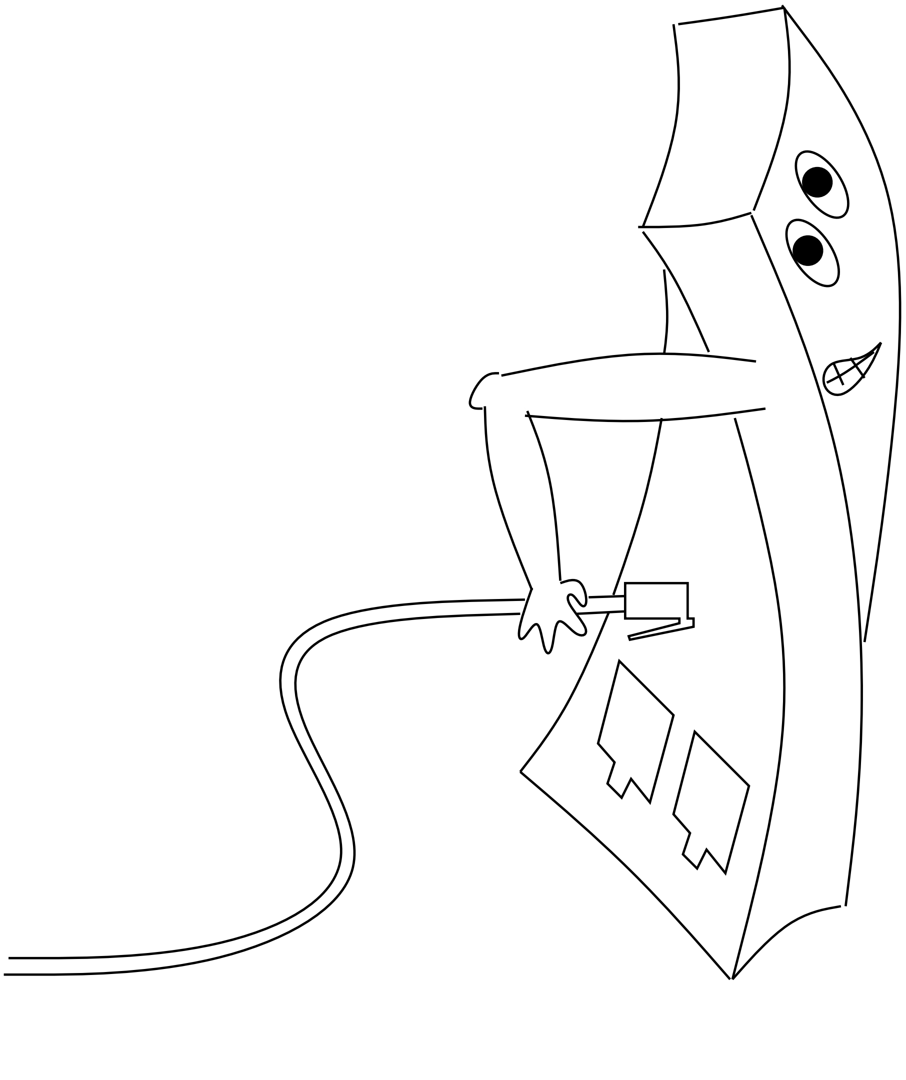
# Hot Little Therm
# User Manual



For HLT Model T4B
Firmware Version 9.4

# Table of Contents

# 1 Introduction

Hot Little Therm is a digital thermometer designed to be connected to a computer serial port. With additional software, it can be used for temperature logging or control, to sound an alarm when the temperature exceeds set limits, and so on.

Therm devices may be daisy-chained together on a single serial port (up to 16 units). Each will respond to a unique address. Each therm can in turn support up to 15 directly-addressed probes, or a much larger number in batch mode.

Since the therm uses a standard protocol (RS-232 at 1200 baud) communication with it is simple and universal: You can use a terminal to test operation, run the therm remotely using a modem, and write your own programs to control it.

## 1.1 Parts List

A basic therm set contains the following parts.

| |
|---|
| Hot Little Therm unit |
| Wall transformer and serial port adapter |
| RJ-11 ”phone” serial cable |
| Temperature probe |
| This manual |

# 2 Hardware

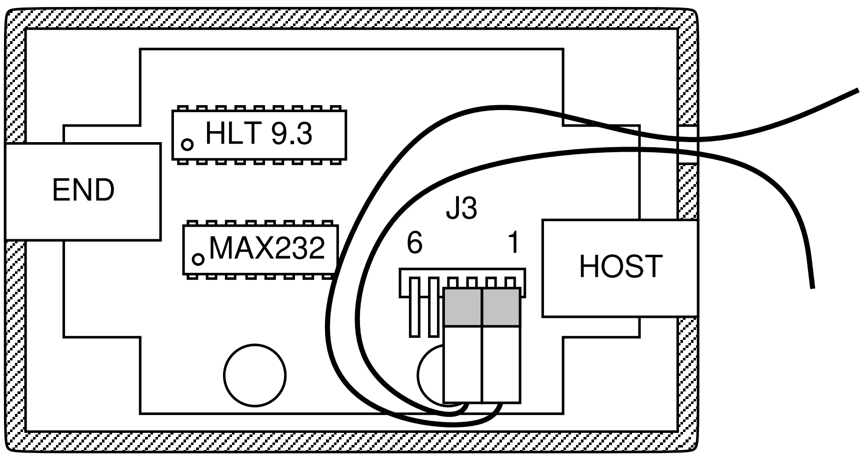



Figure 1: Inside the Hot Little Therm Box

## 2.1 Connecting Hot Little Therm to the Host

Plug the wall wart into the wall and the DB-9 or DB-25 connector of the serial adapter into your computer. Connect the RJ-11 phone cable between the serial adapter and the HOST port of the Hot Little Therm box. That's it. To connect more than one therm, see also §2.4.2.

## 2.2 Connecting Probes to Hot Little Therm

Plug a probe into the 6-pin header (J3) inside the therm box (see fig. 1). You may plug it into either of the positions shown (pins 1-2 or 3-4). The remaining two pins (5-6) are reserved for other uses. Which position is not important, but the polarity is. The white dot on the connector must face up, away from the circuit board.

If you are using a ProbeStick to add more than two probes, see §4.

Probes are connected to the therm via 2-wire cables, one wire for ground and the other to carry power and data. All probes connected to a therm are wired in parallel, even though they have separate plugs. The DS1820 in each probe has a unique 8-byte id signature built into it, which the therm uses to find and control it. With external wiring, many probes can be connected to a single therm; see §2.5. For information about how probes are addressed from the host computer, see §2.4.

As probes are connected and disconnected, the therm automatically adjusts to the new configuration. Probe numbers are assigned automatically by finding all the probe signatures and sorting the list. This means that adding another probe to a therm can change the numbers of some or all of the probes already connected (if the signature of the new probe is lower).

## 2.3 Probe Addresses

A probe address is composed of a probe number and a therm unit number, and identifies a single probe in a chain of therms. The probe number of the first probe connected to a therm is 2. As more probes are installed, they are assigned numbers 3, 4, ..., 15, 0. This was done to avoid having to use control characters in the most common cases (a bit weird, I admit). Probe number 1 activates batch mode (see §2.4.1). Unit numbers start at 0 for the first unit on a serial cable, and count up. The following table gives addresses for some probe and unit number combinations.

| | | Probe Number | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $1^{st}$ | $2^{nd}$ | $3^{rd}$ | ... | $14^{th}$ | $15^{th}$ | Batch Mode |
| Unit Number | $1^{st}$ | 0x20 | 0x30 | 0x40 | ... | 0xf0 | 0x00 | 0x10 |
| | $2^{nd}$ | 0x21 | 0x31 | 0x41 | ... | 0xf1 | 0x01 | 0x11 |
| | $3^{rd}$ | 0x22 | 0x32 | 0x42 | ... | 0xf2 | 0x02 | 0x12 |
| | ... | | | | ... | | | |
| | $15^{th}$ | 0x2e | 0x3e | 0x4e | ... | 0xfe | 0x0e | 0x1e |
| | $16^{th}$ | 0x2f | 0x3f | 0x4f | ... | 0xff | 0x0f | 0x1f |

## 2.4 Serial Port Protocol

Therms speak RS-232 at 1200 baud, 8 bits with no parity and one stop bit (1200-8-N-1). The protocol is very simple, the host sends the therm a command byte:

| Bit 7 … 4 | 3 … 0 |
|---|---|
| Probe # | Therm # |

The addressed therm sends a reply back in one of the following formats:

| Output | Meaning |
|---|---|
| ±ddd.d<CR><NL> | Temperature sample in deg. C |
| ######<CR><NL> | Probe does not exist |
| ******<CR><NL> | Error reading probe |

The temperature reading is always in the same format: A sign followed by 3.1 decimal digits. Pound signs indicate that the requested probe doesn't exist (may be disconnected), while stars indicate a checksum error while trying to read the probe, possibly because the cable is too long, shorted, or wired incorrectly.

NOTE:

Make sure the computer serial port connected to Hot Little Therm is set for *No flow control* or *Raw* mode. Therms do not support hardware (RTS/CTS) or software (XON/XOFF) flow control. If the serial port is set for flow control, it may appear that no therm is connected, or the commands may be eaten by the device driver. If it's not possible to set the port flow control, you should still be able to connect to a therm, but you may need to experiment with looping back flow control signals (e.g. CTS → RTS or DTR → DSR or CD).

If you're still wondering why the probes start at 2 instead of 0, it's because: this avoids the use of control characters (0x00–0x1F) for the most common probe addresses. If you're wondering why the probe number is the top nybble: there's no particular reason for that.

Non-probe one-wire devices (see next section) are detected but not counted in the probe numbering sequence.

### 2.4.1 Batch Mode Protocol

Batch mode allows reading more than 15 probes from a single therm. There are also other uses for this mode, for example finding the firmware revision of the therm board or verifying which probes are connected.

If a command is sent to read probe number 1 (the "$16^{th}$" probe), then all probes connected to the therm are sampled and a long-format listing is produced instead of a single temperature value. The format of the listing is:

| | |
|---|---|
| `V93-7200` | *Firmware revision and serial number* |
| `S1` | *Digital input level* |
| `T10c0720c00000098 +019.8` | *Probe (#2) id and temperature* |
| `T10ec700c000000d0 -003.5` | *Probe (#3)* |
| `X01f6f47b02000037` | *Unknown device id* |
| ... | |
| `Z` | *End* |

Each line of the listing starts with a letter:

- V – Indicates the firmware version number and unit serial number.
- S – Digit indicates the state of auxiliary digital input pin on J3 (0 = lo, 1 = hi). This input does not affect the operation of the therm, but is an extra digital input that can be read in batch mode.

- T – Gives the id and temperature of a probe. The id is always 16 hexadecimal digits, and is unique across all probes manufactured. The temperature is in degrees Celsius, as always.

  One T line will appear for each probe connected. The first 15 probes listed this way are also directly addressable by using their individual addresses, as explained above.

- X – If one-wire devices not compatible with the DS1820 are detected, the therm does not send any device-specific commands to them, but simply prints the device id in an 'X' record. Also, these devices are not counted in direct access mode (see above section).

- Z – Indicates the end of the listing.

The order of the probe ids may not be obvious, but they are always found least-significant bit of the byte first, left to right.

Note:
In batch mode, the command to sample the current temperature is broadcast to all probes, in order to be able to read them more quickly. This may result in a higher current demand than the 2-wire probe bus can supply (it works with several probes but not an unlimited number of them). See §2.5 about adding a 3rd power wire.

### 2.4.2 Daisy Chaining Hot Little Therms

Multiple therms may be daisy-chained on a serial port by plugging additional units into the END connector. Outgoing and incoming characters are passed through the therm between HOST and END ports. If a command doesn't address the therm directly connected to the serial port, it is passed on to the next unit, and so on down the line.

The command byte is not passed transparently through from HOST to END, instead the unit number part of the command is decremented once at each hop (the probe number is not changed, for example 0x21 becomes 0x20). The unit number of every therm is zero – this allows built-in automatic addressing of therm units. The first therm attached to a serial port will respond as unit 0, the second as unit 1, etc.

Note:
This feature affects the programmed unit numbers of older (v.7) firmware. The effective unit number of a v.7 therm will be higher by the number of v.9 therms upstream of it toward the host, because each one will subtract one from the unit number. The following table shows an example of how a mixture of version 7 and version 9 therms might be addressed:

| Connection Order | HLT Version | Unit Number Set | Effective Unit Number |
|---|---|---|---|
| 1 (Closest to host) | 9 | (0) | 0 |
| 2 | 7 | 3 | 4 |
| 3 | 9 | (0) | 1 |
| 4 (Farthest) | 7 | 4 | 6 |

### 2.4.3 Timing of the Response

If a command doesn't address any therm connected to the serial port, no response will ever be sent. Any program that reads the therm device directly must handle this by setting a timeout when waiting for the response. A maximum delay of 1 second is sufficient to ensure the therm has enough time to respond if it is connected.

## 2.5 Custom Wiring

### Connecting Many Probes

If you intend to do custom probe wiring, especially with very long runs of wire or many probes, we suggest you have a look at the Dallas Semiconductor data sheet for the DS1820 sensor and Application Note 108, "MicroLAN in the Long Run", both available from at their web site *http://www.dalsemi.com*.

Any number of probes can be connected to the therm, simply by connecting all like ground and data leads together (see pinout in §6.3). They can be daisy-chained on the same cable, or fanned out in a star, or any combination. Be sure to read the discussion of long probe wires below.

If you are connecting many probes to a single therm and plan to use the batch mode command (§2.4.1) to read them, you may need to run a 3rd power wire along with the ground and data lines. This is necessary to supply the extra current drawn when all the probes become active at the same time. $+5V$ can be drawn directly off the therm board at pin 6 of J3 (see §7).

Also, for this you'll need access to the third pin on the DS1820 (probes are normally shipped with only the Common and Data pins routed to the connector. This would mean cutting apart the rubber covering of the probe. If you're hooking up lots of probes, you may want just buy the raw DS1820 chips from Dallas Semiconductor. You won't have to cut them apart, and they'll be cheaper.

### Non-Probe Devices

You may connect other types of one-wire devices to the probe bus. The therm will detect these devices (see §2.4.1) but it will not count them as temperature probes or send device-specific commands to them. One possible use of this feature would be to use a simple device, such as a DS2401, as an on-off input by connecting it in series with a switch.

### Long Probe Wires

How long can the wire from the therm unit to the probe be? Quick answer: A total of up to 300 feet of cable should work fine, and tests have shown 500 feet to work reliably. If you use too much wire, the therm won't be able to read probes correctly. You'll get `"******"` or `"######"` messages because the CRC checksum will fail.

The main concerns with long probe wires or many probes are:

- Capacitive loading due to the cable
- Reflections from the end(s) of the cable
- Resistance of long wires
- Noise on long wires

Of these, capacitive loading and reflections impose the strictest limits on cable length.

When sending data to the probes, the therm drives the line both high and low, and line capacitance is not very important. When receiving, however, the probes can only pull the line low and must let it float high. To read a bit from a probe, the therm sends a $4\mu$s low pulse and then stops driving the line. The probe may either drive the line low for $30\mu$s nominal to send a logic-zero, or release it and let it float high to send a logic-one. The therm samples the line after $15\mu$s to determine the bit value. The most critical timing occurs when the probe sends a logic-one bit. The line must float high through the pullup resistor within $15\mu$s to be read correctly.

The line voltage approximately follows that of a capacitor charging through a resistor:

$$V_c = V_s[1 - e^{-t/rc}]$$

In this case, $V_s$ is the applied voltage (5 volts), $V_c$ is the line voltage, r is the pullup resistor (5k ohms) and c is the total line capacitance.

The capacitance of a single 10' probe (as measured for 10 probes connected in parallel on the bench) is about 130pF, and this is mostly due to the cable itself. If we solve the equation with $V_c = 2.0$ and $r = 5000$ and $t = 15E-6$ we get a maximum allowable capacitance of around 5800pF. This translates to around 45 probes, or 450 feet of wire, e.g. any combination of probe wires lengths up to a total of 450 feet should work. However, 2.0 volts is marginal, since the capacitance is somewhat variable, and can depend on where and how the wire is run. I'd recommend a more conservative limit, say 300 feet. That is, you could have one probe 300 feet away, or 10 at a distance of 30 feet each.

Reflections from the far end of the probe cable are the second main concern. It is not possible to terminate the cable in its characteristic impedance, due to the open-collector nature of the bus and constraints on the minimum value of the pullup resistor. To obtain the ultimate performance, an active-pullup circuit is recommended for the driver. Hot Little Therm uses a simpler circuit, and limits the slew rate of the negative-going signal (the worst case) with a series resistor. This works well enough for moderate (hundreds of feet) cable lengths.

Here are some suggestions when using long probe cables:

- Use high quality wire, such as Cat-5 twisted pair. Leave unused wires in the bundle disconnected to reduce parasitic capacitance.
- It is preferable to daisy-chain the cable from probe to probe, instead of wiring each probe directly back to the therm, in order to reduce total wire length and reflections from cable ends.
- To compensate for capacitive loading, you can increase the drive on the probe port by reducing the built-in 5k ohm pullup resistance. This requires a wiring change on the therm circuit board. The minimum value allowed is 1.5k ohm, so if a resistor is added in parallel, its value must be greater than 2.2k ohm.

### Long Serial Wires

Almost any 4 or 6-conductor phone cable should work as a therm extension cable, as long as there is a half twist between the two ends (pin 1 on one end is connected to pin 4 on the other, pin 2 to pin 3, etc.). Stock phone extension cables will also work, if you maintain the correct number of half-twists. There is no hard limit on maximum cable length, you'll have to experiment. I've personally run 9600 baud serial cables the better part of a mile.

### Caution

As always when performing electrical wiring, be aware of the environment. Hot Little Therm does not generate or use any voltages normally considered dangerous, but you must be careful when extending the probe or serial port wires to not let them come in contact with high-voltage (e.g. power or telephone) lines. Remember when running wires outdoors that lightning may strike them and be conducted inside.

## 2.6 Auxiliary Digital Input

The therm includes an auxiliary digital input, pin 5 of J3 (see §6.2), that can be read-out in batch mode (§2.4.1). The input is TTL-level, and is protected by a zener diode. You must supply your own connector in order to use this feature.

## 2.7 Calibrating Probes

The probe chip we use is accurate to ±0.5 degrees C between 0 and 70C. If you require greater accuracy, you can calibrate the probe yourself against a known reference.

One suggested method is to put the probe into a picnic cooler with an accurate lab thermometer. Allow some time for the temperature to stabilize (maybe 30 min.), then quickly read the lab thermometer and note the difference between it and the Hot Little Therm probe. If you have several probes, each one must be calibrated separately (at the same time if you like). You can now add this offset to the probe reading (for Unix software, see the `thermcap to#` entry).

Note: The probe may have different error offsets at different temperatures, so you may also want to calibrate it at two or more points and add a variable correction depending on the reading (the standard software does not support this). For a single-point correction, try to calibrate the probe somewhere in the middle of the expected temperature range in use.

## 2.8 Troubleshooting Operation

If you have problems communicating with the therm unit, try using a terminal or terminal emulator to debug the protocol. With at least one therm and a probe connected, sending a space charcter (0x20) will cause the therm to reply with the temperature of the first probe. Sending a control-P (0x10) will cause the therm to dump a reading of its entire state. See §2.4.

- If you get garbled characters when talking to the therm, check that the terminal settings are correct (1200,8-N-1). Failing that, make sure the serial cable is not too long, and the connections are well made.
- If the therm is responding but you can't get it to read a probe, the problem is most likely in the probe wiring. Perhaps the probe is plugged in backward. Or if the wire was modified, perhaps it is too long, or has a short or open.
- If you get no response at all:
    1. Make sure you have the RJ-11 cord to the computer plugged into the HOST port. Therm won't do anything if it's plugged into END.
    2. Make sure the wall wart is plugged in.
    3. Make sure the computer or terminal baud rate and other settings are correct. Make sure your terminal program is working. Disconnect the therm and connect pins 2 and 3 together on the terminal's data connector and make sure that anything you type is echoed.
    4. Perhaps the transmit-data and receive-data (pins 2 and 3) need to be reversed.

# 3 Software

## 3.1 Introduction

Hot Little Therm comes with unsupported example software. It is intended to help you get started using your Hot Little Therm right away. We expect you will want to make changes to it so we include the source code in the distribution. Explanation of the software in this manual is minimal because we expect it to change over time. Each program is documented more fully in README files and manual pages that accompany the source code.

## 3.2 Unix

### 3.2.1 Introduction

All the software is fairly portable, and should work on most any flavor of Unix. You may need to select compile-time options or tweak it a bit to get it to work. Check the comments near the top of a program or in the Makefile to see what can be specified.

Also, in keeping with the Unix tradition, the programs are not all-in-one applications, but rather building blocks that you can use to create other things.

### 3.2.2 `therm` and `thermcap`

Therm is the basic program to read data from the Hot Little Therm. You can install sensors, for example, inside, outside and in the attic and read them at any time by typing `therm inside outside attic`. It uses a configuration file called thermcap to describe all therms and probes connected to a host.

### 3.2.3 `probem`

Probem is a utility program that searches a TTY for Hot Little Therms, reporting any units and probes that it finds. It can be useful when installing or debugging therm wiring.

### 3.2.4 `thermplot`

Thermplot reads temperature log files and plots a graph of time vs. temperature, and outputs it as a PPM image. It can draw on a blank background of any size, or accept a source image on which to overlay the plot.

Thermplot has lots of options to change the appearance of the graph. It makes a good building block for web pages.

### 3.2.5 `xtherm`

Xtherm is like thermplot, but it displays a temperature graph in an X-window, rereading the log file every 15 minutes to automatically update the picture.

### 3.2.6 `hltware`

Hltware *is* an all-in-one application that reads and plots temperatures interactively. It can log to a file, and includes a simple built-in web server.

### 3.3 Windows

#### 3.3.1 `hltware`

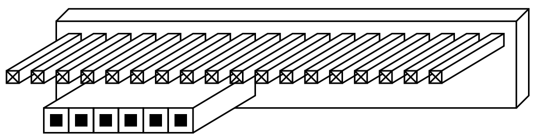
Hltware (see above) is most complete therm client for Windows.

### 3.4 Macintosh

#### 3.4.1 `Therm`

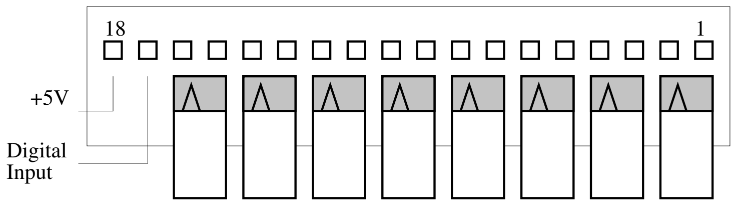
Therm is an interactive application that displays the temperature in real-time on the screen, and can log to a file.

## 4 ProbeStick



The ProbeStick (Spiderplant part no. 510-0020) is designed to make it easy to add several probes to your Hot Little Therm without having to do any wiring. It plugs directly onto the connector on the Therm board, allowing up to eight probes to connect.

To use the ProbeStick, plug the 6-position female connector onto the 6-pin connector (J3) on the Hot Little Therm board. There is only way for it to go on easily. Now you can attach probes to the 18-pin connector, in any of the positions shown in the figure below.




## 5 Electrical and Thermal Specifications

Hot Little Therm uses Dallas Semiconductor DS1820 or DS18S20 1-wire thermometer chips for probe sensors, with the following temperature specifications:

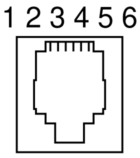
| | |
|---|---|
| Operating Temp. Range | $-55 - 125C$ |
| Resolution | $0.1C$ |
| Absolute accuracy, $0 - 70C$ | $\pm 0.5C$ |
| Worst case at $-55C$ | $+5/-1C$ |
| Worst case at $125C$ | $+1/-3C$ |
| Typical at limits | $+3/-1C$ |

The exact specifications for the DS18S20 are not known at the time of this printing.

The therm unit requires a D.C. supply between 8 and 20 volts (9 volts nominal), and draws about 10mA. Its operating temperature range is at least 0 – 70$C$.

# 6 Pinouts

## 6.1 RJ-11 HOST (J1) / END (J2) Jacks



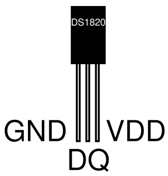

| Pin no. | HOST port | END port |
|---|---|---|
| 1 (optional) | Common | +9V |
| 2 | Common | +9V |
| 3 | Receive | Receive |
| 4 | Transmit | Transmit |
| 5 | +9V | Common |
| 6 (optional) | +9V | Common |

## 6.2 Probe Connector (J3)

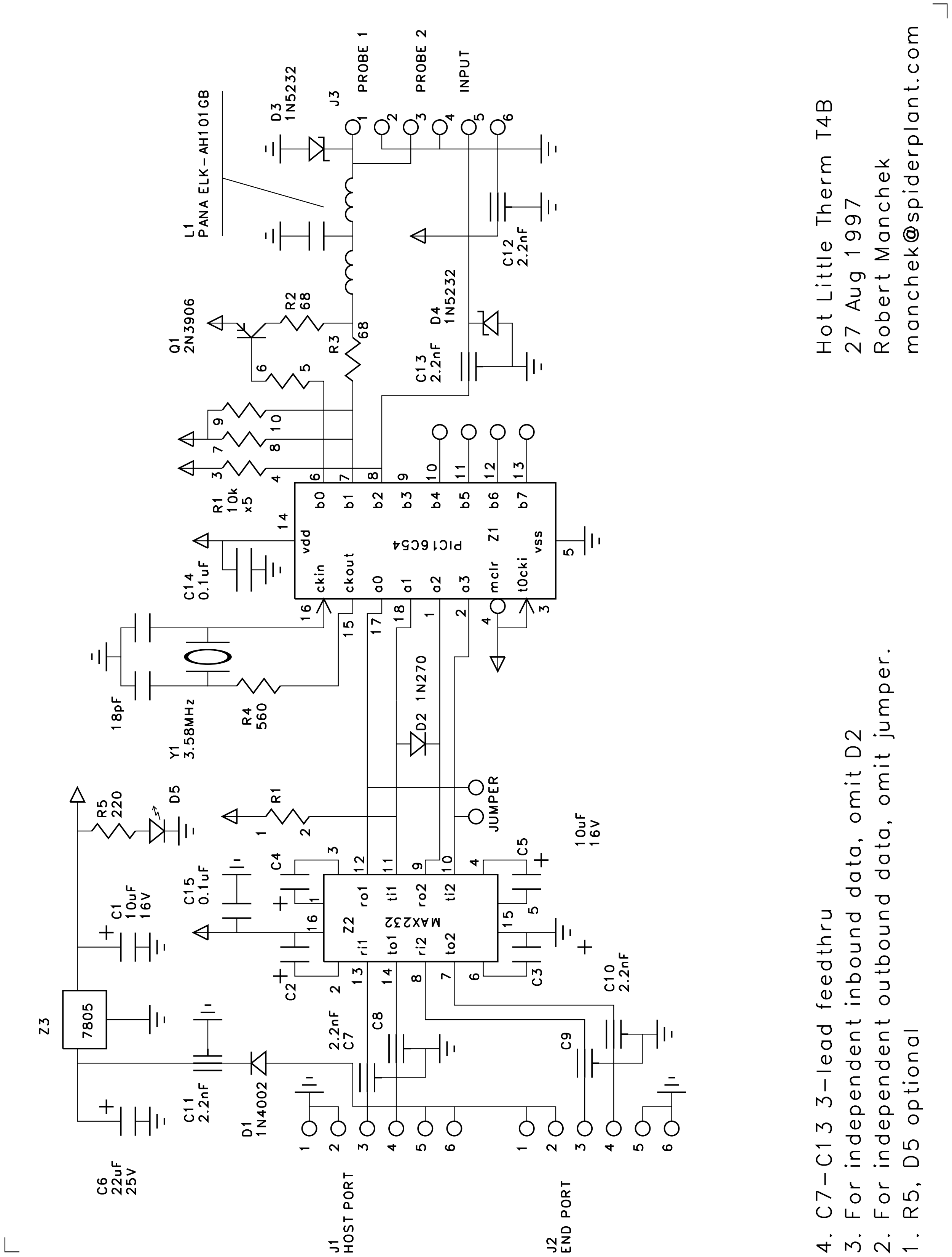
| 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|
| +5V | Digital In | Gnd | Probe | Gnd | Probe |

Probes use a C-Grid connector, Molex part number #50-57-9002

## 6.3 DS1820/18S20 Probe Chip Pinout



# 7 Schematic Diagram



# 8 ASCII Table

As no manual would be complete without one...

This table shows the hexadecimal value and ASCII character equivalent for probe addresses, by therm unit and probe number. Addresses 0x80 – 0xFF are not shown; they are the same characters repeated, but with the highest bit = 1.

Probe number

| | | 0 ($15^{th}$) | 1 (batch) | 2 ($1^{st}$) | 3 ($2^{nd}$) | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|
| | + | 0x00 | 0x10 | 0x20 | 0x30 | 0x40 | 0x50 | 0x60 | 0x70 |
| | 0x0 ($1^{st}$) | ^ @ | ^ P | space | 0 | @ | P | ‘ | p |
| | 0x1 ($2^{nd}$) | ^ A | ^ Q | ! | 1 | A | Q | a | q |
| | 0x2 | ^ B | ^ R | " | 2 | B | R | b | r |
| | 0x3 | ^ C | ^ S | # | 3 | C | S | c | s |
| | 0x4 | ^ D | ^ T | $ | 4 | D | T | d | t |
| | 0x5 | ^ E | ^ U | % | 5 | E | U | e | u |
| Unit number | 0x6 | ^ F | ^ V | & | 6 | F | V | f | v |
| | 0x7 | ^ G | ^ W | ’ | 7 | G | W | g | w |
| | 0x8 | ^ H | ^ X | ( | 8 | H | X | h | x |
| | 0x9 | ^ I | ^ Y | ) | 9 | I | Y | i | y |
| | 0xA | ^ J | ^ Z | * | : | J | Z | j | z |
| | 0xB | ^ K | ^ [ | + | ; | K | [ | k | { |
| | 0xC | ^ L | ^ \ | , | < | L | \ | l | \| |
| | 0xD | ^ M | ^ ] | - | = | M | ] | m | } |
| | 0xE | ^ N | ^ ^ | . | > | N | ^ | n | tilde |
| | 0xF ($16^{th}$) | ^ O | ^ _ | / | ? | O | _ | o | del |

...

# 9 RS-232 Connector Pin Assignments

The following table gives the RS-232 standard assignments for the most commonly used pins, and shows the ones used by Hot Little Therm.

| Abbreviation | Signal Name | DB-25 Pin | DB-9 Pin | Therm Use |
|---|---|---|---|---|
| FG | Frame Ground | 1 | n/a | |
| TX | Transmit Data | 2 | 3 | Data In |
| RX | Receive Data | 3 | 2 | Data Out |
| RTS | Request to Send | 4 | 7 | |
| CTS | Clear to Send | 5 | 8 | |
| DSR | Data Set Ready | 6 | 6 | |
| GND | Signal Ground | 7 | 5 | Common |
| CD | Carrier Detect | 8 | 1 | |
| DTR | Data Terminal Ready | 20 | 4 | |
| RI | Ring Indicator | 22 | 9 | |

# 10 FCC Information

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Caution: Changes or modifications not expressly approved by the party responsible for compliance could void the user's authorization to operate the equipment.

# 11 Warranty Information and Disclaimer

Hot Little Therm may be returned within 60 days of the date of purchase for a full refund, if you are unsatisfied with the product for any reason.

Spiderplant reserves the right to make changes without further notice to Hot Little Therm or to this manual. Spiderplant makes no claim, express or implied, of the fitness or adequacy of Hot Little Therm or application software for any particular purpose or use, or of the accuracy or completeness of information contained in this manual. Spiderplant will not assume liability for any loss or damage caused by the use or misuse of Hot Little Therm or application software. Hot Little Therm is not a medical instrument.

# 12 Contact

Spiderplant
147 Villa St.
Waltham, MA 02453
(781)894-5891
therm@spiderplant.com
www.spiderplant.com

October 23, 2000
Part Number: 101-0005