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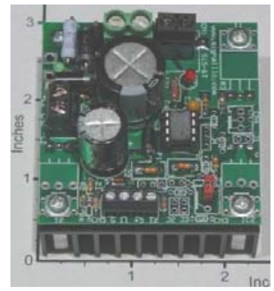
Si15NePITC2-HC12B-30V-2x16A

Networkable, Proportional and Integral (PI), Temperature Controller using 2 Loads (Load1 for Heating and Load2 for Cooling), with 12-Bit Digital Temperature Sensor, Two RS232 Ports, Integrated Heat-Sink



The **Si15NePITC2-HC12B-30V-2x16A** is a 30V, 2x16A, Networkable, Proportional and Integral (**PI**) Temperature Controller using 2 Loads (Heat and Cool at the same time). The fundamental components of this controller are: a 12-Bit digital temperature sensor; two high-power transistors (FETs); and a networkable microprocessor that stores the selected control parameters in a nonvolatile memory and controls the power flow to two loads (Valves, Thermo-Electric (TE) cells, etc) using 750Hz Pulse-Width Modulation (PWM). **The temperature is measured with a 12-bit digital sensor and the process is PI controlled with 0.0625^{0}C steps in the -50^{0}C to +120^{0}C range**. By **PI** control, we mean that the amount of correction used in the control-loop is proportional to the difference and the Integral of the difference between the set and measured temperature values. A single DC power supply (in the 9V to 30V and 0A to 20A range) is required to operate this controller. Two proportional-band parameters are used "**c**"= 001,...199 for Cold band, and "**h**"= 001,...199 for Heat band. One step change in the band parameter represents a 1 degree C change. Two control bands are used because the TE cells are more efficient in heating mode than in the cooling mode. These proportional control bands are centered at the set-temperature value; and a smaller band value represent more aggressive proportional control. Full heating or cooling TE-cell power (100% PWM) is used when the measured temperature is outside of this selected band; and reduced TE-cell power (100% to 0% PWM as specified by the **PI** control) is used inside this band. The integral gain "**i**"= 001,...199 controls the contribution of the integrator to the total **PI** control sum. Larger integral gain values represent higher integral contribution ("**i**"=199 represents 100% contribution). The integrator is reset to zero each time a new set temperature is selected and its growth is limited to prevent excessive integral contribution ("integral windup"). A wide range of thermal loads can be efficiently controlled with proper control parameter selection. **The temperature overshoots and oscillations ("hunting") are limited to approximately + or - 0. 5^{0}C.** Control parameter selection and **PI tuning** are defined in the network section **given below.** The temperature is sampled at approximately 1Hz rate and the control-loop/display is updated with the same rate. An onboard microprocessor measures and controls the temperature; monitors the user inputs; and drives the LCD. A small 12-bit digital thermometer, Signal's part number **Si24DTsens-12B** , (connected to port **CN4** and using the Dallas Semi., DS18B20 sensor) is used to measure and control the temperature in the -50^{0}C to +120^{0}C range, with approximately 1^0 C accuracy and with 0.0625^{0}C steps. Because this sensor is digital, it is virtually immune to noise and loading; ideally suited for remote sensing. This sensor uses a unique "1-wire interface" (with parasite power mode) that requires only 2-conductors for reliable remote (typical length of 20 meters) temperature sensing. As the name (**Ne, Networkable**) implies, the control parameters and the desired set-temperature are selectable in the -50^{0}C to +120^{0}C range, with 0.0625^{0}C steps; using ASCII command strings, obtained from the RS232 Network Port, **CN5**. The RS232 data format and the Local Area Network (LAN) commands are described on the next page. A "**Kill-Switch**" (connected to **J1**) is used for emergency TE turn-off (switch open=TE-Cells are on, Switch closed=TE-Cells are off with zero currents, as shown on the application drawing below). An LCD port (with RS232 Interface Standard) is provided for display of the Set and Measured temperature and status data. The 2 line x 16 character LCD can be ordered from Signal under the part number of **Si14LCD2L16CH-4PC** (with 12" cable and 4-pin connectors and with back-light). A red LED is used to monitor the TE cell (or load) voltage. This board operates with a single unregulated voltage source (9V to 30V range). A small

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(2.4.0"x2.3"x0.95"), integrated, finned heat-sink is used to operate at 600W power level. Higher power-levels can be achieved with more efficient heat-sinks. Typical applications are: Peltier Effect TE Coolers, Heat Pumps,

Specification and Application of Si15NePITC2-HC12B-30V-2x16A

- **Typical Operating Temperature at 20A:** 45^0C with the Metal Heat-Ring Bolted to a small (2.4"x2.3"x0.4") Aluminum Finned Heat-Sink, while it is exposed to ambient air at 25^0C (as shown on photograph).
- **Overall Dimensions:** Length=2.4", Width=2.3", Height=2.1" Inches, (L=61, W=59, H=52 mm).
- **Source-Voltage Requirements: V_C (from pin +P to pin - P):** 9V to 30V DC unregulated voltages.
- **Max. Continuous Average Load-Current:** 20A at 100% duty-cycle, with heat-sink (as shown).
- **Max. Load-Current for 5sec:** 40A at 100% duty-cycle, with heat-sink (as shown).
- **Load Isolation:** The Load or TE cell must be isolated from the source voltage (V_P).
- **Power-Conversion Efficiency:** Approximately 98.5% at full-load (30V and 20A).
- **Type of Temperature Control: PI** control, Proportional (**P**) and Integral (**I**).
- **Set-Temperature** is adjustable from -50^0C to $+120^0$C, in 0. 1^0 C steps; with network commands.
- **Measured-Temperature** is determined with 0.0625^0 C precision and with +/- $½^0$ C accuracy in the -10^0C to $+80^0$C range, and with approximately +/- 1^0 C accuracy in the -55^0C to $+125^0$C range; using the Dallas Semi. DS18B20 (in TO-92 casing) Digital Thermometer.
- **Kill Switch Port, J1:** An external Normally Open Switch or an Open Collector NPN transistor can be connected to **J1** port to disable the load current (**J1** Open=Run, **J1** Short=Stop). The active pin of **J1** is internally connected to +5V using a 4.7k Ohm resistor (as shown on the diagram below).
- **PWM Frequency:** 750Hz with pulse duration is controlled by **PI** program.
- **Jumper Selection:** The Jumper **J1** ("Kill-Switch") is always active and sampled at approx 10Hz rate.
- **Temperature Sampling Rate:** The temperature is sampled at approximately 1Hz rate and the control-loop/display is updated with this same rate.
- **Serial LCD Port, CN4:** RS232 Serial Interface Standard, 0 to 5V, 9600 Baud, 1 Start, 8 Data, No Parity, 1 Stop Bit. A 2-Line by 16-Character Serial LCD displays the Set and Measured %PWM.
- **Load-Current Indicator and Protection:** One onboard red LED is used to monitor the load current. All control inputs are zener-diode protected.
- **About the Voltage Requirement:** The Si15 will work with any DC voltage in the 9 V to 30 V range. In addition, the power filters are included on this board. Consequently, only unregulated (full-wave rectified) DC input power is required in most applications.

A Typical Application of the Si15NePITC2-HC12B-30V-2x16A

In this 12-bit, closed-loop, **PI** temperature control application, the Set-Temperature is adjusted by command strings derived from a Personal Computer (PC) using the Microsoft "Hyper Terminal" program (or any-other ASCII controller operating at 9600 Baud, 1 start-bit, 8 data-bits, 1 stop-bit, No parity-bit). In this application, one Peltier type Thermo-Electric (TE) cell is used (for heating-only in the heat mode and for cooling-only in the cooling mode, as selected by the 'm' command). The TE cells can be purchased from: www.customthermoelectric.com/. The temperature of the enclosed and insolated Hot/Cold Environment is measured with the Dallas Semi. DS18B20 (in TO-92 casing) Digital Thermometer, **Si24DTsens-Spec1-DS18B20**.This sensor can be purchased from Signal Consulting, LLC as **Si24DTsens-12B** (DS18B20 with 12" leads and 3-pin connector). The optional LCD module can be ordered from Signal using the part number of **Si14LCD2L16CH-4PC** (2x16 serial LCD with back-light, 12" cable and with 4-pin connectors). **Warning: The connecting wires to the Load and the Power**

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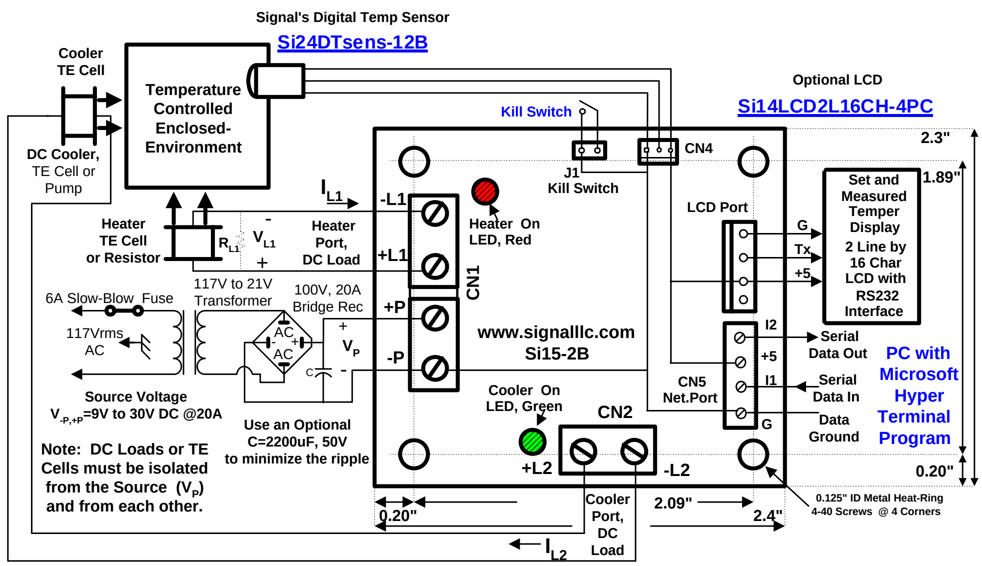
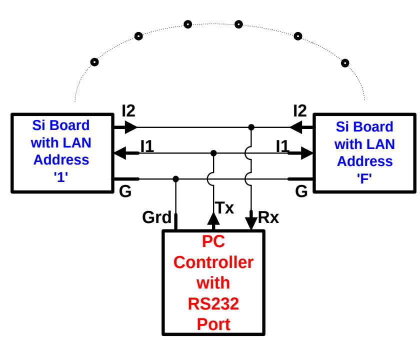
Supply must be heavy gauge copper wire (#12 AWG or heavier) to handle the rated current level. In addition, these heavy gauge wires act as a heat sink, preventing overheating.



Command Format and Local Area Network (LAN) for the Si15NePITC2-HC12B-30V-2x16A

Each board has a unique, 8-bit, ASCII, **none-volatile,** Node-Address ranging from 1….9, A..Z, a,…z; (or a total of 61 Units can be networked).The address can be changed by a **LAN** command (the factory default address is 1). The board uses a modified version of the RS232 serial-data communication standard, where the output-voltage (on pin **I2, CN5**) ranges from 0 to +5V (rather than the usual -12V to +12V). In addition, this output pin is normally an open circuit; and it will only output a serial TTL binary bit-stream when properly referenced by its Node-Address. The serial data input-voltage (on pin **I1, CN5**) has the standard range of -12V to +12V. The serial data-format is: 9600 Baud Rate, 1 Start-Bit, 8 Data-Bits, 1 Stop-Bit, and no Parity-Bit. These features allow the creation of a Local Area Network (**LAN**) with up to 61 nodes (boards). A typical 3-wire **LAN** with "Star Topology" is shown below. Note that the control lines (**G, I1, I2**) with the same name are connected together (or the boards are connected in parallel) and driven by an **ASCII** controller (or **PC**), equipped with an RS232 serial port, operating at 9600 Baud rate.



Command Rules:

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1. All Commands are **ASCII** character strings (Chars.). An ASCII string is denoted here with **Bold Red Letters (Characters)**.

2. Each string is terminated by a Carriage Return Character, **(CR)**. The only exception is the **#** command.

3. Upper-Case Letters are used for Output Commands; and Lower-Case Letters are used for Input Commands.

4. The 1st Char. in a string is either ASCII **#** or a Node Address (**1,..,9,A..Z, a,..,z**). If the 1st Char. is a **#**, it denotes a query to all boards on the LAN to output their Node Address and Program Name.

5. If the 1st Char. is an ASCII (**1..,9, A,..Z, a,…,z**), it directs the rest of the command string to the board that has this address.

6. The 2nd Char. in the string is the Command Character that operates on the addressed board.

7. The 3rd, 4th, 5th and 6th Chars. represent the value of the input data. Where **+** denotes positive Set-Temperature values; and **-** denotes negative Set-Temperature values.

8. The last Char. in the sequence is always the string terminator, **(CR)**.

9. All Commands are stored in a nonvolatile memory and the last values entered are recalled when the controller power is restored.

Command Examples on Input Pin I1:

Ex#1. Com. String: **#** Action: All boards on the LAN will output their Address and Program Name.

Ex#2. Com. String: **1u5(CR)** Action: Change Board 1 Address in EPROM from 1 to 5.

Ex#3. Com. String: **1T(CR)** Action: Board 1 outputs its Set and Measured Temperature.

Ex#4. Com. String: **1Q(CR)** Action: Board 1 outputs the Measured Temperature.

Ex#5. Com. String: **1P(CR)** Action: Board 1 outputs the parameters entered with the ‘m’, ‘c’, ‘h’ and ‘i’ commands.

Ex#6. Com. String: **1M(CR)** Action: Board 1 outputs the Measured PI parameters.

Ex#7. Com. String: **2t25(CR)** Action: Change Board 2 Set-Temperature to +25.0C.

Ex#8. Com. String: **2t+25.0(CR)** Action: Change Board 2 Set-Temperature to +25.0C.

Ex#9. Com. String: **2t-25(CR)** Action: Change Board 2 Set-Temperature to -25.0C.

Ex#10. Com. String: **2t-25.0(CR)** Action: Change Board 2 Set-Temperature to -25.0C.

Ex#11. Com. String: **1c4(CR)** Action: Change Board 1 Cold proportional band to 4C.

Ex#12. Com. String: **1h20(CR)** Action: Change Board 1 Heat proportional band to 20C

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Ex#13. Com. String: **1i16(CR)** Action: Change Board 1 Integral Gain to 16

You must use approximately 25msec (or longer) delays between characters when inputting a command string ("1t..(CR)", "1T(CR)" or "1Q(CR)") to this controller board.
Occasionally, a transient character may be captured and buffered by one more board on the LAN, this **transient character can be cleared by sending one or more (CR) prior to a valid command string.**
Valid Measured Temperature values are given at 1Hz rate; consequently, new valid temperature query commands can be issued at this same rate.

2-Line by 16-Character LCD Display Format:

An optional 2-Line by 16-Character serial LCD (**Si14LCD2L16CH-4PC**) can be connected to port CN2. This +5V, RS232 serial LCD operates at 9600 Baud rate with: 1 Stop-bit, 8 Data-bits, 1 Stop-bit, No Parity-bit. A typical LCD display is given below:
Line 1: NST=+025.00 C Ph
Line 2: NMT=+025.00 C ia

Where: N is the node address, ST=Set-Temperature, Ph= Signed Hexadecimal PWM value used. In the Open circuit mode Ph=00=00% PWM. In the Heat mode, Ph=01,…7F=1% to100% Heating PWM. In the Cooling mode, Ph=FF,…80=1% to100% Cooling PWM in two's complement hex format.

Where: MT=Measured-Temperature, and the "i" field denotes the Cold and Heat integrator states: i=0= both integrators are in the accumulation mode, i=1= Heat integrator is in the clipped mode (no longer accumulate error values) and the Cold integrator is in the accumulation mode; i=2= Cold integrator is in the clipped mode (no longer accumulate error values) and the Heat integrator is in the accumulation mode; i=3= Both integrators are in the clipped mode.

The "a" field denotes the alarm conditions: a=0=No external alarm on jumper pin **J1** (pin **J1** is in the open circuit state); a=2= External alarm on jumper pin **J1** (pin **J1** is in the short circuit state).

Response to Commands on Output Pin I2:

The response to a "**1T(CR)**" command is an ASCII character string (or a line of characters). Each string is terminated with carriage return and line feed characters. An example is shown below:

N=1 ST=+025.00 C MT=+023.87 C

Note that there are two space characters between **1** and **S**; and there are two space characters between **C** and **M**. The length of this character string is 33, including carriage return and line feed characters (not shown in this example). Where **N=1** is the node (or unit) address of the board (can be changed with the **u** command), **ST=+025.00 C** is the last Set-Temperature in degree Centigrade (entered with the **t** command), and **MT=+023.87 C** is the current Measured-Temperature in degree Centigrade.

The response to a "**1Q(CR)**" command is: **T1=+023.87 C** (with carriage return and line feed).
The response to a "**1Q(CR)**" when the sensor is not connected is: **T1=No Sensor** (with carriage return and line feed). Each character string (line) is a continuous stream of ASCII characters with an occasional pause (or delay) between characters. This delay is approximately 1msec.

The response to a "**1P(CR)**" command is: N=1 h=008 c=004 i=032 d=000 m=h a=30 Ph=00

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Where: N=1=current node address, h=008= heat-band value entered by the "**h**" command (1,…199) c=004= cold-band value entered by the "**c**" command (1,…199), i=032= integral gain value entered by the "**i**" command (1,…199), d=000= Not used, m=h= mode value entered by the "**m**" command (m=h=Heat mode, m=c=Cold mode), a=30=same as ia=30, Ph =00= as defined in LCD display format.

The response to a "**1M(CR)**" command is: N=1 Bm=o Pp=0010 Ip=017D Dp=0000 Sp=018D Ha=0943 Ca=0000.
Where: Bm=o=actual mode (o=open mode, h =heat mode, c=Cold Node), Pp=0010=Proportional PWM Hex value used currently (0000, to 07FF)=0% to 100% PWM, Ip=017D=Integral PWM Hex value used currently (0000, to 07FF)=0% to 100% PWM, Dp=0000=Not Used, Sp=018D= Sum of Pp and Ip, Ha=0943= Current Heat accumulator value in Hex, Ca=0000= Current Cold accumulator value in Hex.

Network Configuration: The on-board microprocessor provides the bus arbitration, required to avoid data collisions on the 3-wire LAN bus. The **Si..Ne..** boards can be arranged in many Local Area Network (LAN) topologies: Star, Daisy-Chain, etc. You may create your own network or you may order one or more of the Network Cable Assemblies listed in the Application Note. **Before you build your network, click on this blue link and read this Application Note: SigNote on Configuring a LAN-2**. **Network Configuration:** The on-board microprocessor provides the bus arbitration, required to avoid data collisions on the 3-wire LAN bus. The Si..Ne.. boards can be arranged in many Local Area Network (LAN) topologies: Star, Daisy-Chain, etc. You may create your own network or you may order one or more of the Network Cable Assemblies listed in the Application Note. Before you build your network, click on this blue link and read this Application Note: **SigNote on Configuring a LAN-2**.

Factory Default PI Parameters: To restore the default parameters enter these commands.

1h20(CR) for Heat-Band Par., 1c4(CR) for Cold-Band Par., 1i32(CR) for Integral Gain

The PI default parameters (given above) are factory selected to cover a wide range of thermal loads and these parameters seldom need to be changed. If fine tuning is required please use the modified Ziegler-Nichols method given below.

PI Control Tuning: The Ziegler-Nichols method is a well-known online tuning strategy. The first step in this method is setting the 'i' gains to zero, increasing the proportional gain (K) (by reducing the Cold proportional band with the "**c**" command in the cold mode or the Heat proportional band with the "**h**" command in the Heat mode) until a sustained and stable oscillation (as close as possible) is obtained on the output. Then the critical gain Kc and the oscillation period Pc is recorded and the P and I gain values adjusted using a modified Ziegler-Nichols method given below. **Modified Ziegler-Nichols Method:** Set the integrator gain to zero (type **1i0(CR)**); and find critical proportional gain Kc (by adjusting the Cold proportional band using the "**c**" command in the cold mode; or adjusting the Heat proportional band using the "**h**" command in the Heat mode). Choose a new proportional gain K_{new} =0.5 * Kc (or new cold band or heat band value is = 2 times the critical band value). Increase the Integral gain with "**i**" command until the average steady-state error value is zero (Measured-Temperature is equal to the Set-Temperature).