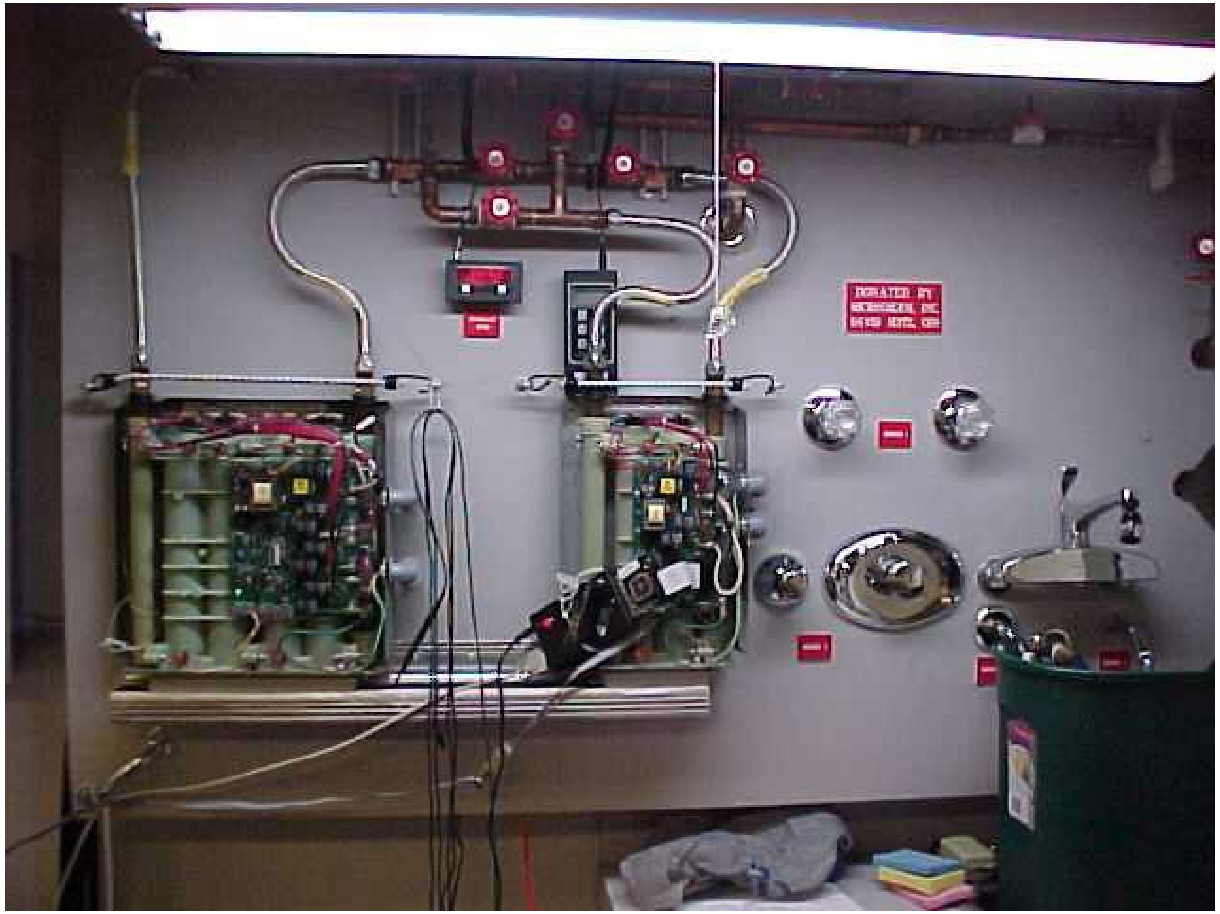
SENSORS 2

Connecting the Sensors and SEISCO Water Heater

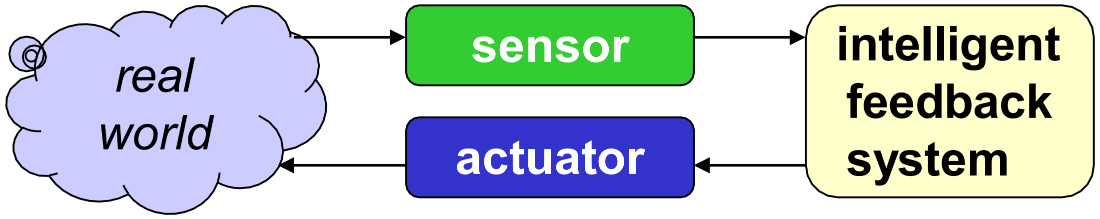


Some slides from Andrew Mason

Associtate Professor, ECE

Transducers

- Transducer
  - a device that converts a primary form of energy into a corresponding signal with a different energy form
    - Primary Energy Forms: mechanical, thermal, electromagnetic, optical, chemical, etc.
  - take form of a **sensor** or an **actuator**
- Sensor (e.g., thermometer)
  - a device that detects/measures a signal or stimulus
  - acquires information from the "real world"
- Actuator (e.g., heater)
  - a device that generates a signal or stimulus

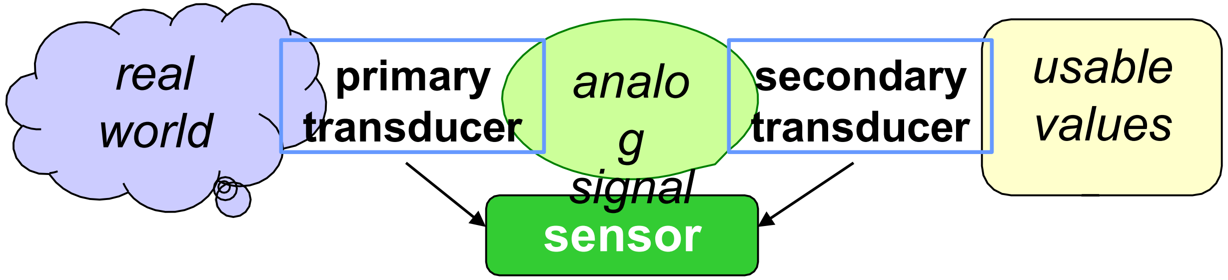


Sensor Systems

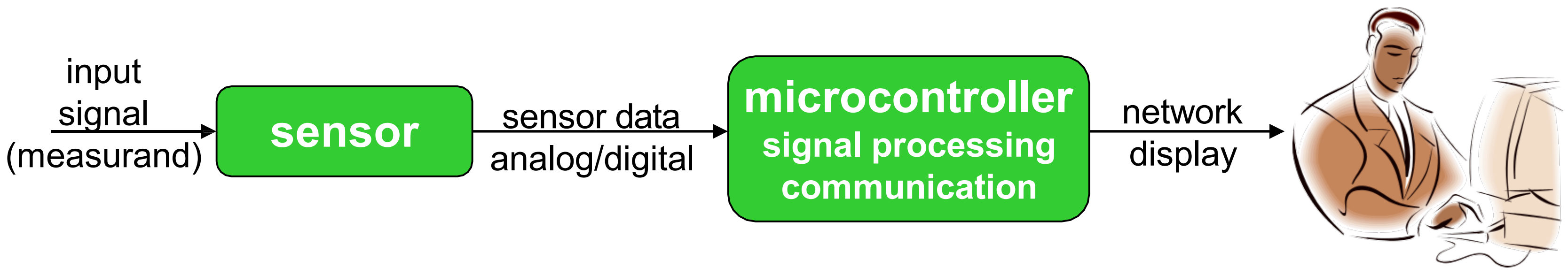
*Typically interested in **electronic sensor***

- convert desired parameter into electrically measurable signal

- General Electronic Sensor
  - primary transducer: changes "real world" parameter into electrical signal
  - secondary transducer: converts electrical signal into analog or digital values



- Typical Electronic Sensor System



Temperature Sensor Options

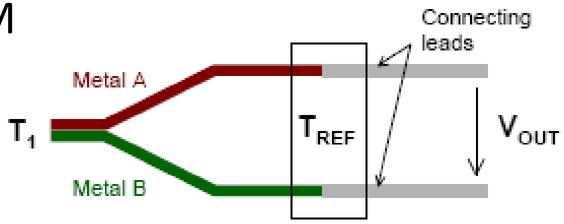
- Resistance Temperature Detectors (RTDs)
  - Platinum, Nickel, Copper metals are typically used
  - positive temperature coefficients

$$R_T = R_0\left[1+\alpha_1 T+\alpha_2 T^2+\cdots\alpha_n T^n+\right]\cong R_0\left[1+\alpha_1 T\right]$$

- Thermistors ("thermally sensitive resistor")
  - formed from semiconductor materials, not metals
    - often composite of a ceramic and a metallic oxide (Mn, Co, Cu or Fe)
  - typically have negative temperature coefficients

$$R_T = R_0 \exp\left[B\left(\frac{1}{T}-\frac{1}{T_0}\right)\right]$$

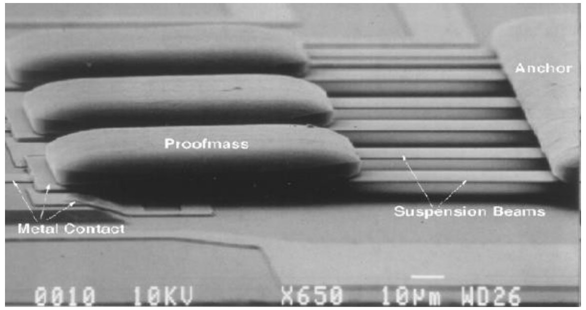
- **Thermocouples**
  - based on the Seebeck effect: dissimilar metals at diff. temps. ➔ signal

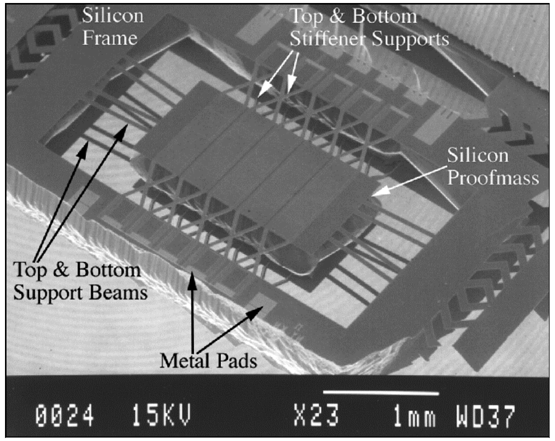


	THERMOCOUPLES	RTD	IC
ACCURACY	Limits of error wider than RTD or IC Sensor	Better accuracy than thermocouple	Best accuracy
RUGGEDNESS	Excellent	Sensitive to strain and shock	Sensitive to shock
TEMPERATURE	-400 to 4200° F	-200 to 1475° F	-70 to 300° F
DRIFT	Higher than RTD	Lower than TC	
LINEARITY	Very non-linear	Slightly non-linear	Very linear
RESPONSE	Fast dependent on size	Slow due to thermal mass	Faster than RTD
COST	Rather inexpensive except for noble metals TCs, which are very expensive	More expensive	Low cost

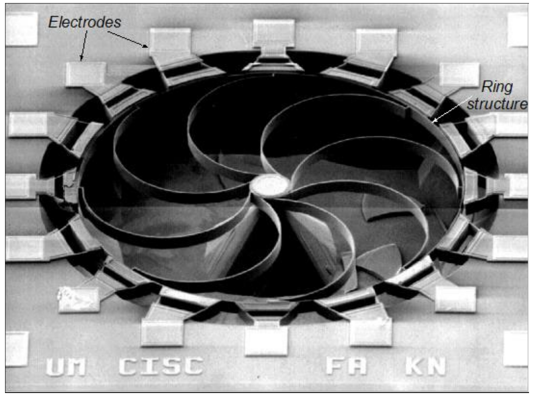
Example MEMS Transducers

- MEMS = micro-electro-mechanical system
  - miniature transducers created using IC fabrication processes
- Microaccelerometer
  - cantilever beam
  - suspended mass

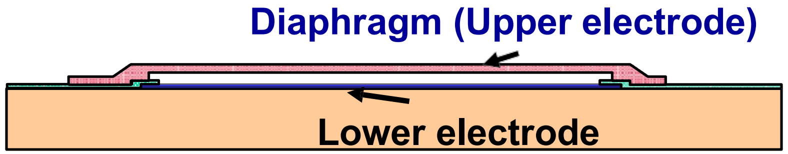


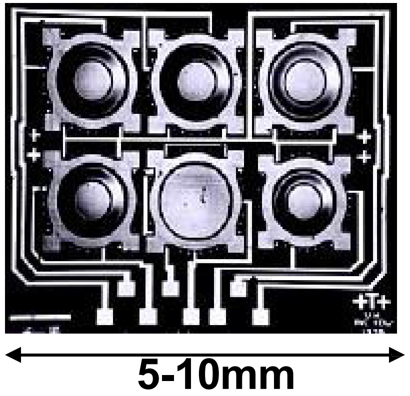


- Rotation
  - gyroscope



- Pressure



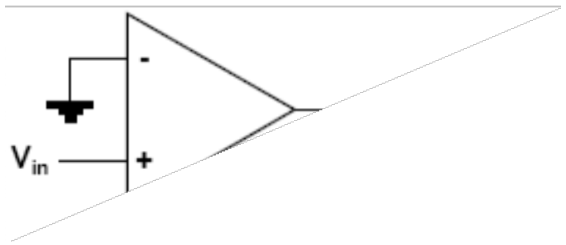


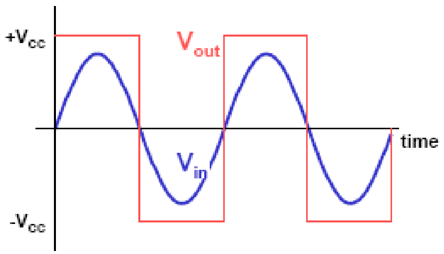
Operational Amplifiers

- Properties
  - open-loop gain: ideally infinite: practical values 20k-200k
    - high open-loop gain ➔ virtual short between + and - inputs
  - input impedance: ideally infinite: CMOS opamps are close to ideal
  - output impedance: ideally zero: practical values 20-100Ω
  - zero output offset: ideally zero: practical value <1mV
  - gain-bandwidth product (GB): practical values ~MHz
    - frequency where open-loop gain drops to 1 V/V
- Commercial opamps provide many different properties
  - low noise
  - low input current
  - low power
  - high bandwidth
  - low/high supply voltage
  - special purpose: comparator, instrumentation amplifier

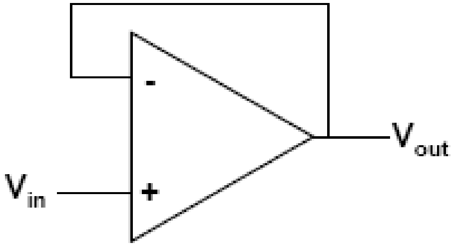
Basic Opamp Configuration

- Voltage Comparator
  - digitize input



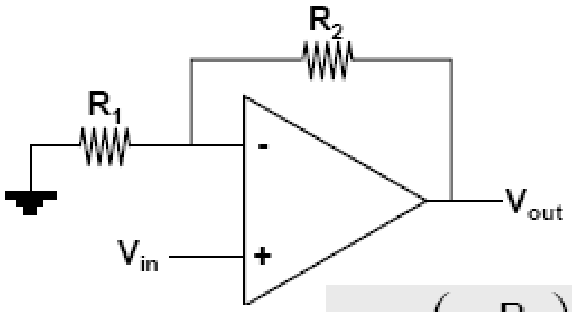


- Voltage Follower
  - buffer



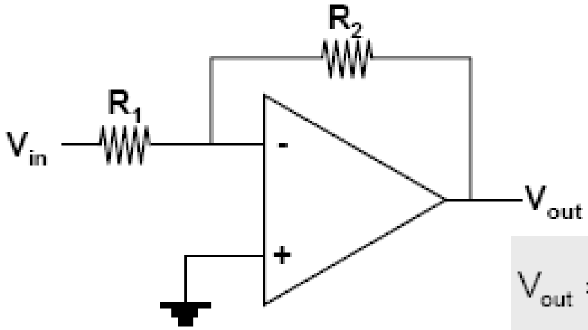
$$V_{out} = V_{in}$$

- Non-Inverting Amp



$$V_{out} = \left(1 + \frac{R_2}{R_1}\right) V_{in}$$

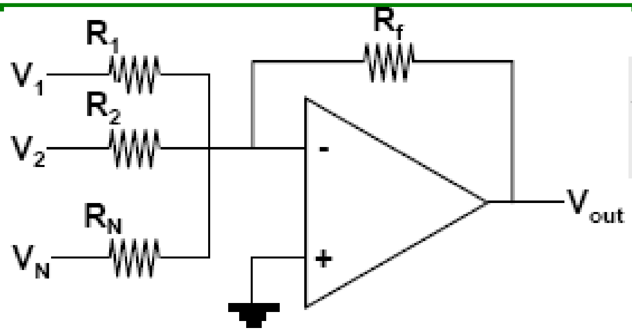
- Inverting Amp



$$V_{out} = -\frac{R_2}{R_1} V_{in}$$

More Opamp Configurations

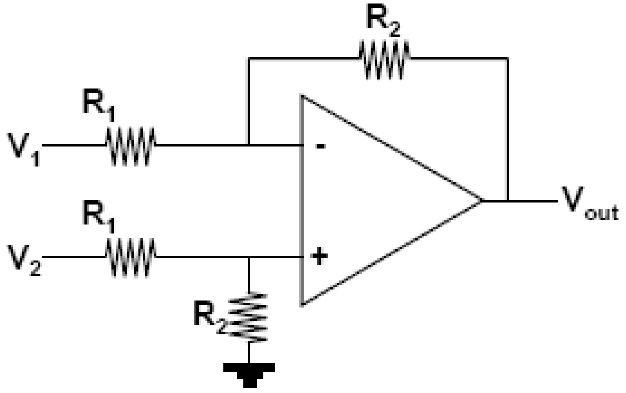
- Summing Amp



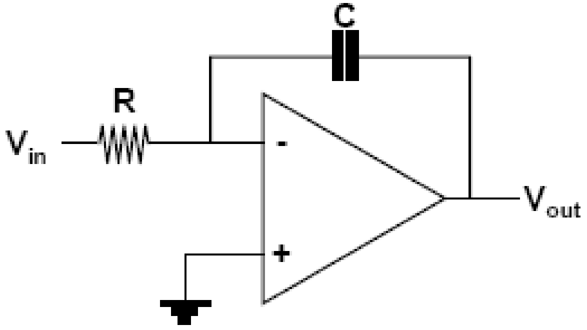
$$V_{out} = -\left(V_1\frac{R_f}{R_1} + V_2\frac{R_f}{R_2} + \cdots + V_N\frac{R_f}{R_N}\right)$$

- Differential Amp

$$V_{out} = R_2 (V \ldots$$



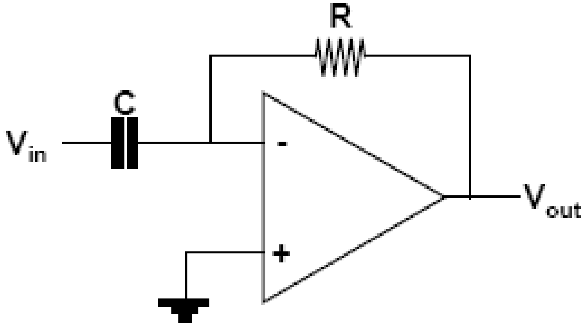
- Integrating Amp



$$V_{out} = -\frac{1}{j\omega CR}V_{in} = -\frac{1}{RC}\int V_{in}dt$$

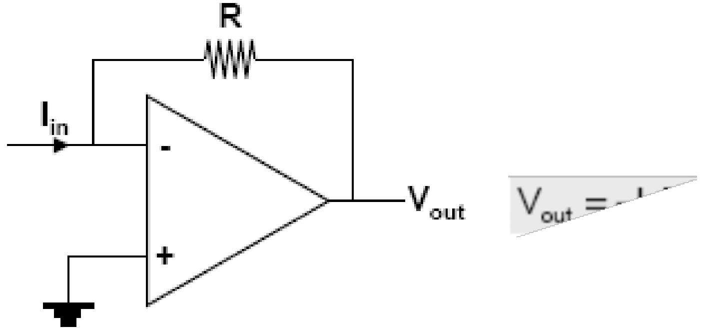
- Differentiating Amp

$$V_{out} = -\frac{R}{\frac{1}{j\omega C}}V_{in} = -RC\frac{dV_{in}}{dt}$$

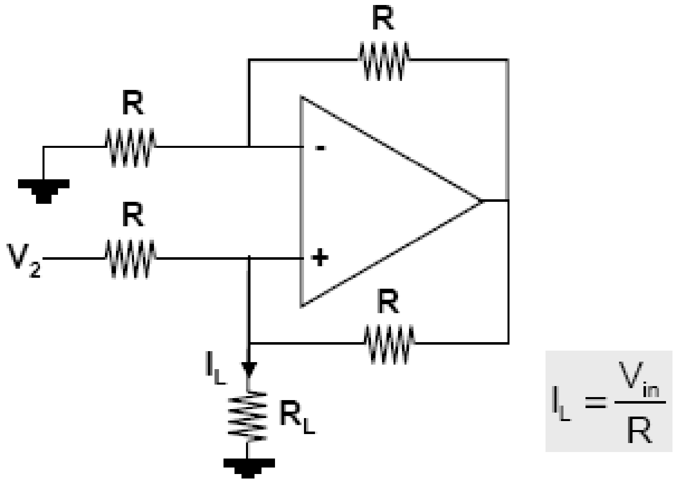


Converting Configuration

- Current-to-Voltage

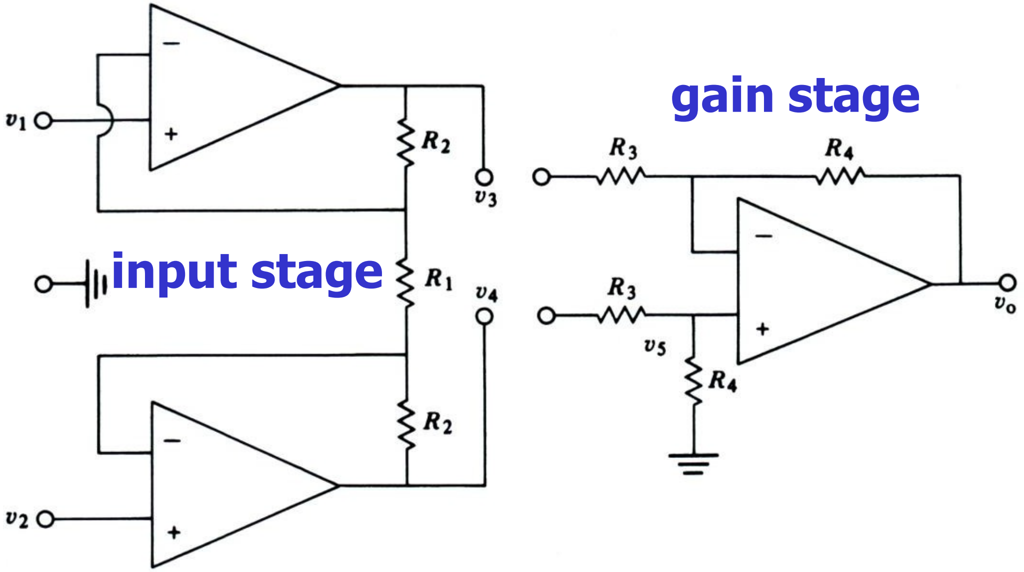


- Voltage-to-Current



Instrumentation Amplifier

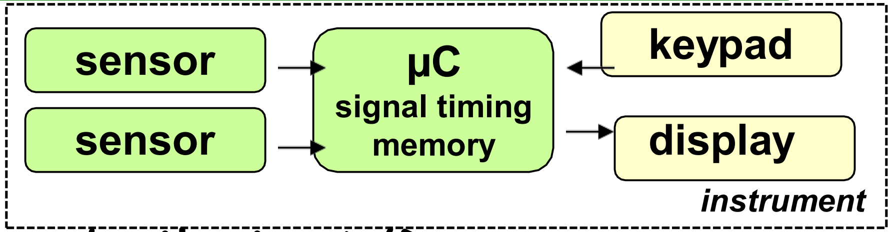
- Robust **differential gain** amplifier
- Input stage
  - high input impedance
    - buffers gain stage
  - no common mode gain
  - can have differential gain
- Gain stage
  - differential gain, low input impedance
- Overall amplifier
  - amplifies only the differential component
    - high common mode rejection ratio
  - high input impedance suitable for biopotential electrodes with high output impedance



total differential gain

$$G_d = \frac{2R_2 + R_1}{R_1}\left(\frac{R_4}{R_3}\right)$$

Connecting Sensors to Microcontrollers



- Analog
  - many microcontrollers have a built-in A/D
    - 8-bit to 12-bit common
    - many have multi-channel A/D inputs
- Digital
  - serial I/O
    - use serial I/O port, store in memory to analyze
    - synchronous (with clock)
      - must match byte format, stop/start bits, parity check, etc.
    - asynchronous (no clock): more common for comm. than data
      - must match baud rate and bit width, transmission protocol, etc.
  - frequency encoded
    - use timing port, measure pulse width or pulse frequency

Connecting Smart Sensors to PC/Network

- "Smart sensor" = sensor with built-in signal processing & communication
  - e.g., combining a "dumb sensor" and a microcontroller
- Data Acquisition Cards (DAQ)
  - PC card with analog and digital I/O
  - interface through LabVIEW or user-generated code
- Communication Links Common for Sensors
  - asynchronous serial comm.
    - universal asynchronous receive and transmit (UART)
      - 1 receive line + 1 transmit line. nodes must match baud rate & protocol
    - RS232 Serial Port on PCs uses UART format (but at +/- 12V)
      - can buy a chip to convert from UART to RS232
  - synchronous serial comm.
    - serial peripheral interface (SPI)
      - 1 clock + 1 bidirectional data + 1 chip select/enable
  - I^2C = Inter Integrated Circuit bus
    - designed by Philips for comm. inside TVs, used in several commercial sensor systems
  - IEEE P1451: Sensor Comm. Standard
    - several different sensor comm. protocols for different applications

MICROPROCESSOR CONTROLLED HOT WATER HEATER

US006246831B1

(12) **United States Patent**
Seitz et al.

(10) **Patent No.: US 6,246,831 B1**
(45) **Date of Patent: Jun. 12, 2001**

(54) **FLUID HEATING CONTROL SYSTEM**

(75) Inventors: **David E. Seitz**, Conroe; **David Paul Sharp**; **Thomas Lamson Harman**, both of Houston; **Louis J. Everett**, College Station; **Rodney H. Neumann**, The Woodlands, all of TX (US)

(73) Assignee: **David Seitz**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/334,337**

(22) Filed: **Jun. 16, 1999**

(51) **Int. Cl.**[7] **F24H 1/10**

(52) **U.S. Cl.** **392/486**; 219/497; 219/483; 392/466

(58) **Field of Search** 392/465, 466, 392/479, 480, 481, 484, 485, 486, 487, 488, 489; 219/483, 497

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,175,075	*	3/1965	Nord et al.	392/484
3,909,588		9/1975	Walker et al. .	
4,031,352	*	6/1977	Oosterberg	219/497
4,320,285	*	3/1982	Koether	219/497
4,337,388		6/1982	July .	
4,638,147		1/1987	Dytch et al. .	
4,829,159		5/1989	Braun et al. .	
4,920,252		4/1990	Yoshino .	
5,128,517	*	7/1992	Bailey et al.	219/497
5,216,743		6/1993	Seitz .	
5,479,558		12/1995	White et al. .	
5,504,306		4/1996	Russel et al. .	
5,710,408	*	1/1998	Jones	219/497
5,763,858	*	6/1998	Jones	219/497
5,789,723	*	8/1998	Hirst	219/497
5,811,764	*	9/1998	Hirst	219/497
5,866,880		2/1999	Seitz et al. .	
5,928,546	*	7/1999	Kramer et al.	219/497
6,047,108	*	4/2000	Sword et al.	392/466
6,080,971	*	6/2000	Seitz et al.	392/485

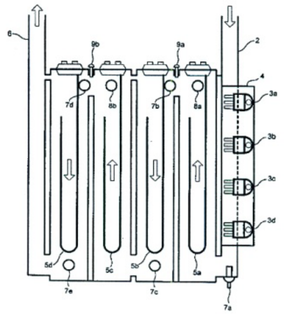
* cited by examiner

Primary Examiner—Teresa Walberg
Assistant Examiner—Fadi H. Dahbour
(74) *Attorney, Agent, or Firm*—Browning Bushman

(57) **ABSTRACT**

An improved system, method and apparatus for control of an instantaneous flow-through fluid heater system is disclosed. The control incorporates a logic control method providing modulation of power in small steps to a plurality of heating elements retaining responsiveness to closed-loop control needs without inducing light flicker. Further, the life of the coils of heating circuit electromechanical relays are extended by energizing the coils with a pulse-width-modulated drive decreasing in duty cycle and thus the latent coil heat when an increase in mains voltage is sensed. The life of the contacts of same relays are extended by inhibiting heating element triac drive immediately upon sensing loss of relay coil power, such as by an over temperature limit switch opening, thus ensuring that relay contacts open with zero heating element current. In addition to the software "watch-dog timer" internal to the microcontroller, a redundant fail-safe circuit external to the microcontroller prevents a program lockup condition from leaving any heating element triac or relay drive in an energized state. A combination of control hardware and program provide self-diagnostic detection of an inoperative thermistor, stuck relay, or a failed triac or heating element. An improved means of sensing water level is disclosed incorporating a low-level, high frequency signal, allowing detection of non-conducting distilled water and the reliable detection of water in the presence of main-frequency currents as would exist in ungrounded sheathed heating elements with electrical leakage or as would exist with bare-elements.

29 Claims, 59 Drawing Sheets

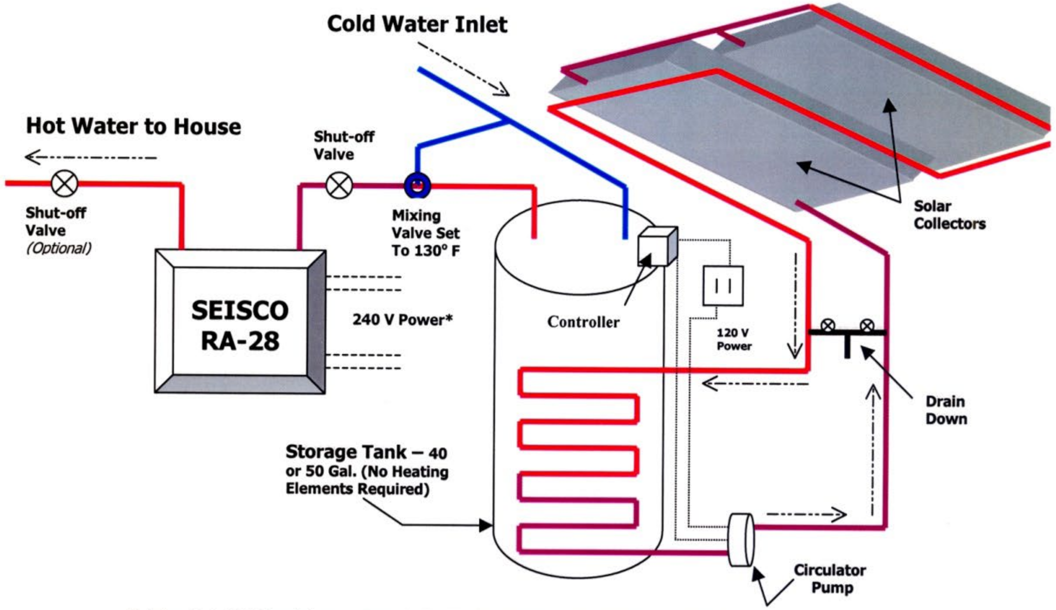


Everyone Loves the Seisco

SEISCO®
by Microtherm, Inc.
www.seisco.com
888-296-9293
223 W. Airtex Houston, Texas 77090

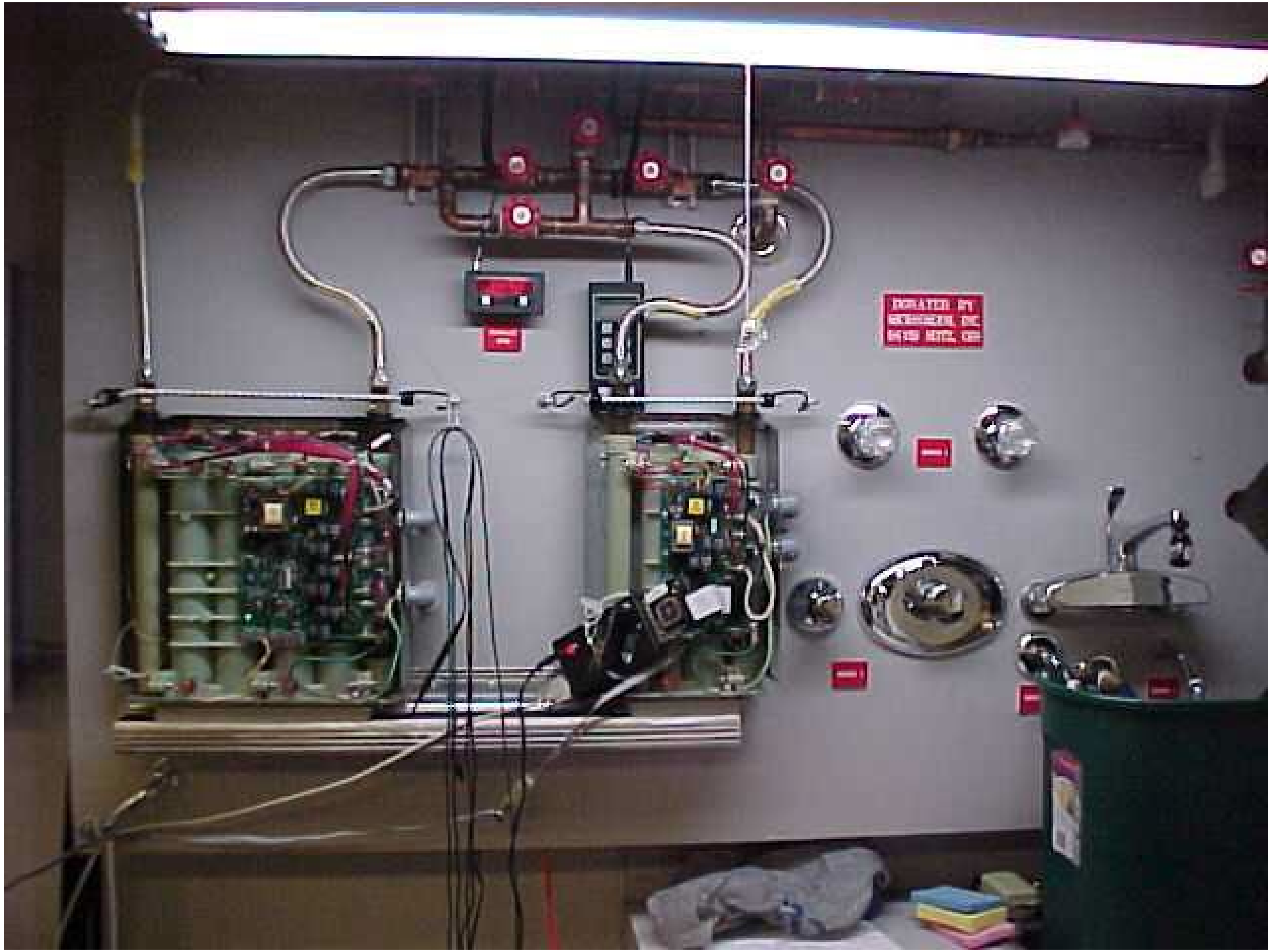
SEISCO Model RA-28
Tank-Less!! ELECTRIC
Continuous Water Heater –
Solar Water Heating Application

Recommended SEISCO Model RA-28 Back-up to Domestic Solar Water Heating System with Storage Tank and Closed-Loop Heat Exchanger



* The RA-28 Model requires **FOUR** 30 Amp, 240 Volt circuits from the main electrical panel or from an installed 120 Amp sub-panel or disconnect box.

- Temperatures from the Solar Heated Storage Tank can reach 160° F, thus requiring a mixing valve ahead of the Seisco to prevent the high temperature switch from tripping and disabling the Seisco.
- If the Storage Tank contains heating elements, they should be disconnected or the power turned off to enable the Seisco to provide the back-up heating. The Seisco should be set to turn on when the water from the Storage Tank drops below 120° F.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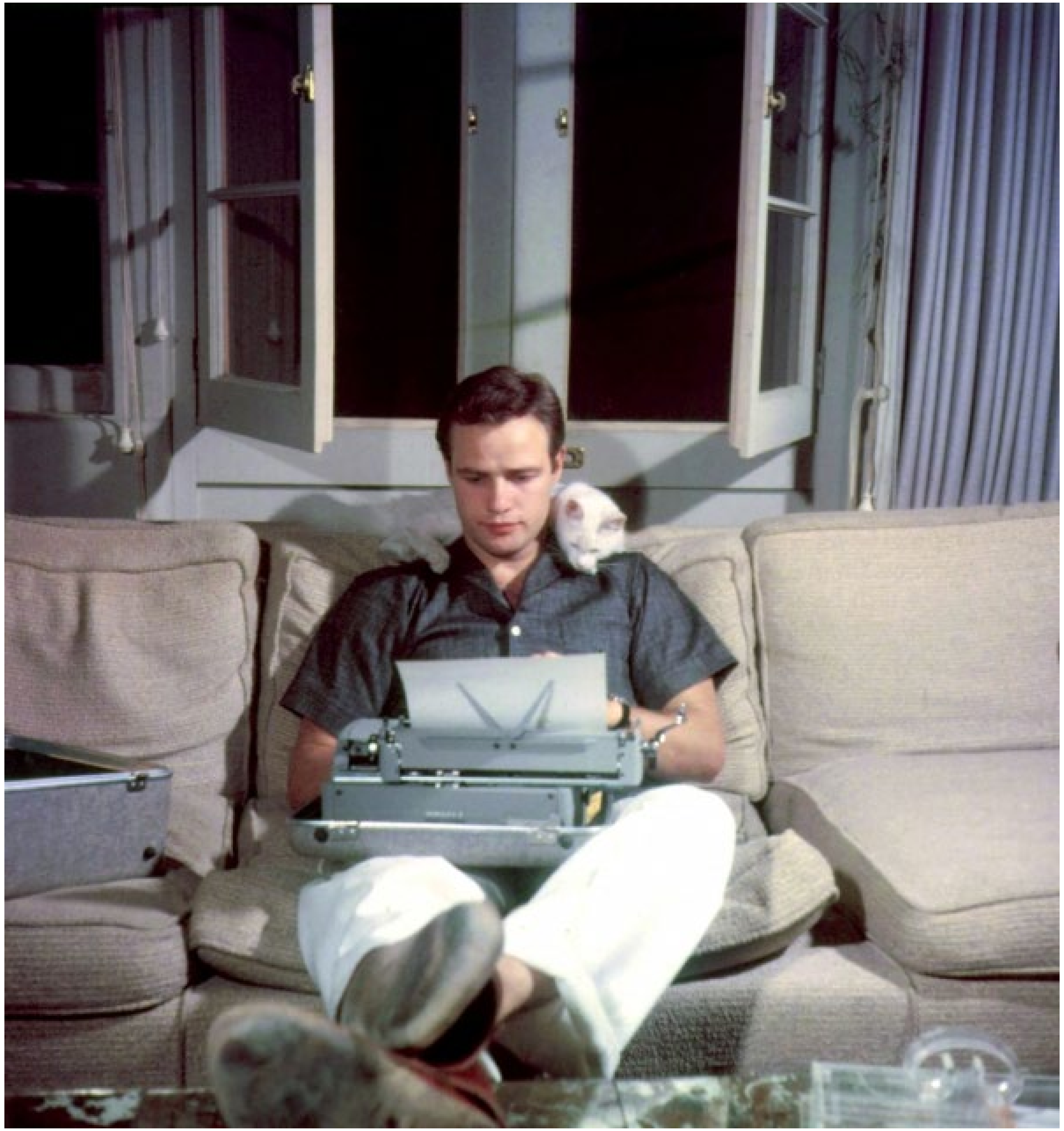
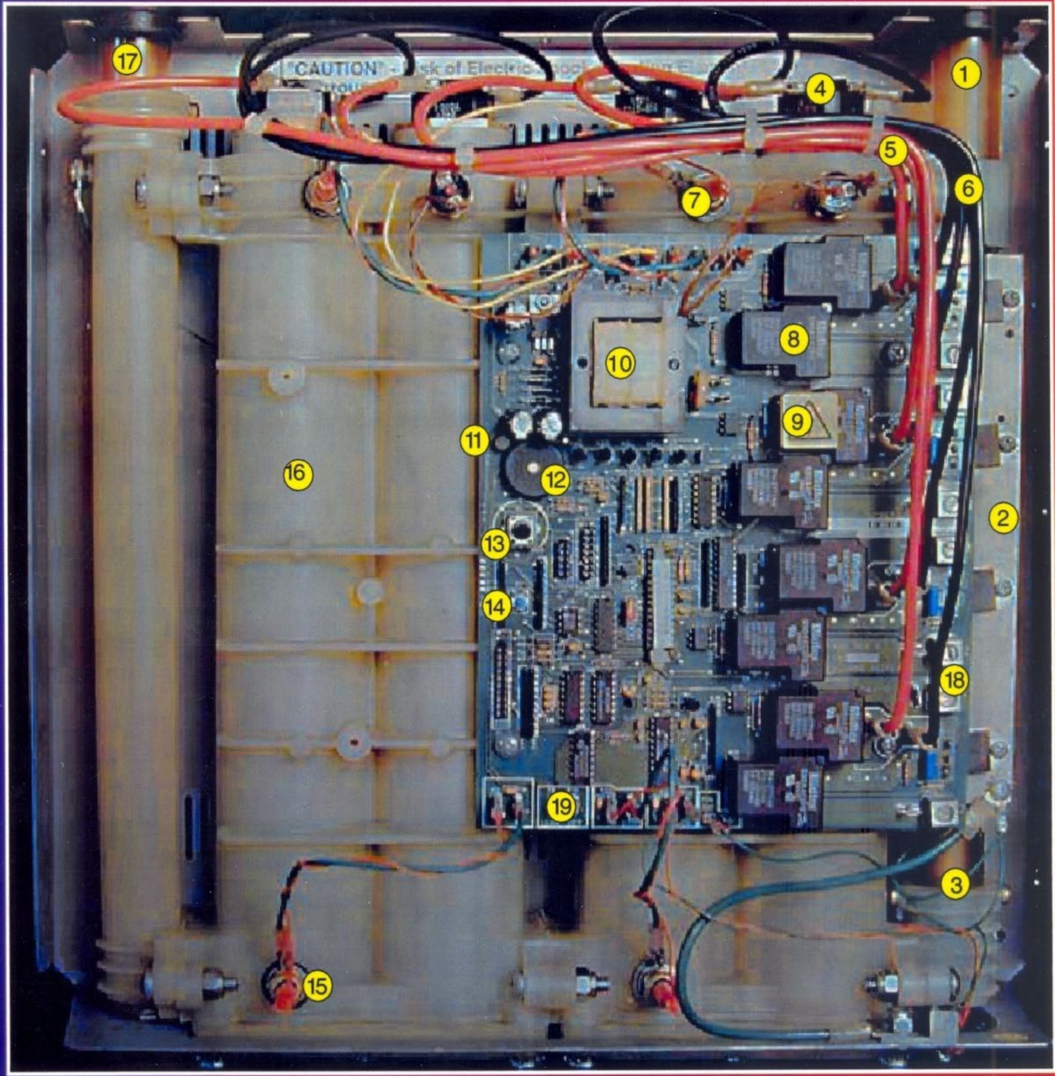
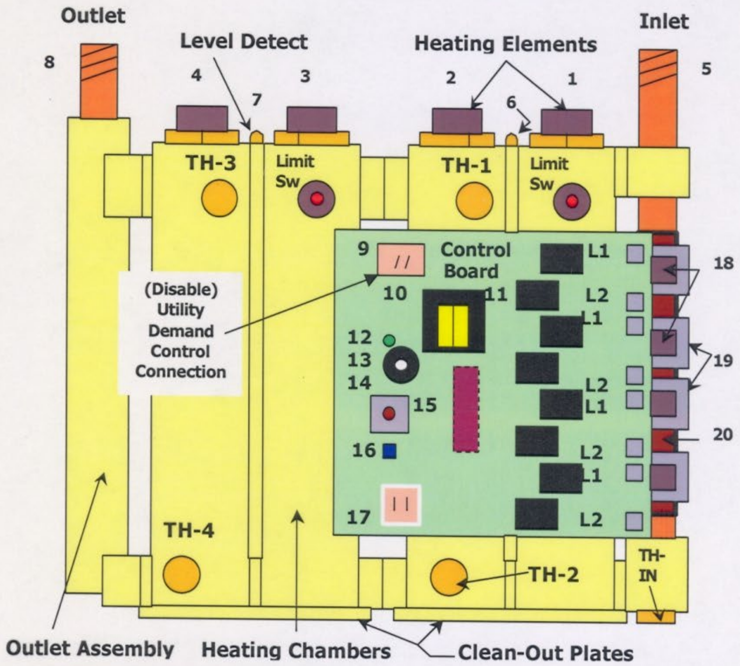


Informational guide to the inner workings of the the SEISCO water heater.



SEISCO

SEISCO® - Four Chamber Models (18, 22 & 28 KW)
Internal Workings and Parts Identification

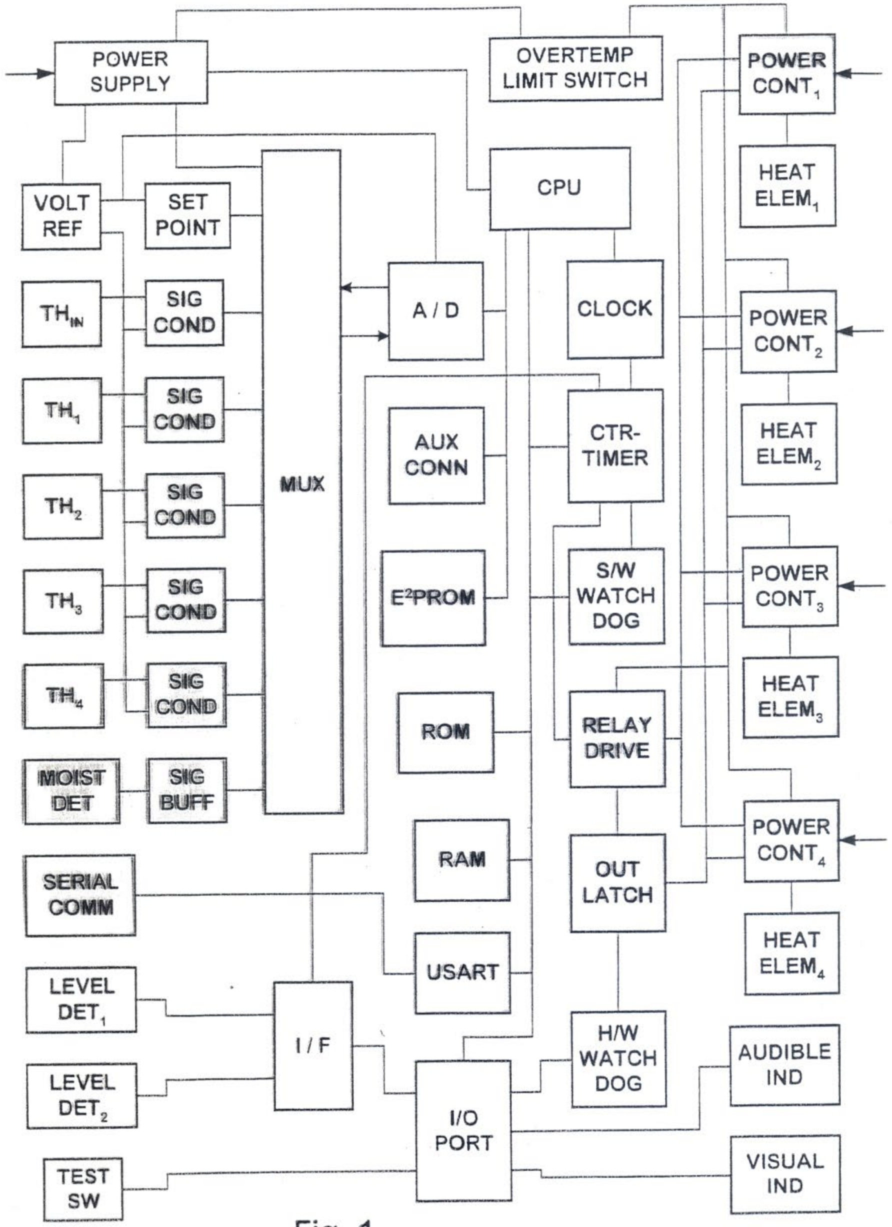


LEGEND

1 – Heating Element #1
2 – Heating Element #2
3 – Heating Element #3
4 – Heating Element #4
5 – Inlet Water Tube, ¾
6 – Water-Level Detect Screw
7 – Water-Level Detect Screw
8 – Outlet Water Tube, ¾
9 – Disable, Demand Control Switch
10 – Transformer
11 – Heating Element Relays (8 ea.)
12 – LED Light Indicator
13 – Audible Speaker
14 – Output Temperature Control

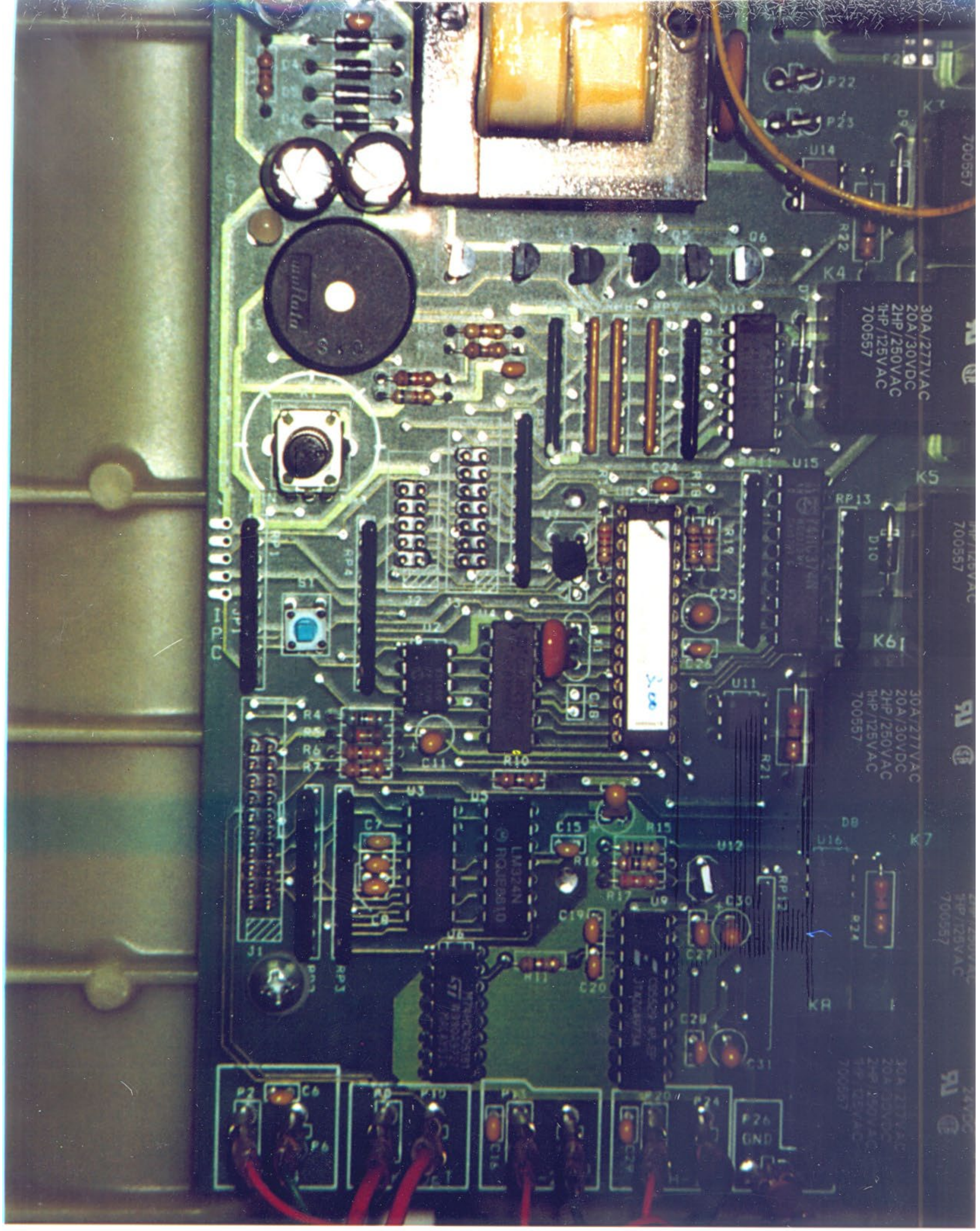
LEGEND

15 – Microprocessor Control Chip
16 - Blue Button; Manual Audible Activation
17 – Terminal Spades for Leak Detect Wires
18 – Triacs (4 each)
19 – Triac Mounting Blocks to Heat Sink (4 ea.)
20 – Copper Heat Sink Tube
L1 – Power Connection Lugs (208 – 240 VAC)
L2 – Power Connection Lugs (208 – 240 VAC)
Limit Sw : Over Temperature Limit Switches (2)
TH-IN : Inlet Temperature Sensor
TH-1 : Chamber Temperature Sensor #1
TH-2 : Chamber Temperature Sensor #2
TH-3 : Chamber Temperature Sensor #3
TH-4 : Chamber Temperature Sensor #4

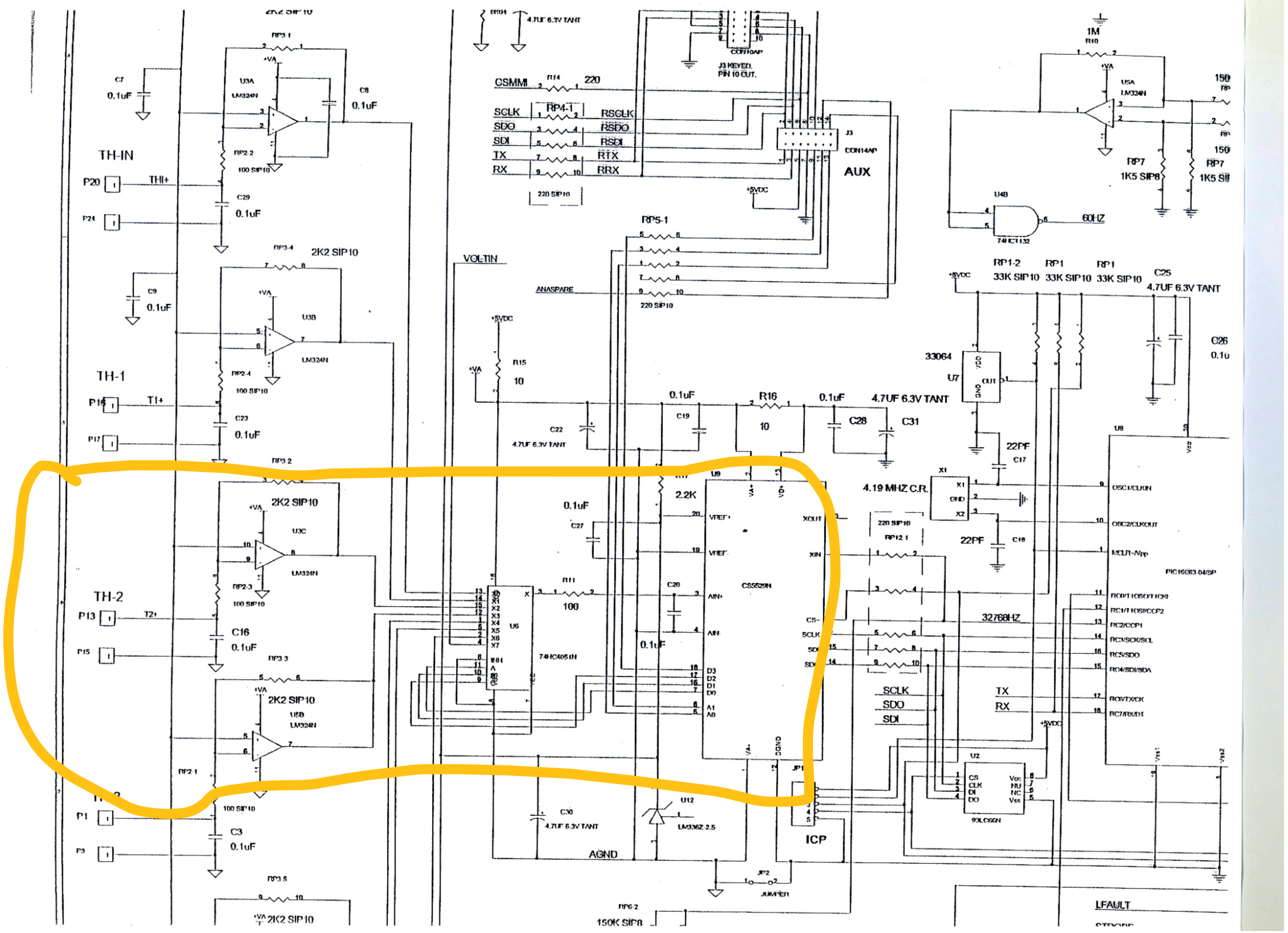


POWER SUPPLY
OVERTEMP LIMIT SWITCH
POWER CONT1
HEAT ELEM1
VOLT REF
SET POINT
CPU
TH_IN
SIG COND
A / D
CLOCK
POWER CONT2
TH1
SIG COND
AUX CONN
CTR-TIMER
HEAT ELEM2
TH2
SIG COND
MUX
TH3
SIG COND
E²PROM
S/W WATCH DOG
POWER CONT3
TH4
SIG COND
HEAT ELEM3
ROM
RELAY DRIVE
MOIST DET
SIG BUFF
POWER CONT4
SERIAL COMM
RAM
OUT LATCH
HEAT ELEM4
LEVEL DET1
USART
I / F
LEVEL DET2
H/W WATCH DOG
AUDIBLE IND
I/O PORT
TEST SW
VISUAL IND

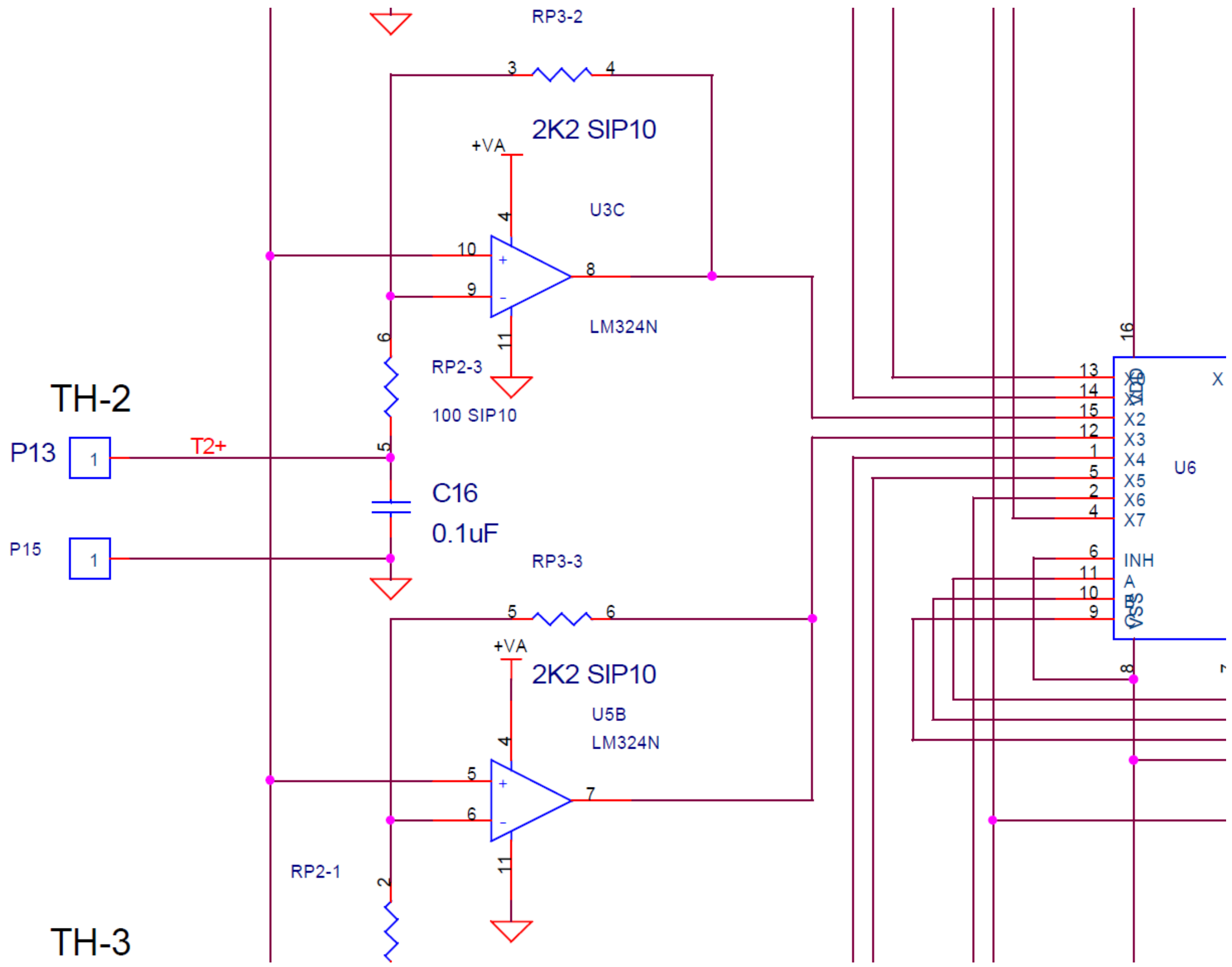
Fig. 1

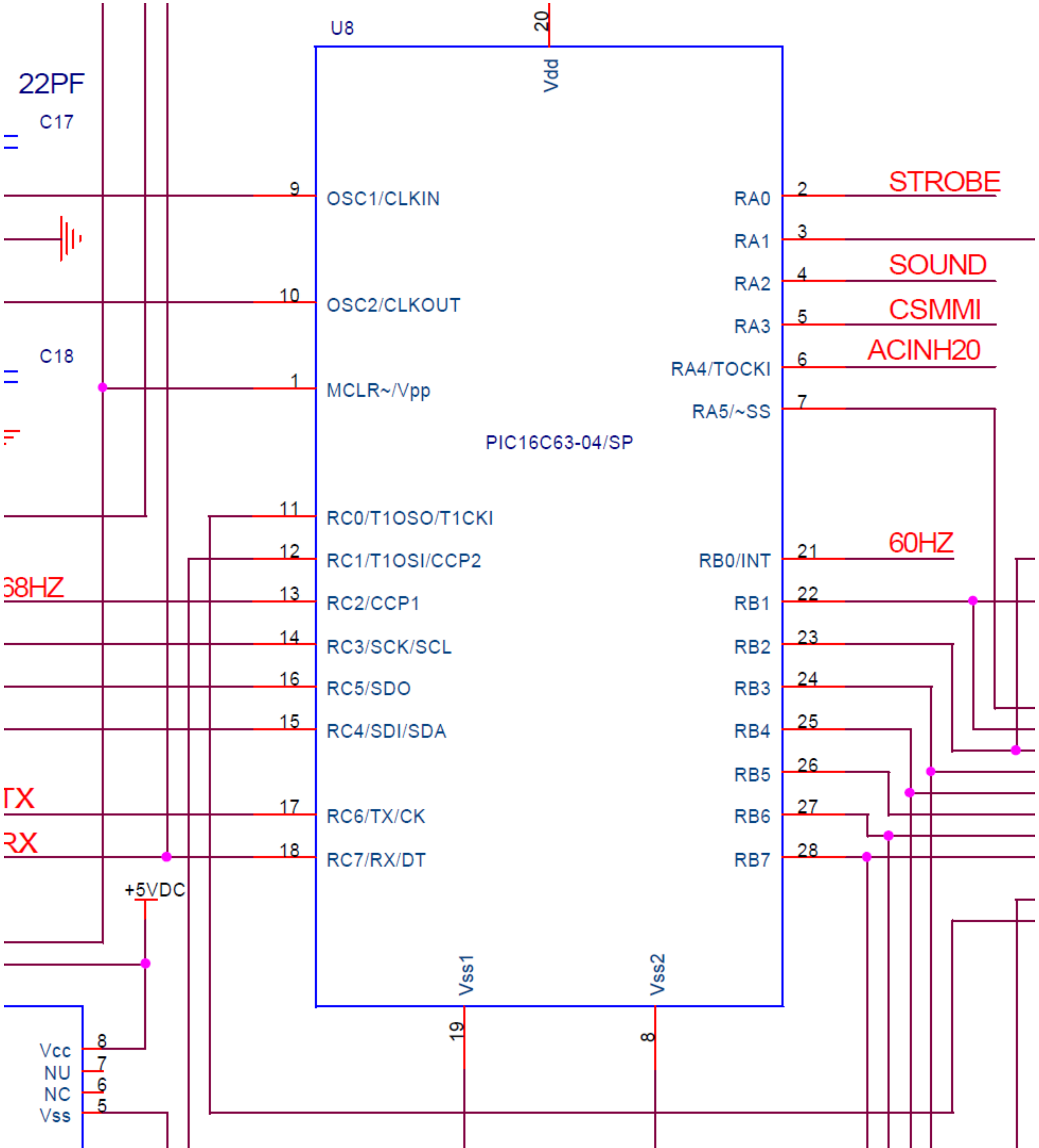

30A/277VAC
20A/30VDC
2HP/250VAC
1HP/125VAC
700557
LM324N

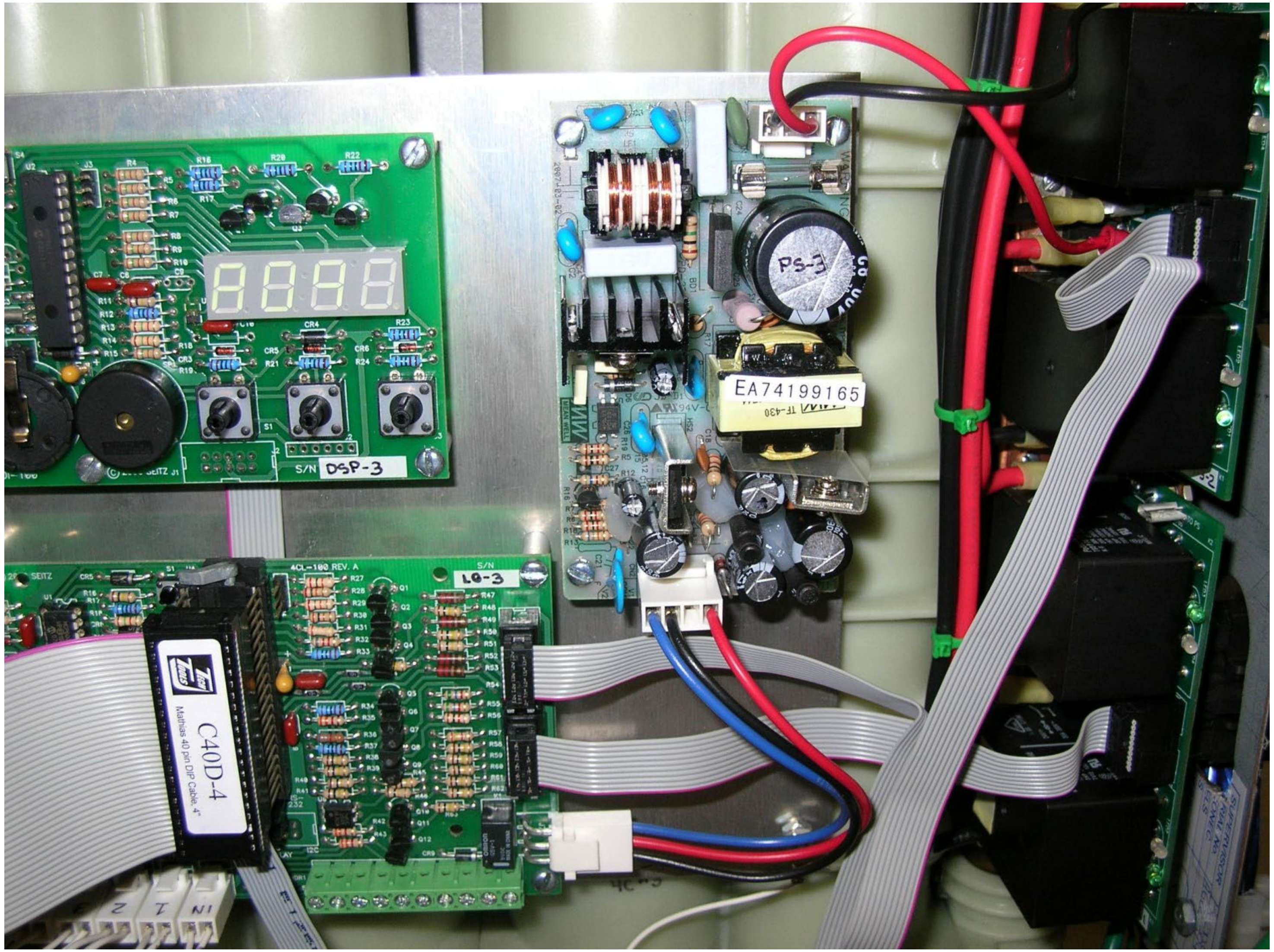
Analog IN
& Mux & A2D

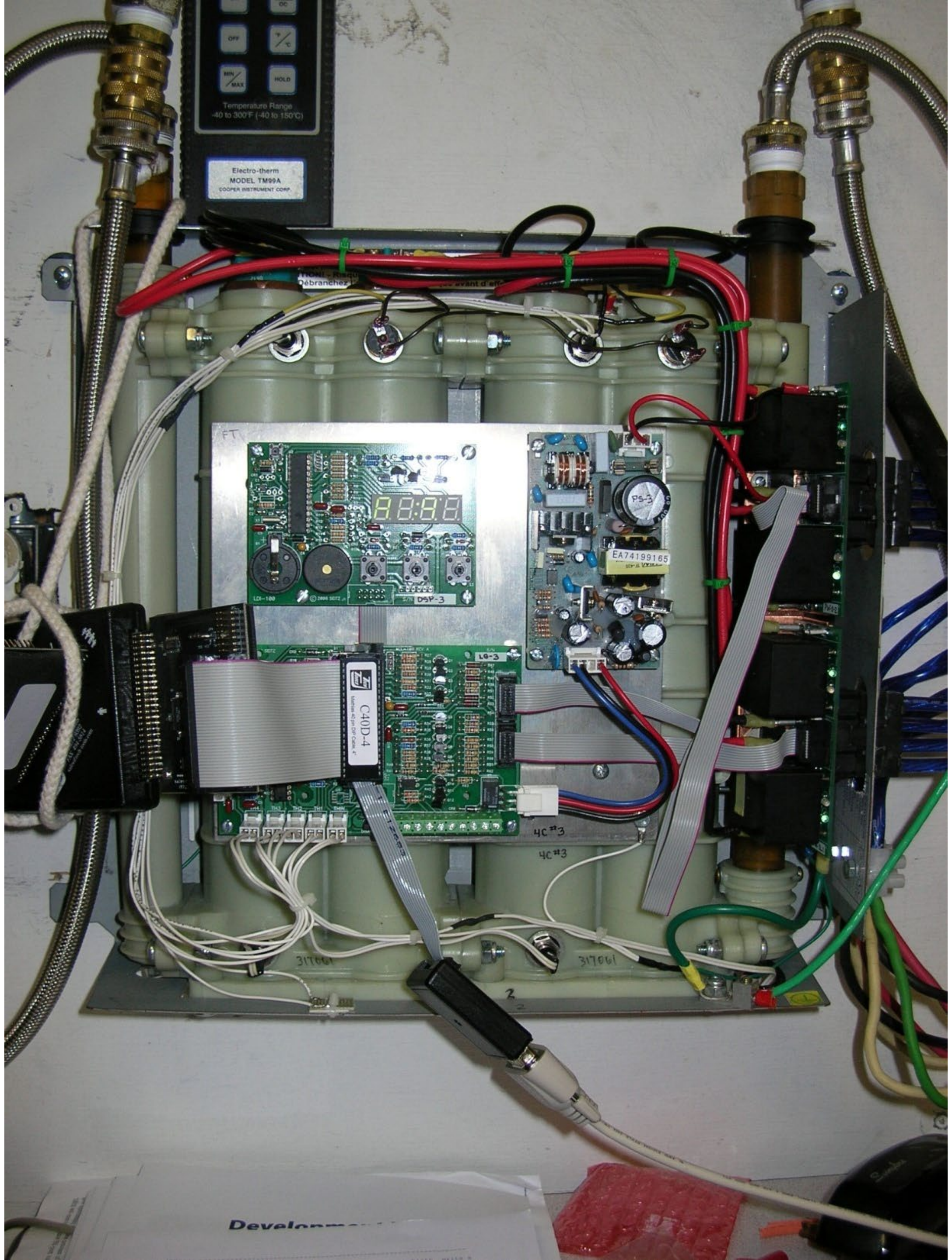


Thermistor IN, Amplifier



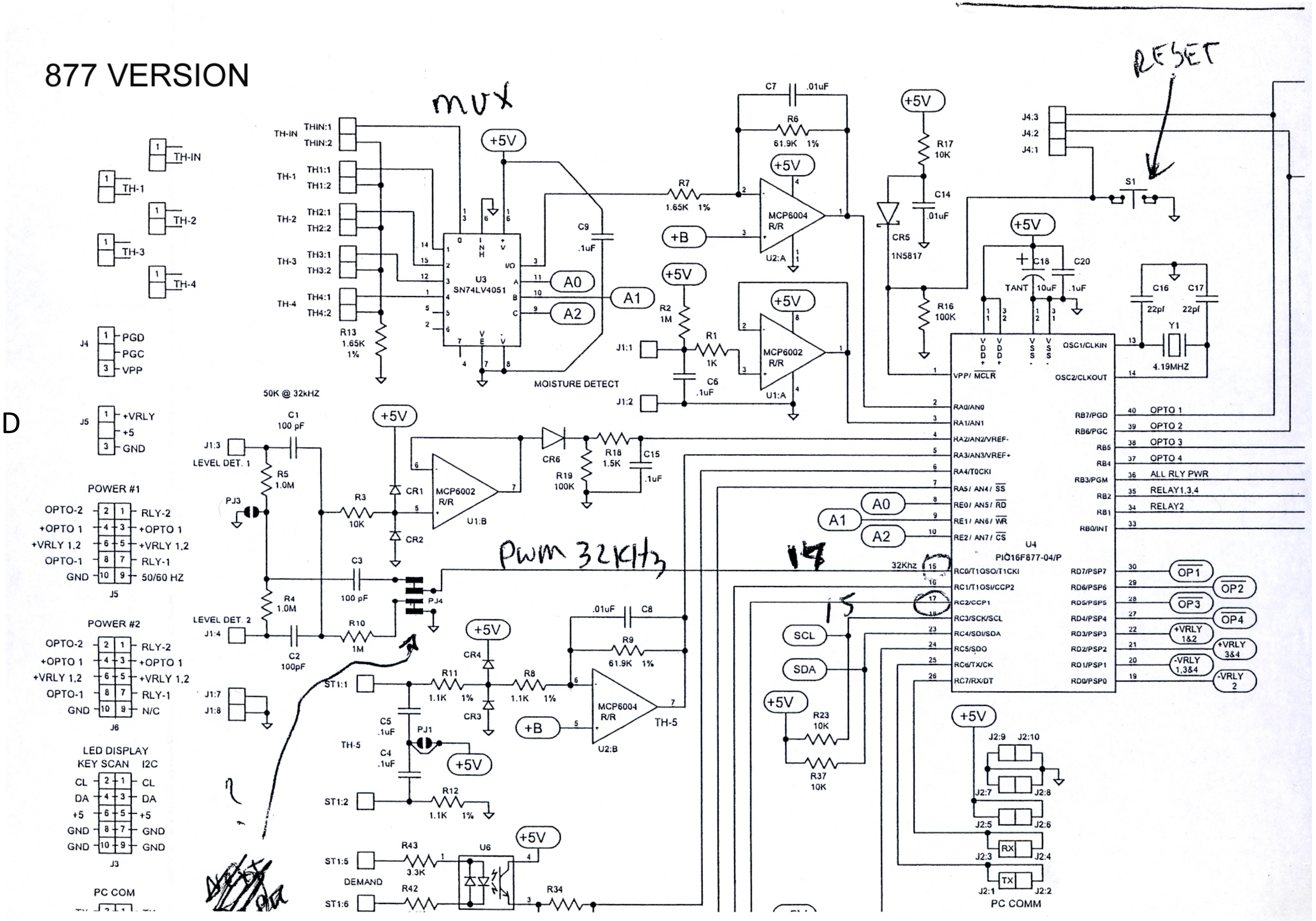

22PF
C17
C18
U8
20
Vdd
9
OSC1/CLKIN
10
OSC2/CLKOUT
1
MCLR~/Vpp
PIC16C63-04/SP
11
RC0/T1OSO/T1CKI
12
RC1/T1OSI/CCP2
13
RC2/CCP1
14
RC3/SCK/SCL
16
RC5/SDO
15
RC4/SDI/SDA
17
RC6/TX/CK
18
RC7/RX/DT
38HZ
TX
RX
+5VDC
Vss1
Vss2
19
8
RA0
2
STROBE
RA1
3
RA2
4
SOUND
RA3
5
CSMMI
RA4/TOCKI
6
ACINH20
RA5/~SS
7
RB0/INT
21
60HZ
RB1
22
RB2
23
RB3
24
RB4
25
RB5
26
RB6
27
RB7
28
Vcc
NU
NC
Vss
8
7
6
5


S/N DSP-3
PS-3
EA74199165
4CL-100 REV. A
C40D-4
Mathias 40 pin DIP Cable 4"


OFF
HOLD
Temperature Range
-40 to 300°F (-40 to 150°C)
Electro-therm
MODEL TM99A
COOPER INSTRUMENT CORP.
PS-3
EA74199165
DSP-3
C40D-4
4C#3
317661

877 VERSION

Mux and A2D Gone



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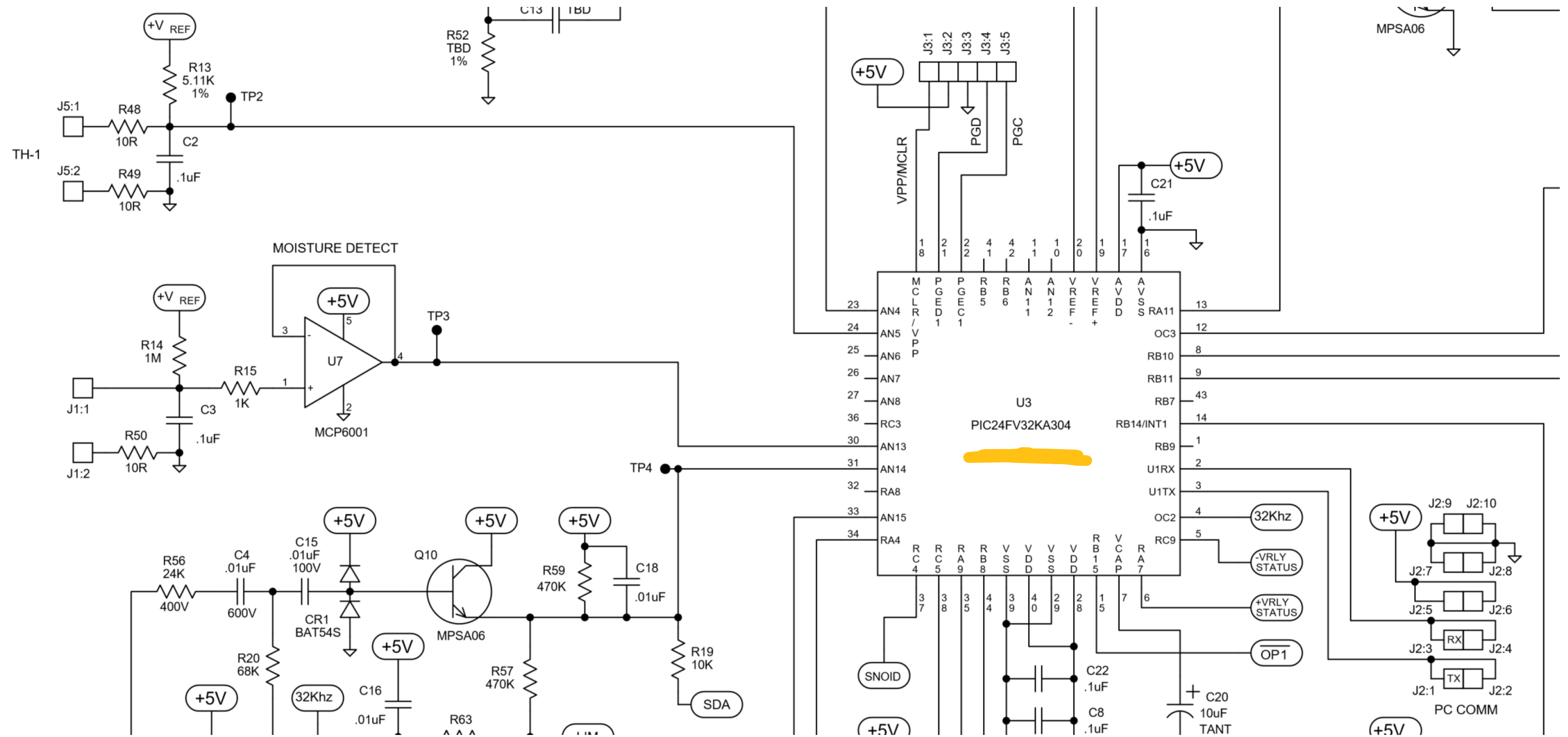

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