours.

3. to SETthe DEVIATION LIMIT and ENABLE DEVIATION INTERRUPT

   EDIn(n(n(.(n)))) where 0 <= n(n(n(.(n)))) <= UTL

   A) The allowed temperature deviation before generating a deviation interrupt is +/- the set value around the target chamber set temperature.

   B) The deviation checking is automatically disabled during transitions between chamber temperature set points and begins once the chamber temperature is within the deviation limits of the set temperature.

   C) The deviation limits will be checked each time a new heat/cool period is calculated (once every 2 seconds, default).

4. to READ the CHAMBER TEMPERATURE

   T

   A) The resolution of the temperature reading read over the bus is .1 degree centigrade.

   B) The LED display will only display from .1 deg up to 199.0 deg. At temperatures >200 the display resolution is 1 deg.

5. to READ the SET TEMPERATURE

   C

   A) The resolution of the temperature reading read over the bus is .1 degree centigrade.

   B) The LED display will only display to .1 deg up to 199.9 deg. AT temperatures >200 the display resolution is 1 deg.

6. to READ the REMAINING TIME at the CURRENT TEMPERATURE

   M

   A) Time is interpreted as minutes unless the HR option is installed whereby time is interpreted in hours.

3-4.2 GPIB COMMANDS: SCAN MODE

(See Command Summary TABLE 3-4 and TABLE 3-5)

1. to SET/DELETE a SCAN TEMPERATURE

   (-) (n(n(n(.(n))))Am where -100.0 <= (-)n(n(n(.(n)))) <= UTL

   A) A temperature <-100 or > UTL is ignored and no action is initiated by the controller.

   B) UTL is the user-settable limit temperature. UTL can only be set <= PLIMIT. PLIMIT is the highest temperature allowed for the TC01 and is 315 deg C.

   C) -Am will delete scan temperature and time m

   D) Scan Temps can be assigned in any order. However, Scan Temps will be executed in ascending order of 'm'.

   E) The resolution of the temperature set over the interface is .1 deg. However, the LED display will only display to .1 deg up to 199.9. At temps >200 deg, the display resolution is 1 deg.

2. to SET/DELETE a SCAN TIME
   n(n(n)0Bm where 0 <= n <= 1999 and 0 <= m <= 9

   A) A time < 0 or > 1999 is ignored and no action is initiated by the controller.

   B) A time between 1800 and 1999 sets the time to infinity.

   C) -Bm will delete scan temperature and time m

   D) Scan times can be assigned in any order. They, along with their corresponding Scan Temp, will be executed in ascending order.

   E) Time is interpreted as minutes unless the HR option is installed whereby time is interpreted as hours.

3. to SET the number of CYCLES for the SCAN MODE

   n(n(n))B- where a <= n(n(n)) <= 180

   A) An input >1800 ans <= 1999 sets the number of cycles to infinity.

   B) The number of cycles that have been set can only be displayed before the Scan sequence has begun (see #7 below) or, once the Scan sequence has started, by stopping the scan sequence and executing command #7 below. See command #12 of this section.

4. to SET the DEVIATION LIMIT and ENABLE DEVIATION INTERRUPTS

   EDIn(n(n(.(n)))) where 0 <= n(n(n(.(n)))) <= UTL

   A) The allowed temperature deviation before generating a deviation interrupt is +/- the set value around the target chamber set temperature.

B) The deviation checking is automatically disabled during transitions between chamber temperature set points and begins once the chamber temperature is within the deviation limits of the set temperature.

C) The deviation limit will be checked each time a new heat/cool period is calculated (once every 2 seconds, default)

5. to READ a SCAN TEMPERATURE

   Am where 0 <= m <= 9

   A) The resolution of the temperature measurement of the interface is .1 deg. However, the LED display will only display to .1 deg up to 199.9 deg. At temperatures >200 deg, the display resolution is 1 deg.

6. to READ a SCAN TIME

   Bm where 0 <= m <= 9

   A) Time is interpreted as minutes unless the HRS has been selected whereby time is interpreted as hours.

7. to READ the CURRENT CYCLE NUMBER

   B-

   A) '1' will be displayed during the first cycle or loop, '2' will be displayed during the second, etc. The scan will terminate automatically after the cycle where the current cycle number equals the number of cycles 'to do.' When the scan mode is terminated, the heat and cool outputs are disabled, the 'set temp' is set for 25 deg. and the time-at-temperature is set to infinity, and the number of cycles 'to do' is set to infinity. If the Scan Mode has not started, or has been stopped (see #12 of this section) then this command displays the original number of cycles set.

8. to READ the CURRENT CHAMBER TEMPERATURE

   T

   A) The resolution of the temperature reading read over the bus is .1 degree centigrade. The LED display will only display to .1 deg up to 199.9 deg. At temperatures >200, the display resolution is 1 deg.

9. to READ the CURRENT SCAN TEMPERATURE

   C

   A) See 8 A) above

10. to READ the REMAINING TIME at CURRENT TEMPERATURE

    M

    A) Time is interpreted as minutes unless the HR option is installed whereby time is interpreted as hours.

11. TO START THE SCAN MODE

    AB

    A) Starting the Scan Mode without any valid Scan Temp/Scan Time data programmed will cause a 'command error' response.

12. to STOP the SCAN MODE

    BA

    A) Heat and Cool outputs are disabled; the time-out function is turned off. Upon restarting, execution begins at the FIRST valid Scan Temp/Time data of the 'loop' or 'cycle' in which it was stopped. It does NOT at the scan data at which the Scan was stopped.

3-4.3 GPIB COMMANDS: CONTROL GROUP

1. to RESET the CONTROLLER

   R

   A) The controller is reset to power up conditions:

      1) Single temp mode
      2) All scan temperatures and times cleared
      3) Set temperature equal to 25 degrees
      4) Time-at-temperature equal to infinity
      5) # of cycles equal to infinity
      6) Compressor and auxiliary outputs disabled
      7) Heat/Cool outputs disabled
      8) RS232-C echo disabled
      9) IEEE-488 \address displayed for 3 seconds
      10) Local controls enabled
      11) PID coefficients unchanged
      12) Scan interrupts are disabled
      13) UTL = PLIMIT
      14) Deviation limit checking disabled

2. to ENABLE LOCAL CONTROL

   See IEEE std 488-1975

   A) Sample GPIB command

      lcl 7 (see your GPIB system documentation for its command)

   B) After the return to local command is received, pressing the RESET key (the 'C' key) on the local keyboard is necessary to return the controller to local control.

3. to ENABLE REMOTE CONTROL

   See IEEE std 488-1975

   A) Sample GPIB command

      rem 703 (see your GPIB system documentation for its command)

   B) The controller is also set in remote mode whenever it is selected during a bus transfer.

4. to ENABLE RS232 ECHO MODE

   H

   A) The default mode is 'no echo' of characters that come in the RS232 port.

   B) This command sets the controller in the 'echo mode' which causes any character put to the RS232 port to be echoed back out the RS232 port.

   C) To re-enter the 'no echo' mode, the controller must be RESET. Note that RESET will clear all SCAN times and temps and the controller will enter the single temp mode.

      See command #1 above.

5. to ENABLE the HEAT and COOL OUTPUTS

   ON

   A) Setting the single mode 'set temp' or starting the 'scan mode' also automatically enables the heat and cool outputs.

6. to ENABLE the AUXILIARY #1 OUTPUT

   OUT1ON

   A) This auxiliary output is typically used for compressor control in mechanically cooled temperature chambers. At power up, the TC01 sets a status bit that instructs it to use the AUX #1 output for compressor control. The TC01 will automatically turn the compressor ON when one of the following conditions is met:

      1) When the SET temperature <= 40 deg and heat/cool outputs enabled.

      2) When the TC01 is in the scan mode and the next scan set temperature is less than the current scan set temp and the time remaining at the current point is < 1 minute and heat/cool outputs enabled.

      3) Whenever cooling is required (and has been required continuously for > 1 minute) regardless of the current set temperature value and heat/cool outputs enabled.

      4) If a new set temp < current set temp in the single temp mode.

B) The TC01 will automatically turn the compressor OFF when:

1) The SET temperature > 40 deg C and cooling has not been required for a period of 1 minute and not in the last minute of a scan temp point.

2) The TC01 has received an OFF command or whenever the heat/cool outputs are disabled.

The TC01 will always perform the above automatic compressor control unless it receives an “OUT1ON” or an “OUT1OFF” command. Once it receives either, the automatic compressor control is disabled until the TC01 is RESET or turned OFF then ON again. Once disabled, the user can then enable or disable this output (via “OUT1ON” or “OUT1OFF”) at will to control whatever external event desired, including any compressor. The auxiliary output consists of an open collector output plus a 5 volt/270 ohm current source which can be used to drive opto coupler circuits. See figure 3 for auxiliary output interface.

7. to ENABLE the AUXILIARY #2 OUTPUT

   OUT2ON

   A) This auxiliary output is not used by internal TC01 functions. The default condition is DISABLED.

8. to ENABLE SCAN MODE INTERRUPTS

   ESI

   A) This command allows the TC01 to output the various characters that signify end-of-soak-times as discussed in Section 3-4.5.

9. to ENABLE DEVIATION INTERRUPT

   Deviation Interrupts are automatically enabled by setting the deviation limit. See 3-4.3 #4. The interrupt character output by the TC01 is discussed in section 3-4.5.

10. to DISABLE LOCAL CONTROL

    See IEEE-488 standard 488-1975 or above

11. to DISABLE RS232 ECHO

    R

    A) Note that this is a reset command which will also reset most other controller parameters. See COMMAND 1 of this section.

12. to DISABLE the HEAT and COOL OUTPUTS

    OFF

13. to DISABLE the AUXILIARY #1 OUTPUT

    OUT1OFF

    See discussion at command #6.

14. to DISABLE the AUXILIARY #2 OUTPUT

    OUT2OFF

15. to DISABLE SCAN MODE INTERRUPTS

    DSI

    A) See discussion at command #8.

16. to DISABLE the DEVIATION INTERRUPT

    DDI

    A) See discussion in this section at command #9.

3-4.4 GPIB COMMANDS: SPECIAL

1. to INPUT CHARACTER STRING from SYSTEM CONTROLLER & OUTPUT SAID STRING to RS232-C INTERFACE

   !ssss...sss where ssss...sss is an ASCII character string

   A) This command allows direct control of custom circuitry by the GPIB System Controller. Any custom circuitry with an RS232 interface can be controlled by this command, and interrogated with the use of the next command. Thus an unlimited number of events and status thereof can be incorporated as part of the automated test facility. For ex ample, one may wish to test, say, 100 components (resistors, thermistors, etc.) in an automated setup. One way to accomplish this would be to build the necessary switching circuitry with an RS232 interface. Then, the GPIB System Controller would direct the proper switching sequence via the TC01 controller. Similarly, command #2 below could be used to ascertain status information from the switching circuitry.

2. TO INPUT CHARACTER STRING FROM RS232 INTERFACE TO IEEE-488 SYSTEM CONTROLLER
   S

   Sample 9825 command

   wrt703,”S”,red703,R$

   System controller reads a line of characters that are sent to the TC01 via the RS232 port.

   A carriage return or line feed terminates the sequence.

3. PID COEFFICIENT CHANGE

Modification if the PID coefficients used in the TC01 algorithm is not generally recommended for the casual user. The standard TC01 PID coefficients have been chosen to provide a good compromise between fast settling time and good overshoot characteristics. However, for those who wish to optimize the TC01 transient or steady state response for their particular application, an application note (part #680008) has been written to assist in the PID coefficient changes. See our home page at www.sunelectronics.com to download the app note.

The TC01 controller calculates the amount of heating or cooling required to maintain the chamber temperature at the set temperature using a 3 mode proportional, integral, derivative servo equation. There is a weighing coefficient for each of the three components of the control equation. At power up, the TC01 reads the default PID coefficients from its EEPROM memory and will use these coefficients unless they are changed, by the user, using this command. Once changed, the TC01 will continue to use the new coefficients until changed by another command or until the TC01 is powered off. Therefore, if another command or default coefficients are to be used, they must be set each time the TC01 is powered on. A new “INIT” command has been added to allow the user to permanently change the PID coefficients.

to SET PID WEIGHING COEFFICIENTS

PID=(-)n,(-)n,(-)n where 0 < n < 9

A) The above values of ‘n’ are interpreted as exponents of 2. Therefore each multiplier has a range of 2^(-9) to 2^(+9).

B) The first value is the ‘proportional coefficient.’ Multiplier
The second value is the ‘integral coefficient’ multiplier
The third value is the ‘derivative coefficient’ multiplier

to READ the CURRENT PID COEFFICIENTS

PID?

A) The three multipliers will be sent, each followed by CR LF

4. OUTPUT THE INSTALLED OPTIONS

OPT

The OPT command allows the user to determine the type of unit that he is talking to, the type of probe, and the units of time that have been selected. Upon receiving the OPT command the TC01 will send an ASCII string containing “ TC01, probe type, time units “. The substring TC01 informs the user that he is talking to a TC01. The probe type substring provides info on the type of temperature sensor that the TC01 is configured for. The substring time units will be MIN when minutes selected or HRS for hours time selection.

5. OUTPUT AUXILIARY INPUT STATE

   IN1

   A) The value returned is 0 if the input is a TTL logic low, and 1 if the input is at logic high.

   B) See figure 3 for wiring information.

6. to SET UPPER TEMPERATURE LIMIT (UTL)

   (-)n(n(n(n(.(n))))UTL where -100 <= (-)n(n(n(n(.(n)))) <= PLIMIT

   A) UTL may be set to any value between -100 and PLIMIT inclusive. The value is PLIMIT is 315 deg C.
   B) UTL is set equal to PLIMIT at power up.

7. to OUTPUT CURRENT TEMPERATURE LIMIT (UTL)

   UTL

8. INIT TC01 OPERATING MODES

   INITn,p,i,d,M or H,C

   The INIT command allows the user to change most TC01 modes. The INIT command is a remote only command. The parameters that it changes are stored in EEPROM such that the information is saved with power off.

   n is a digit between 1 and 7 and selects the temperature probe type as follows;
   1= RTD 3 wire 100 ohm .385 alpha
   2= RTD 3 wire 100 ohm .392 alpha
   3= J thermocouple
   4= K thermocouple
   5= T thermocouple

   , data separator

   p allows permanent change to the PID P coefficient

   , data separator

   i allows permanent change to the PID I coefficient

   , data separator

   d allows permanent change to the PID D coefficient

   , data separator

   M to set time units to minutes or H for hours units

   , data separator

Finally always send C character

3-4.5 TIME-OUT/PROBLEM INDICATIONS

TIME-OUT INDICATIONS — SINGLE TEMPERATURE MODE

When the desired soak time (time-at-temperature) has been reached, the operator is alerted to this fact in three ways. Firstly, the “TIME-OUT’ LED located on the front panel is turned ‘ON’. Secondly, a continuous tone is emitted from a transducer located on the TC01 power supply board. Thirdly, a ‘service request’ is made by activating the SRQ line on the GPIB bus. When the GPIB system controller subsequently polls the TC01 that requested service, the timed-out TC01 responds with a HEX 41.

Any TC01 that has not timed-out will respond to the polling with a HEX 00. The LED and audio indication will continue until the controller is sent a RESET command via the GPIB bus, or is reset manually (if local lockout not enabled) by depressing the ‘C’ (clear) key on the TC01 keyboard. Setting or reading TIME or TEMP will also clear the buzzer and LED.

TIME-OUT INDICATIONS — SCAN MODE

Time-out indications may be ENABLED or DISABLED per commands in 3-4.3. The default condition is that Time-Out indications are DISABLED.

The TC01 SCAN mode allows a maximum of 10 segments to be programmed through the IEEE-488 bus. Each segment is described by a temperature and a soak-time (time-at-temperature). Additionally, the scan mode sequence chosen by the user can be programmed to be automatically repeated any number of times up to a total of 1800 ‘cycles’. Thus we may define several types os ‘time-outs’ that would be useful to the user.

The first to consider is a time-out indication at the end soak time point within the temperature scan sequence. Another type would be a time-out signifying completion of the last soak time in a scan sequence. Since the scan sequence can be cycled, yet another time-out indication would be to alert the user that all cycles programmed have been completed.

The TC01 outputs three different interrupt characters, one for each of the three distinct time-outs (assuming time-out indications are ENABLED). The table below describes said characters. The characters are sent out 1 minute before completion of time-out.

TIME-OUT TYPE	INTERRUPT CHARACTER SENT (HEX)
SOAK TIME COMPLETE	43
CYCLE (‘LOOP’) COMPLETED	44
END OF TOTAL RUN	45

PROBLEM INDICATORS

Four problem indicators have been incorporated into the TC01.

PROBLEM TYPE	INTERRUPT CHARACTER SENT (HEX)
Deviation Limit Exceeded (when enabled)	46
Chamber Temp exceeds UTL	47
Command Error	42
IEEE-488 Bus lock-up time-out	4F

3-5 REMOTE ADDRESS SELECT SWITCH

Figure 7 shows the location of the RS232-C connector, the IEEE-488 connector, and the address select switch on the remote I/O panel.

The talk/listen address for the IEEE-488 interface is set using the four position switch located on the I/O panel. The switches are such that a “zero” is set having the switch “ON” and a “one” is set with the switch “OFF”. If there is any doubt about which address is encoded, the display will show the GPIB address for three seconds immediately upon power-up or upon given a RESET (clear) command.

TABLE 3-2 lists the contact pin assignments for the IEEE-488 connector.
TABLE 3-3 lists the 16 possible addresses as determined by the switch settings.

TABLE 3-2

IEEE-488 CONTACT ASSIGNMENTS

CONTACT	SIGNAL LINE	CONTACT	SIGNAL LINE
1	DIO 1	13	DIO 5
2	DIO 2	14	DIO 6
3	DIO 3	15	DIO 7
4	DIO 4	16	DIO 8
5	EOI	17	REN
6	DAU	18	GND
7	NRFD	19	GND
8	NDAC	20	GND
9	IFC	21	GND
10	SRQ	22	GND
11	ATN	23	GND
12	SHIELD	24	GND, LOGIC

TABLE 3-3

IEEE-488 BUS ADDRESS SWITCH SETTING

ADDRESS SWITCH 1 2 3 4	TALK ADDRESS CHARACTER	LISTEN ADDRESS CHARACTER	DECIMAL VALUE
0 0 0 0	@	SP	0
1 0 0 0	A	!	1
0 1 0 0	B	“	2
1 1 0 0	C	#	3
0 0 1 0	D	$	4
1 0 1 0	E	%	5
0 1 1 0	F	&	6
1 1 1 0	G	‘ (single quote)	7
0 0 0 1	H	(	8
1 0 0 1	I	)	9
0 1 0 1	J	*	10
1 1 0 1	K	+	11
0 0 1 1	L	, (comma)	12
1 0 1 1	M	- (dash)	13
0 1 1 1	N	. (period)	14
1 1 1 1	O	/	15

0 = switch “on”
1 = switch “off”

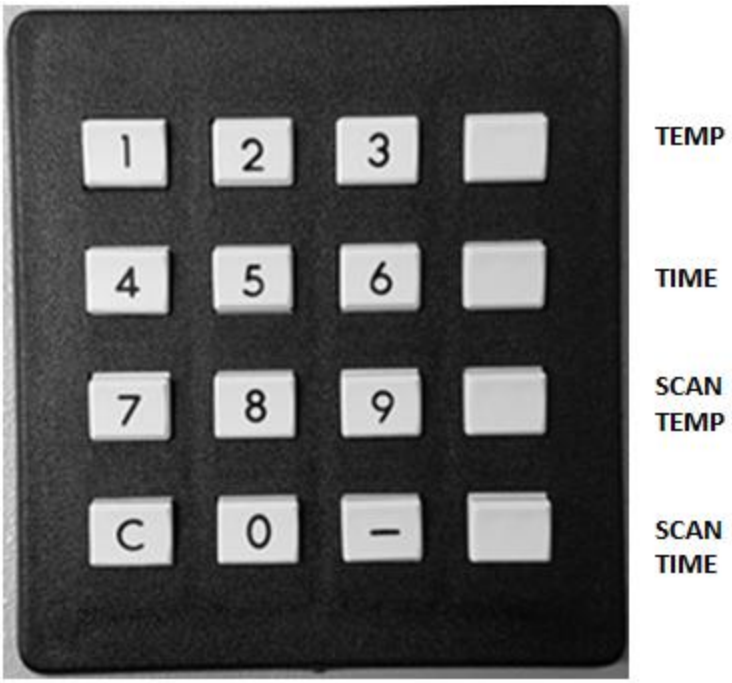


Fig. 3.5-1 Chamber Keyboard Layout 1 (Before 2017)

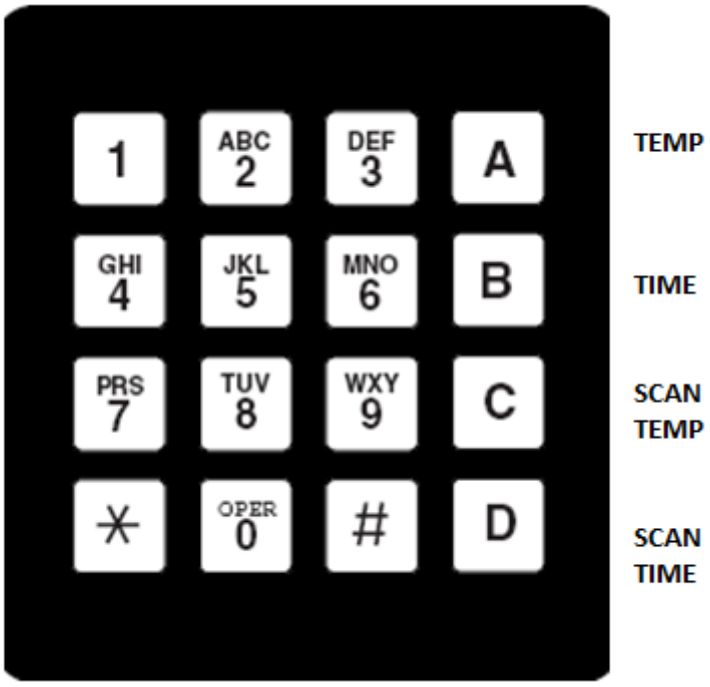


Fig. 3.5-2 Chamber Keyboard Layout 2 (2017)

TABLE 3-4 COMMANDSUMMARY/EXAMPLES FOR KEYBOARD LAYOUT 1

FUNCTION	KEYBD/DISPLAY*	RS232*	IEEE-488*
SINGLE TEMP MODE			
SET Chamber Temp	50 TEMP	50.0C	50.0C
SET Time-at-Temp	5 TIME	5M	5M
SET Deviation Limit	(n/a)	EDI10	EDI10
OUTPUT Chamber Temp	automatic	T	T
OUTPUT Current Set Temp	TEMP	C	C
OUTPUT remaining Time at current Temp	TIME	M	M
SCAN MODE			
SET Scan Temp m	50 SCANTEMP 0	50.0A0	50.0A0
SET Scan Time m	5 SCANTIME 0	5B2	5B2
SET # of Cycles	10 SCANTIME -	10B-	10B-
SET Deviation Limit	(n/a)	EDI10	EDI10
OUTPUT Scan Temp m	SCANTEMP 0	A0	A0
OUTPUT Scan Time m	SCANTIME 0	B0	B0
OUTPUT Current Cycle #	SCANTIME -	B-	B-
OUTPUT Chamber Temp	automatic	T	T
OUTPUT Current SET Scan Temp	TEMP	C	C
OUTPUT Current remaining Scan Time	TIME	M	M
DELETE Scan Temp m	- SCANTEMP 0	-A0	-A0
DELETE Scan Time m	- SCANTIME 0	-BO	-B0
START Scan Mode	SCANTEMP SCANTIME	AB	AB
STOP Scan Mode	SCANTIME SCANTEMP	BA	BA

*For the single temperature mode, the commands assume a desired temperature of 50 deg C, and a soak time of 5 minutes. A 10 degree deviation limit is required. For the SCAN mode, the commands assume that the first allowed segment (m=0) is being set to a temperature of 50 deg C for 5 minutes. Additionally, 10 cycles of the scan sequence are desired along with a 10 degree deviation alarm.

+ Denotes new command/feature since last manual update.

TABLE 3-4 COMMANDSUMMARY/EXAMPLES FOR KEYBOARD LAYOUT 1 (cont'd)

FUNCTION	KEYBD/DISPLAY*	RS232*	IEEE-488*
CONTROL GROUP			
Reset (Clear)	C	R	R
ENABLE Local Control	(n/a)	Press Key	lcl 7 **
ENABLE Remote Control	(n/a)	automatic	rem703**
ENABLE RS232 Echo	(n/a)	H	H
ENABLE HEAT/COOL Out	H/C switches ON	ON	ON
ENABLE Auxiliary #1 Out	(n/a)	OUT1ON	OUT1ON
ENABLE Auxiliary #2 Out	(n/a)	OUT2ON	OUT2ON
ENABLE Scan Interrupts	(n/a)	ESI	ESI
ENABLE Deviation In'rpt	(n/a)	EDI10	EDI10
DISABLE Local Control	(n/a)	(n/a)	llo 7 **
DISABLE RS232 Echo	(n/a)	R	R
DISABLE Heat/Cool Out	H/C switches OFF	OFF	OFF
DISABLE Auxiliary #1 Out	(n/a)	OUT1OFF	OUT1OFF
DISABLE Auxiliary #2 Out	(n/a)	OUT2OFF	OUT2OFF
DISABLE Scan Interrupts	(n/a)	DSI	DSI
DISABLE Deviation In'rpt	(n/a)	DDI	DDI
SPECIAL			
TRANSFER GPIB to RS232	(n/a)	(n/a)	!sss
TRANSFER RS232 to GPIB	(n/a)	(n/a)	S
PID COEFFICIENTS CHANGE	(n/a)	refer to manual	
+ OUTPUT probe option	(n/a)	OPT	OPT
OUTPUT Aux Input State	(n/a)	IN1	IN1
SET UTL	(n/a)	180UTL	180UTL
OUTPUT UTL	(n/a)	UTL	UTL
+ INIT	(n/a)	INITn,...	INITn,...

* See Previous page for * details
** See your GPIB System Controller documentation for its commands
\+ Denotes new command/feature since last manual/update

TABLE 3-5 COMMAND SUMMARY/EXAMPLES FOR KEYBOARD LAYOUT 2

FUNCTION	KEYBD/DISPLAY*	RS232*	IEEE-488*
SINGLE TEMP MODE			
SET Chamber Temp	50 TEMP	50.0C	50.0C
SET Time-at-Temp	5 TIME	5M	5M
SET Deviation Limit	(n/a)	EDI10	EDI10
OUTPUT Chamber Temp	automatic	T	T
OUTPUT Current Set Temp	TEMP	C	C
OUTPUT remaining Time at current Temp	TIME	M	M
SCAN MODE			
SET Scan Temp m	50 SCANTEMP 0	50.0A0	50.0A0
SET Scan Time m	5 SCANTIME 0	5B2	5B2
SET # of Cycles	10 SCANTIME #	10B-	10B-
SET Deviation Limit	(n/a)	EDI10	EDI10
OUTPUT Scan Temp m	SCANTEMP 0	A0	A0
OUTPUT Scan Time m	SCANTIME 0	B0	B0
OUTPUT Current Cycle #	SCANTIME #	B-	B-
OUTPUT Chamber Temp	automatic	T	T
OUTPUT Current SET Scan Temp	TEMP	C	C
OUTPUT Current remaining Scan Time	TIME	M	M
DELETE Scan Temp m	# SCANTEMP 0	-A0	-A0
DELETE Scan Time m	# SCANTIME 0	-BO	-B0
START Scan Mode	SCANTEMP SCANTIME	AB	AB
STOP Scan Mode	SCANTIME SCANTEMP	BA	BA

*For the single temperature mode, the commands assume a desired temperature of 50 deg C, and a soak time of 5 minutes. A 10 degree deviation limit is required. For the SCAN mode, the commands assume that the first allowed segment (m=0) is being set to a temperature of 50 deg C for 5 minutes. Additionally, 10 cycles of the scan sequence are desired along with a 10 degree deviation alarm.

+ Denotes new command/feature since last manual update.

TABLE 3-5 COMMAND SUMMARY/EXAMPLES FOR KEYBOARD LAYOUT 2 (cont'd)

FUNCTION	KEYBD/DISPLAY**	RS232**	IEEE-488**
CONTROL GROUP			
Reset (Clear)	*	R	R
ENABLE Local Control	(n/a)	Press Key	lcl 7 ***
ENABLE Remote Control	(n/a)	automatic	rem703***
ENABLE RS232 Echo	(n/a)	H	H
ENABLE HEAT/COOL Out	H/C switches ON	ON	ON
ENABLE Auxiliary #1 Out	(n/a)	OUT1ON	OUT1ON
ENABLE Auxiliary #2 Out	(n/a)	OUT2ON	OUT2ON
ENABLE Scan Interrupts	(n/a)	ESI	ESI
ENABLE Deviation In'rpt	(n/a)	EDI10	EDI10
DISABLE Local Control	(n/a)	(n/a)	llo 7 ***
DISABLE RS232 Echo	(n/a)	R	R
DISABLE Heat/Cool Out	H/C switches OFF	OFF	OFF
DISABLE Auxiliary #1 Out	(n/a)	OUT1OFF	OUT1OFF
DISABLE Auxiliary #2 Out	(n/a)	OUT2OFF	OUT2OFF
DISABLE Scan Interrupts	(n/a)	DSI	DSI
DISABLE Deviation In'rpt	(n/a)	DDI	DDI
SPECIAL			
TRANSFER GPIB to RS232	(n/a)	(n/a)	!sss
TRANSFER RS232 to GPIB	(n/a)	(n/a)	S
PID COEFFICIENTS CHANGE	(n/a)	refer to manual	
+ OUTPUT probe option	(n/a)	OPT	OPT
OUTPUT Aux Input State	(n/a)	IN1	IN1
SET UTL	(n/a)	180UTL	180UTL
OUTPUT UTL	(n/a)	UTL	UTL
+ INIT	(n/a)	INITn,...	INITn,...

** See Previous page for ** details
*** See your GPIB System Controller documentation for its commands
+ Denotes new command/feature since last manual/update

INTERRUPT CHARACTER

Condition	RS232 (ASCII)	IEEE-488 (HEX)
No interrupt	(n/a)	00
Single Temp Mode time-out	I	41
Command Error	CMD ERROR!!	42
SCAN Temp Point time-out	P	43
SCAN Temp Cycle time-out	L	44
SCAN Temp End of Run	E	45
DEVIATION Alarm	D	46
Chamber Temp > UTL	O	47
GPIB lock-up time-out	(n/a)	4F

SECTION IV - USER ADJUSTMENTS / MODIFICATIONS

4-1 INTRODUCTION

User adjustments are limited to calibration of the temperature transducer, adjustment of the baud rate of the RS232-C interface, modification of the failsafe polarity, polarity of the cooling sense output, and selection of 110 or 220 volt operation. The temperature probe type and minutes/hours time units are covered in RS232 and GPIB command section, see INIT command.

4-2 TEMPERATURE TRANSDUCER CALIBRATION

Calibration for the TC01 is accomplished by adjusting two calibration pots; one for '0' degree centigrade calibration point and one for a '100' degree centigrade calibration point. The calibration pots are below the keyboard. Two panhead screws are installed in the calibration holes to protect the pots.
As one looks at the front panel, the '0' degree calibration pot is accessed through the hole on the right while the '100' degree pot is accessed through the left hole. A small-bladed screwdriver will be needed for the adjustment.

4-2.1 PROBE CALIBRATION

The controller is calibrated by adjusting the 0 degree pot for a 0 degree reading on the TC01 display with the probe held at a 0 degrees centigrade. Similarly, the 100 degree pot is adjusted for a 100 degree reading with the probe held at 100 degrees centigrade. The calibration procedure can be accomplished with the probe in the chamber while using another standard temperature meter to monitor the chamber or the freezing and boiling points of distilled water can be used as the two calibration points. For this latter method, carefully remove the temperature probe from the chamber so that it may be placed in contact with the hot or cold water. Sun also manufactures a dual well probe calibrator that provides the 0 and 100 deg C temperatures.

4-3 RS232 BAUD RATE CHANGE

The baud rate of the RS232 port is factory set at 9600 baud. The baud rate is field-changeable by 2 jumpers on the CPU board. The jumpers are located below the uP socket on the CPU board. Proceed as follows:

The controller will need to be taken out of the chamber for the baud rate change.
CAUTION: BE SURE THAT THE CHAMBER IS UNPLUGGED!

1. The CPU board is the board that contains the LED display. To gain access to the CPU board, remove 4 front panel screws that hold the board stack to the front panel sheet metal.

2. Install jumpers in location BAUD-0 and BAUD-1 as given below. The two jumpers are located just below the square uP socket.

3. If the cool polarity or failsafe polarity need to be changed do them now see below.

4. Replace board stack and reinstall TC01 controller.

Jumper BAUD-0	jumper BAUD-1	baud rate
out	out	9600
in	out	4800
out	in	2400
in	in	1200

4-4 COOLING LOGIC SENSE INVERSION

The ‘sense’ of the cool output as shipped from the factory is such that when cooling is required, the cool output (terminal #2, figure 3) will be switched to the ‘hot side’ of the incoming power. If an inversion is required for interfacing, then a jumper will need to be installed.

1. The CPU board is the board that contains the LED display. To gain access to the CPU board, remove 4 front panel screws that hold the board stack to the front panel sheet metal.

2. Install jumper in location COOLPOL. The jumper is located below the square uP socket.

3. If the baud rate or failsafe polarity need to be changed do them now see above and below.

4. Replace board stack and reinstall TC01 controller.

4-5 FAILSAFE LOGIC SENSE INVERSION

The ‘sense’ of the failsafe input as shipped from the factory is such that when a low level is input, the TC01 will go into the failsafe mode and turn off the heat and cool outputs. If an inversion is required for interfacing, than a jumper will need to be installed.

1. The CPU board is the board that contains the LED display. To gain access to the CPU board, remove 4 front panel screws that hold the board stack to the front panel sheet metal.

2. Install jumper in location FS POL. The jumper is located below the square uP socket.

3. If the baud rate or cooling polarity needs to be changed do them now see above.

4. Replace board stack and reinstall TC01 controller.

SECTION V - REPAIR / PARTS REPLACEMENT

5-1 PARTS REPLACEMENT POLICY

Field service of the TC01 is not always possible due to the type os test equipment required for proper troubleshooting. Any problem with the controller should be brought to the attention of Sun systems by telephone. If the problem cannot be fixed by phone, Sun Systems will issue an RMA number (see paragraph 1-9) to initiate factory repair os the controller.

5-2 OUT OF WARRANTY REPAIR

Out-of-warranty repair is supported by Sun Systems by submitting the controller and associated RMA number (see paragraph 1-9) for factory repair. A minimum repair charge of one hour labor plus parts will be incurred. If parts and/or labor exceed the minimum, the customer will be contacted and informed of repair changes before proceeding. Turn around time for repair varies depending on work-loads and parts availability, but normally a controller will be repaired and returned to the customer within 2 working days of receipt.

See section 1-9 for details on return of merchandise.

SECTION VI - ERROR CODES

E0 FOREGROUND PROGRAM ERROR

E1 PROBE INT ERROR

E2 ILLEGAL OP CODE

E3 FAILSAFE ACTIVE MODE

FIGURE 1 - TC01 BLOCK DIAGRAM

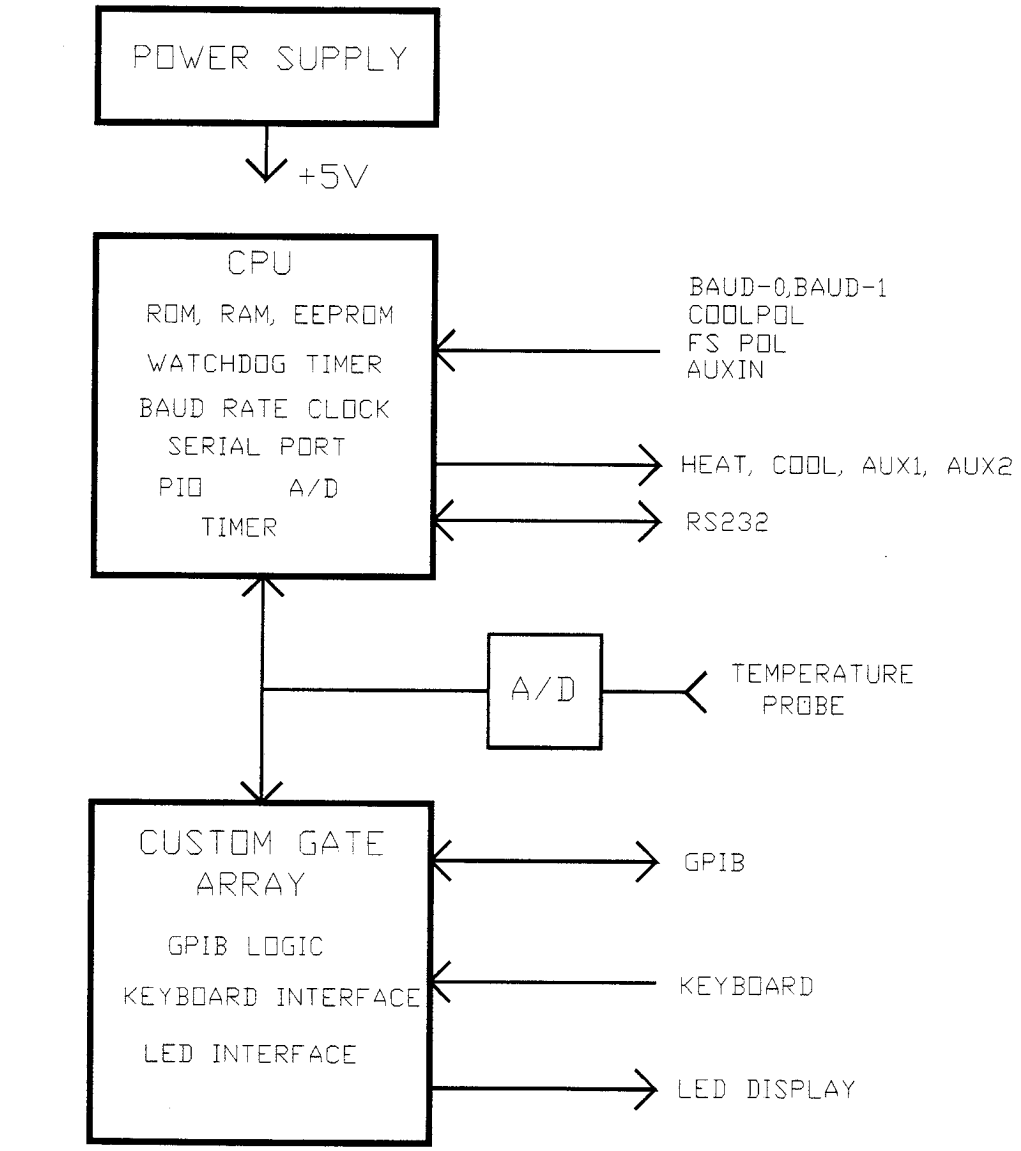


FIGURE 1 TC01 BLOCK DIAGRAM

FIGURE 3 - PROCESS I/O CONNECTIONS

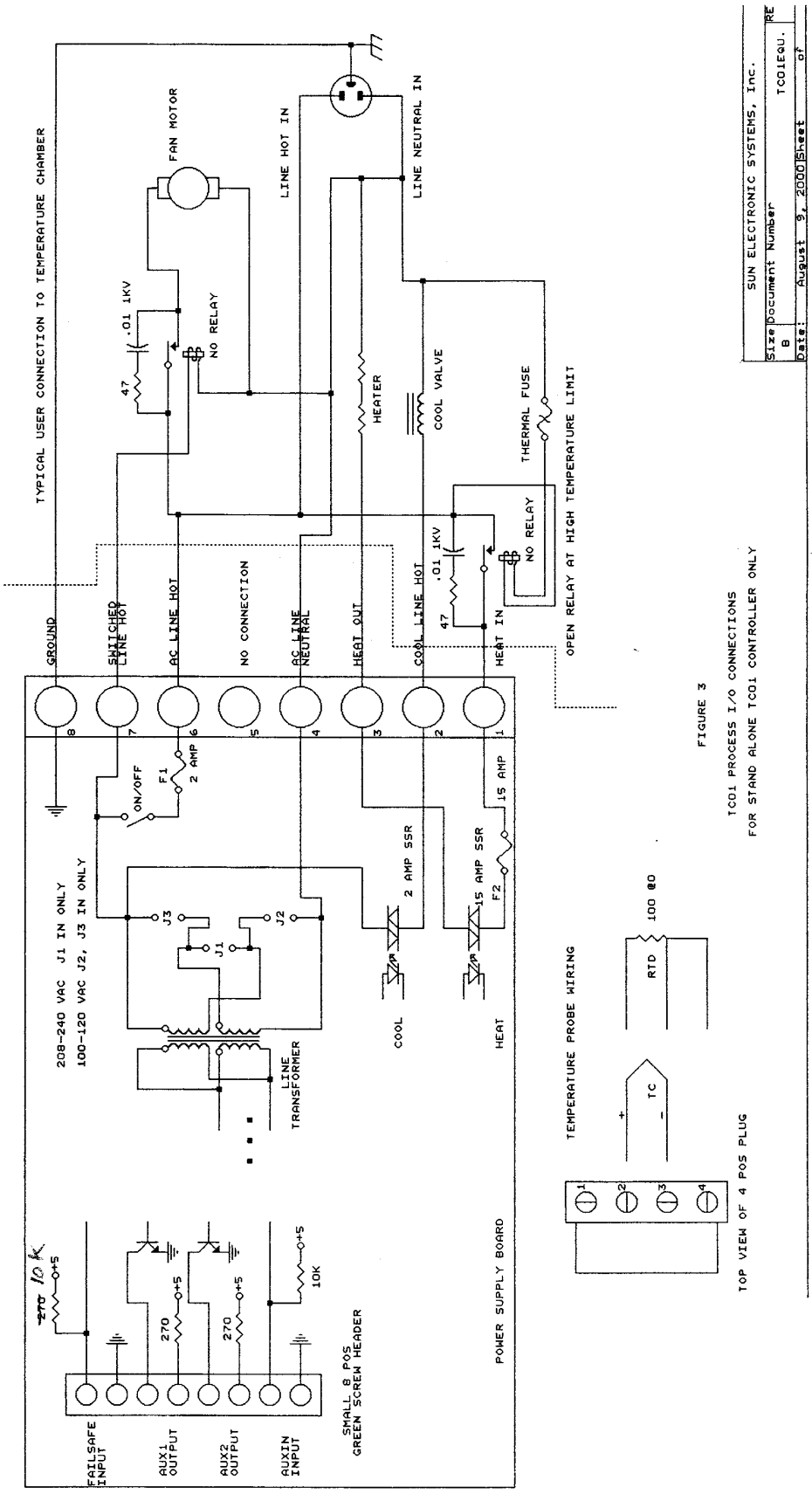


FIGURE 4 - TC01 FRONT PANEL

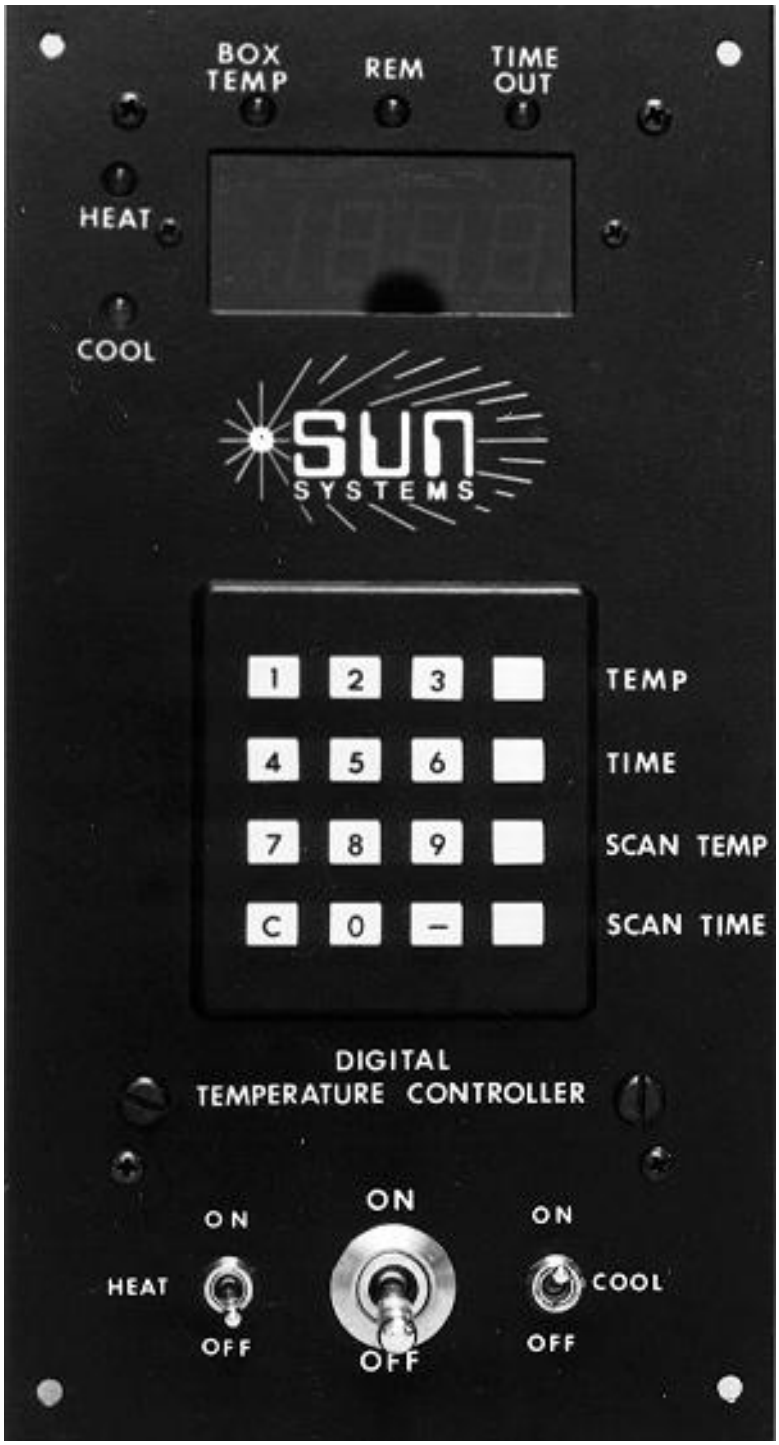


FIGURE 5 - FRONT PANEL CUTOUT

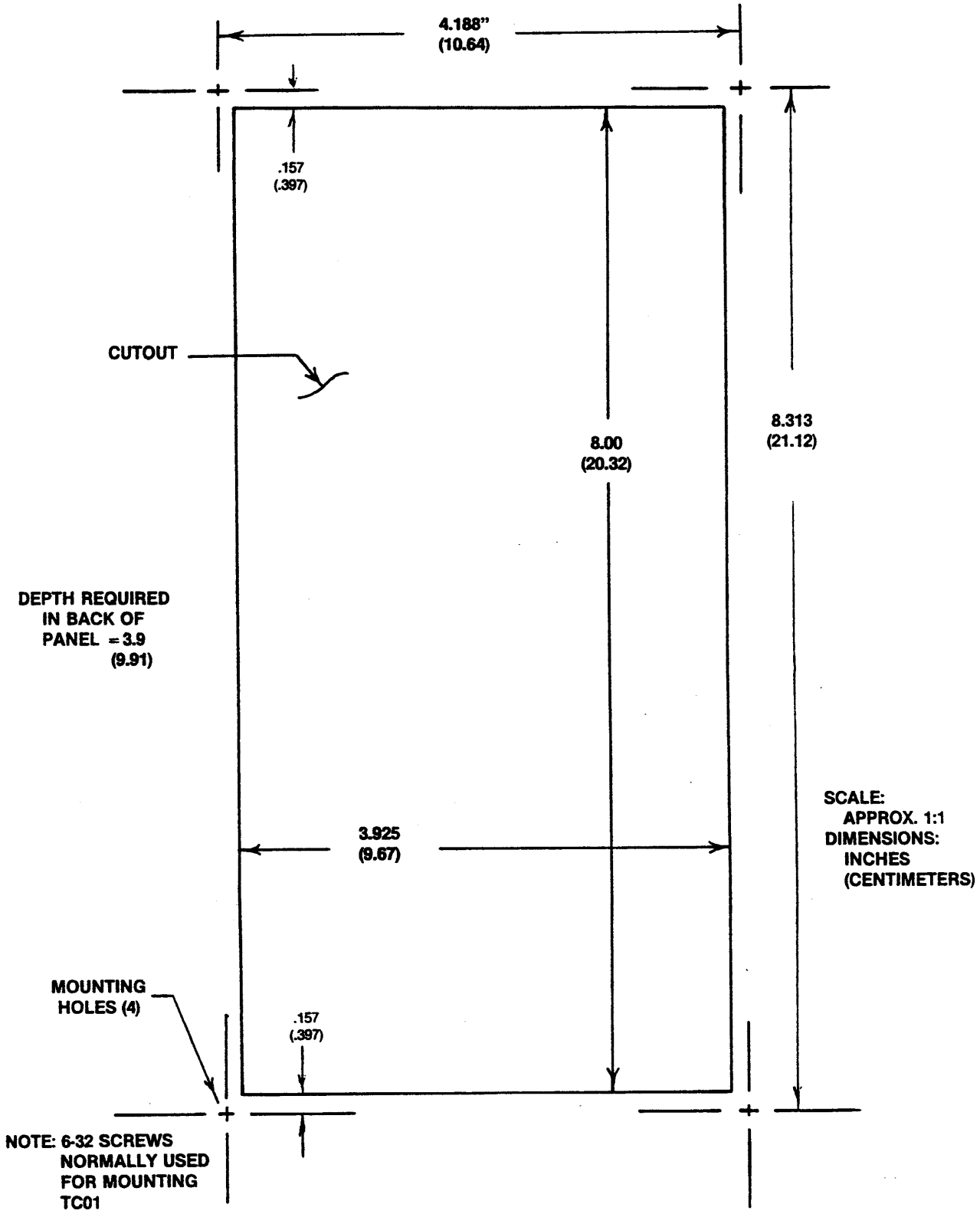
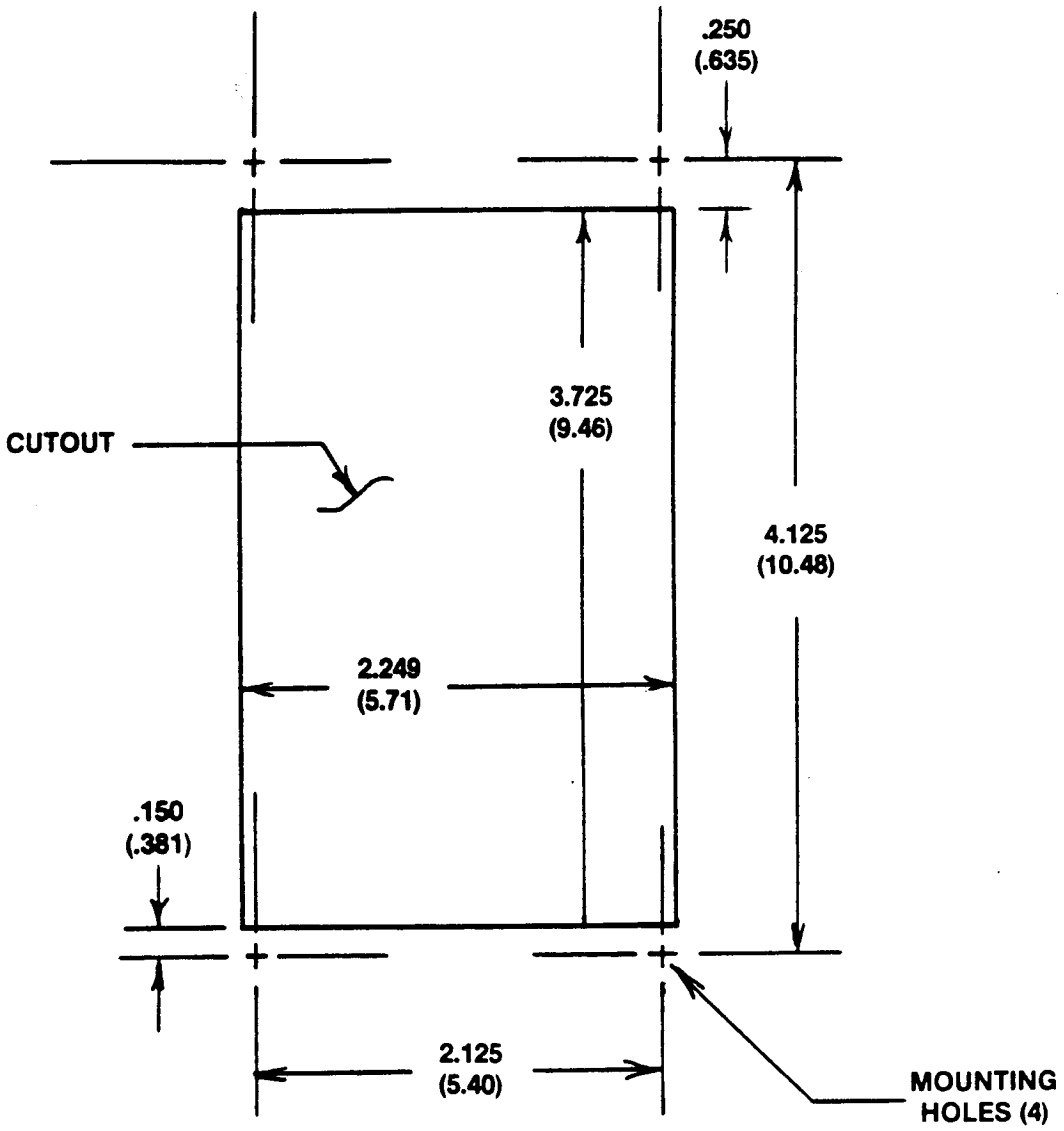


FIGURE 6 - REMOTE I/O CUTOUT



SCALE: APPROX. 1:1
APPROX 1 = 1
DIMENSIONS:
INCHES (CENTIMETERS)

NOTE: 6-32 SCREWS NORMALLY USED FOR MOUNTING

FIGURE 7 - REMOTE I/O & ADDRESS SWITCH

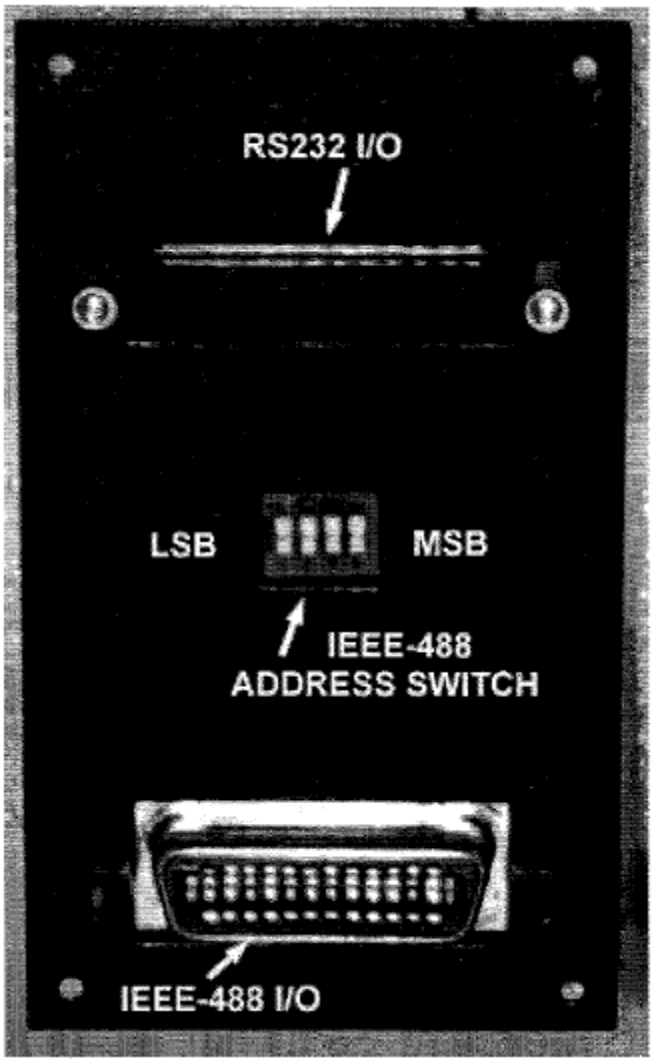


FIGURE 8 - TC01-F CONTROLLER, REAR VIEW

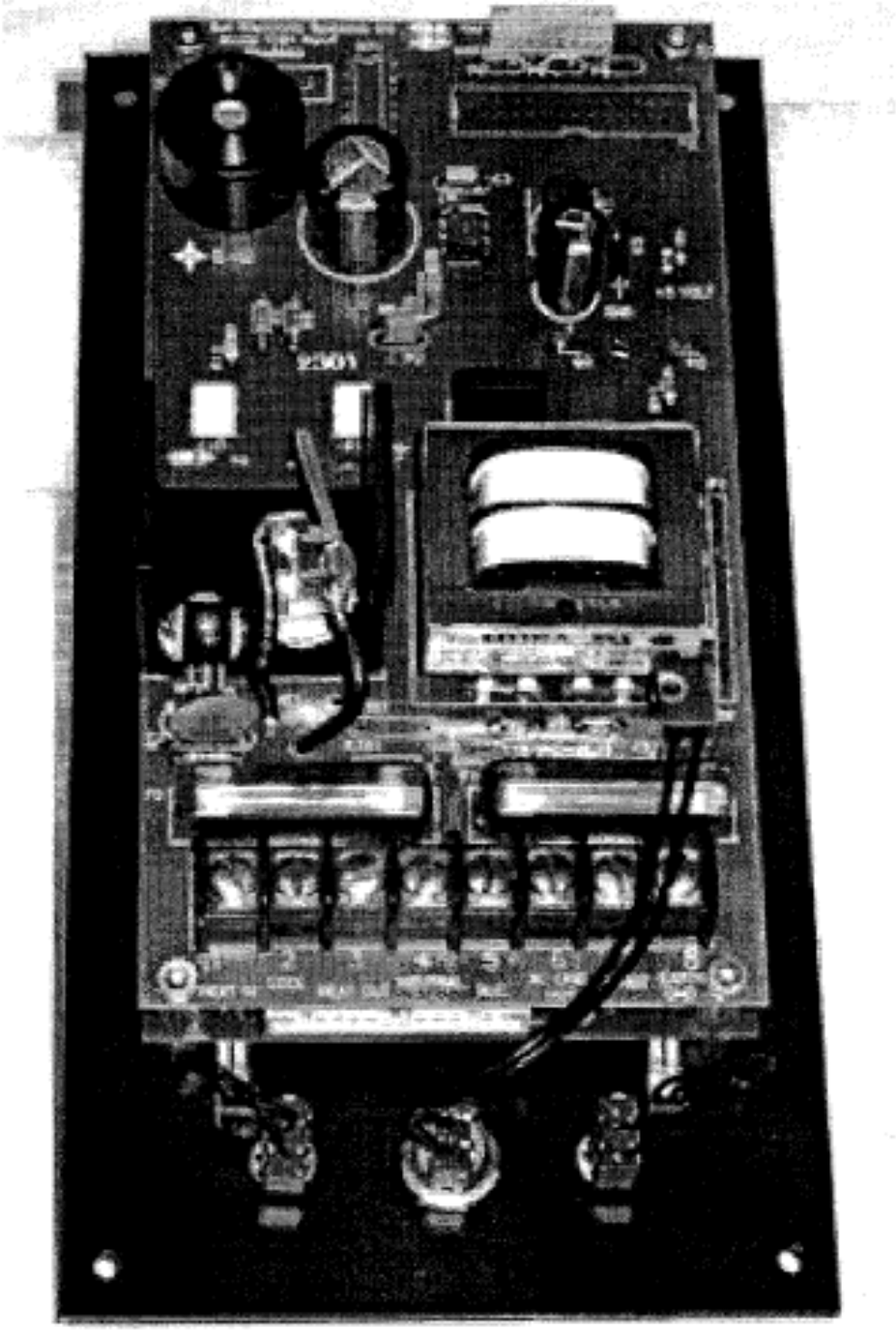


FIGURE 9 - TC01-F, CPU BOARD

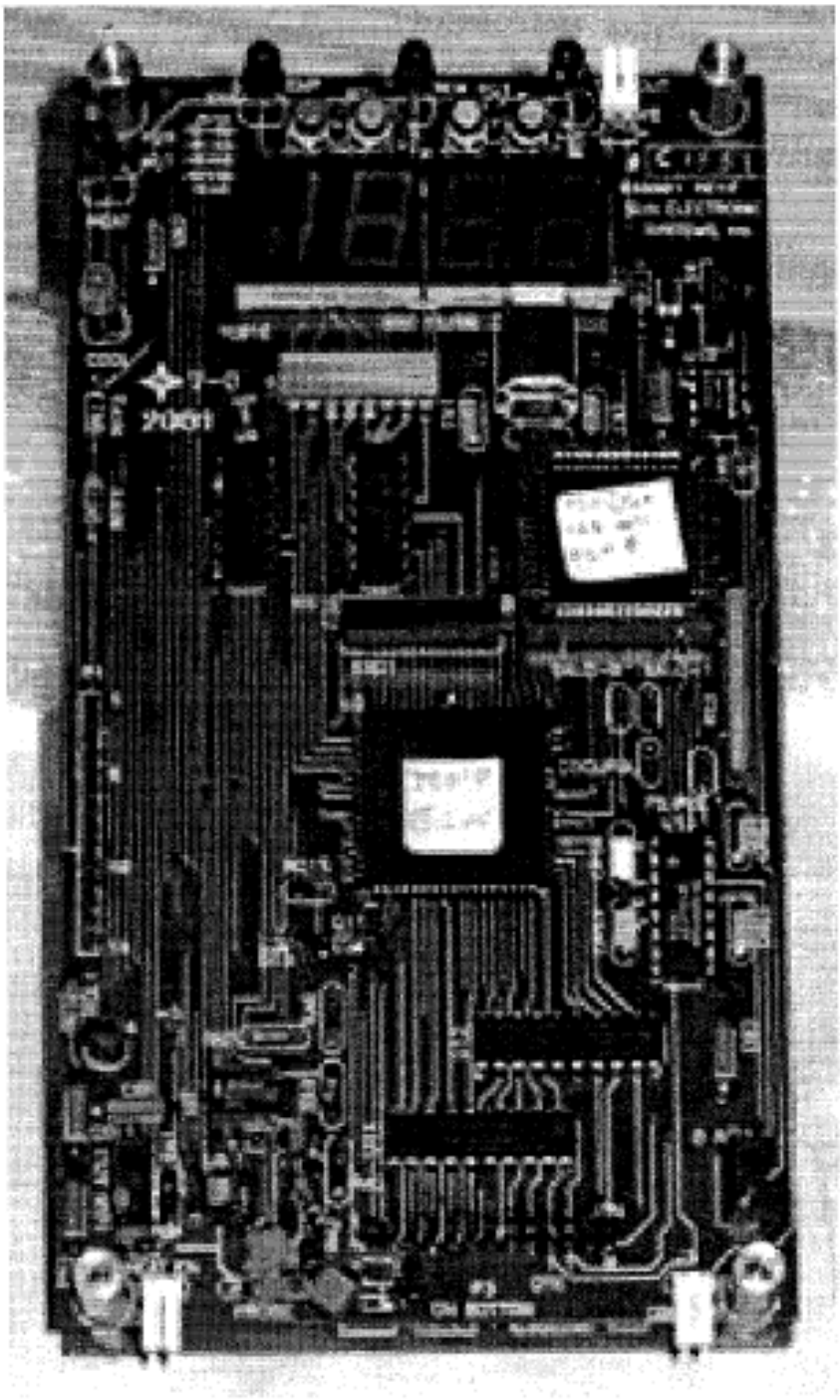


FIGURE 10 - TC01-F, POWER SUPPLY BOARD

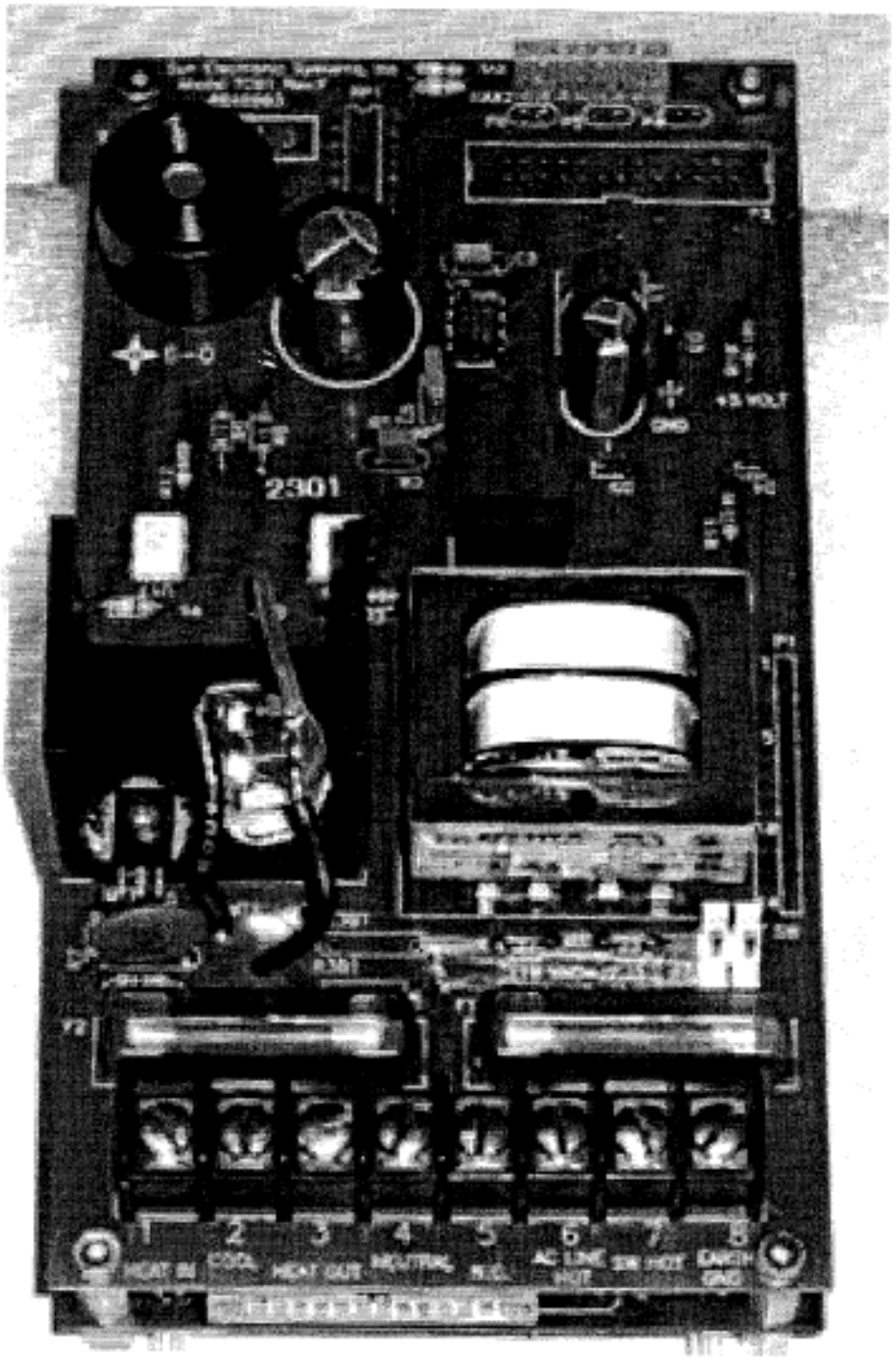


FIGURE 11 - TC01-F, HEAT TRIAC

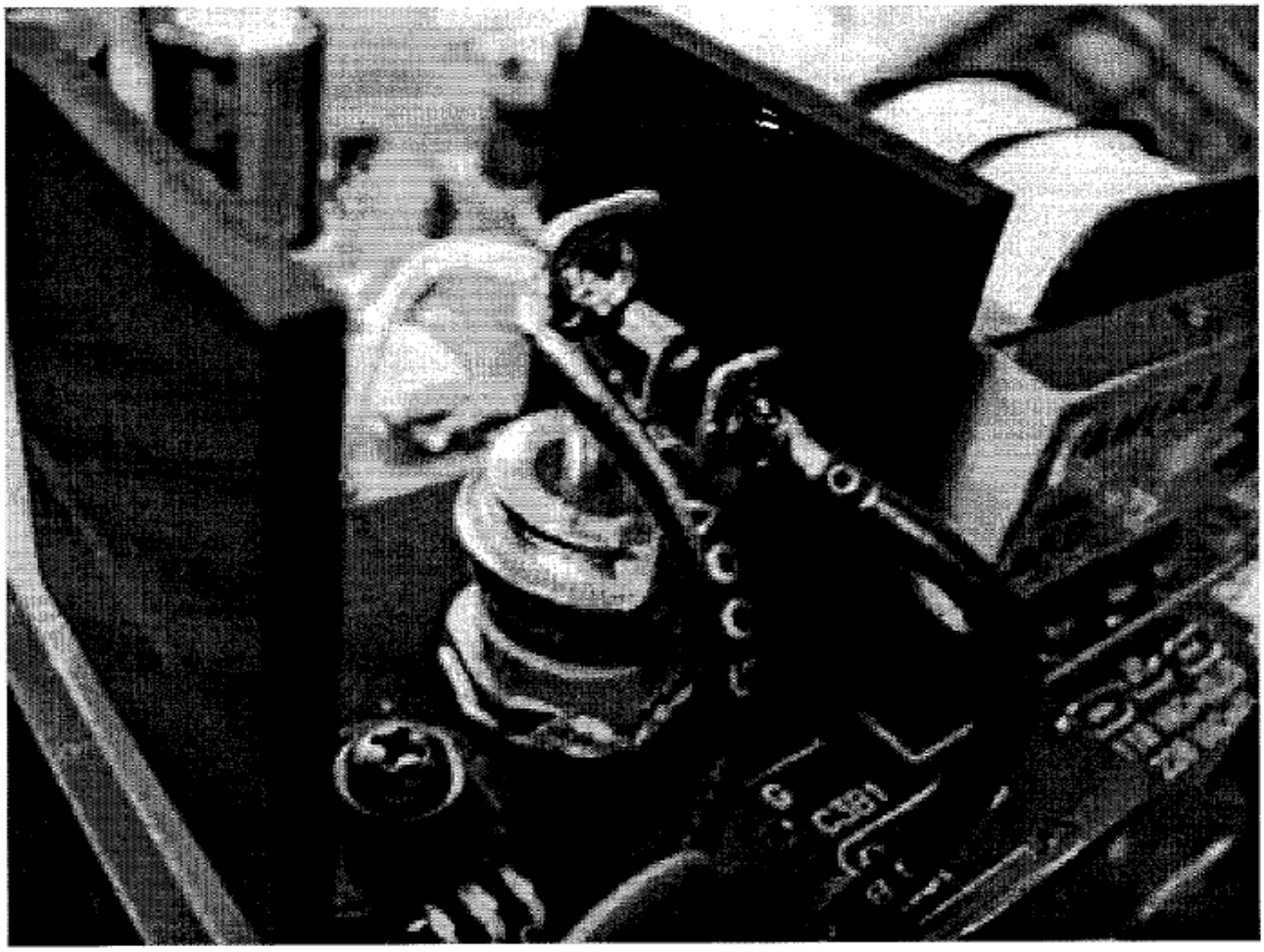


FIGURE 12 - TC01 REV. A-E and REV. F COMPARISON