

TS-530A TEMPERATURE CONTROLLER Instruction Manual



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PICOWATT
Veromiehentie 14
FI-01510 VANTAA, Finland
phone 358 9 822087
fax 358 9 822184
Internet: www.picowatt.fi



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1. INTRODUCTION

The **TS-530A** is a precision low-power PID temperature controller designed especially for dilution cryostats. Its heating power ranges from nanowatts to about 1 W and it can take input from almost any thermometer giving a positive analog output voltage.

The TS-530A is mainly used together with the **AVS-47B** Resistance Bridge, and then it provides the additional advantage of sharing a common computer interface with the bridge. This not only saves one interface port of your computer, or one GPIB address, but it also simplifies programming, as the thermometer and controller can be handled by the same program routines.

Whereas thermometry below 1K may sometimes be tricky, the TS-530A is quite easy to use and you are likely to do everything right by intuition. If you are using our AVS-47B already, the only thing you have to do is to plug in the interconnection cable(s) and connect the heater.

This manual discusses the general subject of controlling temperature only very briefly, but the functions of the TS-530A are described in detail. Operating principle is explained with the aid of a block diagram. The latter part of this manual is devoted to interfacing the TS-530A with a computer through the AVS-47B resistance bridge.

Your new temperature controller is the latest version of the model TS-530A. It does not differ in performance, but this version is equipped with a universal power supply which can be connected to any common mains voltage in the world without user intervention. Thanks to the new power supply, the TS-530A can be optionally modified for additional -12V..0..+12V battery input.

We now suggest an easier way of scaling the output currents in the case that the heater deviates from the standard 100 ohms. Using parallel and series resistors outside the controller makes it unnecessary to touch the internals of the controller, reducing the risk of damaging the unit by mistake.

Some operations to the instrument require that it be opened. There may be hazardous voltages inside the unit, which one can touch. Therefore, such operations are allowed only for a qualified serviceman: "A person having appropriate technical training and experience necessary to be aware of hazards to which he is exposed in performing a task, and of measures to minimize the danger to him or other persons". It is in our interest to help you get maximum use of this instrument and its performance. Should you have any questions, problems or suggestions, you are welcome to contact us.

2. WARRANTY

Picowatt warrants this product to be free from defects in material and workmanship. Our liability under this warranty is limited to repairing or replacing any instrument or part thereof which, within **three years** after the shipment to the original purchaser, proves defective. This warranty is void if the instrument has not been used according to the instruction manual, or if it has been used under exceptional environmental conditions (see below).

In need of warranty repair, the instrument must be returned to **Picowatt**, by prepaid airfreight, and with a detailed description of the fault or malfunction following the instrument.

The name and e-mail address of a person who is able to give supplementary information should be included whenever possible. **Picowatt** will pay the return shipment of the instrument, if the repair was covered by warranty.

If no fault is found, or if there is a strong indication that the warranty is void, the purchaser is charged for all freight and shipping costs in addition to the repair. Therefore it is recommended that **Picowatt** be contacted prior to shipment, so that we can give instructions for additional tests or simple component replacements and unnecessary shipments may be avoided.

CAUTION: the TS-530A is a delicate laboratory instrument. It has been designed only for the purpose of controlling temperature by means of supplying current to a passive heater resistor. Using this instrument for any other purpose will void the warranty and may cause permanent damage to the instrument.

The TS-530A has been designed to operate in a laboratory environment, which means normal living room atmosphere, temperature, humidity and purity of air. The unit does not tolerate continuous vibration or hard shocks.



3. SPECIFICATIONS

SET POINT Range from +1mV to +4.2000V. Resolution 100 μ V, risetime 1s.

INPUT SIGNAL Analog output from any thermometer. Input range 0...+4.2V. Both positive and negative dV/dT is acceptable. Input current less than 1 μ A.

ERROR AMPLIFIER Switched-capacitor amplifier has proportional gains from 5 dB to 60 dB in 5 dB steps. Bandwidth (-3 dB) is 10 Hz.

ERROR METER Centered analog meter with highest sensitivity around zero and reduced sensitivity at the ends of the scale.

INTEGRATOR Analog integrator with time constants 2, 5, 10, 20, 50, 100, 200, 500 and 1000s. A reset position is provided for PD control mode, and a latch position for temporary storage of accumulated charge.

DERIVATOR Modified derivator has dominant time constants 0, 1, 2, 5, 10, 20, 50 and 100s. Derivator has a 20 dB/dec roll-off for frequencies above 10 Hz.

POWER BIAS A constant amount of power can be applied to the heater. Possible values are 0, 20, 40, 60, 80 and 100% of the maximum power of the selected output range.

POWER AMPLIFIER Linear current source with low ripple and noise. Maximum output power is $(0.1A)^2 \cdot R_H$ or $(9V)^2 / R_H$, whichever is less.

Nominal power ranges from 1 μ W to 1W are obtained with a 100 Ω heater. Other heater values can also be used, and it is possible to re-scale the output currents so that the power ranges will be exact powers of ten.

The heater output power of the TS-530A is a linear function of the error signal. Therefore the gain of the system remains constant regardless of power level.

POWER METER Analog meter indicates either true dissipated power ($I_H \cdot V_H$), or percentage of maximum current of the range.

4. CONTROLS AND FUNCTIONS

SET POINT This 5 digit code switch is used to determine the manual set point voltage, which is compared with the analog input voltage, as applied to the rear panel input connector. One step corresponds to 100 μ V, and the maximum setting is 4.2000 V. Lowest useful setting for the code switch is 00010.

ENTER BUTTON The code switch can be dialled safely without danger of unwanted jumps in output power. The new setting does not become current until the ENTER switch is pressed. The ENTER LAMP indicates whether the current set point was last entered from the code switch or through the computer interface.

dR/dT SWITCH This switch is one of those three functions that are only manually accessible. Use it to change the polarity of the control loop to be suitable either for sensors with positive temperature coefficient, like Pt or RhFe, or negative, like Ge and carbon. Note that in any case, the output from your thermometer must be a positive voltage.

ERROR SHORT SWITCH The internal control error signal can be forced to zero. Then the heater output will depend only on the bias power setting and charge stored in the integrator, and this charge is changing only very slowly, as there is no error voltage to integrate. This switch allows you to make temporary arrangements at the controller input while retaining the present level of heater power. Error can be shorted also remotely.

GAIN Proportional gain is provided by the error amplifier. At full 60 dB gain, a 5 mV error voltage will produce the maximum output of the selected power range. Proportional gain is a common factor also to the integrator and derivator circuits. This makes the integrator and derivator time constants independent of gain.

INTEGRATOR Integrator time constant can be selected from 9 logarithmically spaced discrete values 2...1000 seconds. The integrator can be reset at both ends of the scale for convenience. An infinite (= very long) time constant allows the integrator to be latched so that it retains its contents even though error voltage is nonzero. The analog integrator will, however, drift slowly either up or down, and therefore infinite position should be used only for a short time.



DERIVATOR Derivator provides additional, frequency dependent forward gain with +90 degrees phase shift, and it is used to reduce overshoot or speed up step response. This gain will also amplify system noise. With $T_D = 100$ s the maximum gain magnitude of 100 (40 dB) will occur at 1 Hz frequency. Do not use a long derivator time constant and a high proportional gain at the same time, as this will make the heater output noisy and unstable. In zero position the derivator is turned off.

POWER BIAS Power bias switch allows the user to apply a constant amount of heating power. This power, indicated as percentage of the maximum power of the selected range, is independent of proportional gain. Power bias is especially useful in PD control mode, where a properly set bias can greatly reduce control error. Five evenly spaced power levels are provided.

POWER RANGE Power range indicates the nominal maximum power that is available on that selected range with standard current sense resistors and a 100Ω heater. For any other heater value, following rules apply:

TS-530A can deliver a maximum heater current of 100 mA on highest range, 30 mA on the lower, then 10 mA etc. For heater values less than 100Ω, the **available current** determines the maximum power.

Maximum output voltage is slightly over 9 V. for heater values greater than 100Ω, it is this **voltage** that limits maximum power on the highest range to a value of $(9V)^2/R_H$.

On zero range, there will be a small current, depending on error signal, flowing to sensor. This should stay below 10 μA. If you have a high-resistance heater, this may still cause some heating. Then use the OUTPUT SHORT switch.

When the zero power range and current display mode are selected, the output meter shows how much current, as percentage of the full range current, would flow to heater on any range other than zero.

OUTPUT SHORT The output short switch provides a rapid shutdown of heater output without need to switch the power range all the way down. Further, the output leakage is much lower when this switch is used.

ERROR METER The error meter indicates the magnitude of the error voltage, amplified by proportional gain. The meter has a nonlinear response, so that its sensitivity is highest in the middle, and lower at both ends of the scale. The purpose of this arrangement is to make trends visible also when the error is large while permitting high resolution near to balance.

Deflection from center to the first division corresponds to about 0.2 V at the amplifier *output*, and full deflection to about 5 V.

POWER METER

METER SWITCH The power meter has two display modes that are selected by the METER switch. In power mode, the meter indicates true power dissipated in the sensor ($V_H * I_H$). Heater resistance does not affect calibration of the meter. Full deflection corresponds to maximum power of the selected power range. In current mode, full deflection occurs at the maximum output current of the selected range.

Power mode is usually more readable, as it has a linear scale. 10% of maximum current heats by 1% of maximum power, which is easily forgotten when looking at a meter that shows the current only. However, you will find current mode more useful, if your heater resistance is something very different from 100Ω.

Selecting the “current” display mode and zero power range, you can verify the heater output level in advance, before activating the output.

MAINS SWITCH When power is turned on, gain will have its lowest value, integrator and derivator are reset, and power bias and output range are at zero. Set point may be random, and must be entered using the ENTER switch .

INPUT CONNECTOR A BNC connector, jacket grounded. (Analog cables made for the TS-530 are not suitable for the TS-530A).

DATA INTERFACE CONNECTOR The TS-530A can be interfaced with a computer through the AVS-47B Resistance Bridge. For that purpose, a 37-way ribbon cable must be connected from the data connector to the programming output connector of the AVS-47B. This connector also provides access to the DAC output and other

monitor output voltages. Refer to Appendix E for pin assignments.

HEATER OUTPUT Two connector types are provided for the heater. If the heater wires come up from the cryostat as one coaxial cable, you can use the rear panel BNC connector.

In case of two coaxial cables, connect the low end of the heater to the TS-530A ground by using the black banana terminal.

Please note that the

BNC JACKET IS CONNECTED BOTH TO THE TS-530A ENCLOSURE AND TO THE CIRCUIT GROUND.

This arrangement is necessary in order to protect the output stage against electrostatic discharges.

Heater output is also available at the two banana terminals. Connect the black terminal to the shield of the heater cable, if a shield exists.

Only one BNC connector is used in the TS-530A in order to remind, that the minus-pole of the heater output is firmly grounded to the enclosure of the instrument. In the old TS-530, the enclosure was isolated from the circuit ground, a fact that resulted in high sensitivity to ESD.

MAINS INPUT The TS-530A should be connected to a grounded mains outlet for electrical safety. Mains ground is internally connected to the metal case of the instrument and to the circuit ground. Mains input is filtered against conducted EMI. The universal power supply accepts input voltages between 90 and 250V, 50-60Hz.

PRIMARY FUSE The primary fuse rating is:
1 A-T (slow action)
Fuse size is 5x20 mm.

5. PRINCIPLE OF OPERATION

The operating principle of the TS-530A is briefly described with the aid of a simplified block diagram.

Analog output from a thermometer and a set point voltage from the internal set voltage source are applied to the controller input. Error signal is formed by a switched capacitor amplifier, which also provides the proportional gain.

The amplified error signal is fed to a summing amplifier as such, but it is also fed to the integrator and derivator sections. The integrator is an analog, low-drift circuit, whose time constant (it is actually gain rather than a time constant) is varied by adjusting voltage division of R1 and R2, and the input resistor R3.

The derivator has been modified from the basic, pure derivator circuit, in order to reduce its sensitivity to noise and to stabilize its gain. Derivator time constant is varied by changing R4 and R7 simultaneously. R4 is used to determine the time constant, but because it also affects the pass-band gain of the derivator, a gain compensation is done by making $R5/R4 = R6/R7$.

Signals from the error amplifier, integrator and derivator, plus a selectable constant voltage (bias power) from a voltage divider, are all applied to the summing amplifier with equal weights. This PID output voltage is a linear function of the error voltage. If this voltage was used to drive the heater output, then the heating power and therefore also the change in temperature, would no longer depend in a linear but quadratic way on the input ($P=I^2 \cdot R$). To prevent this, and to make the overall system as linear as possible, a square root is taken of the PID output before driving the power stage.

The power amplifier is a linear series-pass transconductance amplifier, whose output is a current proportional to the input. Although more complicated, current output has been used rather than a voltage output because it is inherently short-circuit protected and can be used with any heater resistance value. The output range is selected by changing R_s .

The level of the heater current is shown by the output meter. For convenience, this meter has also a power display mode, which shows the true dissipated power as calculated from $V_H \cdot I_H$. Calculation is made by a pulse height-width circuit that produces a continuous pulse train, so that pulse height is proportional to heater voltage and pulse width is proportional to heater current.

The manual set point information is obtained from a 5-decade front panel code switch . This is in BCD format which is not suitable for the digital-to- analog converter . Therefore it is first converted to a binary number.

Set point can also be given remotely, from the computer interface that is installed in the AVS-47B Resistance Bridge. An internal serial format is used for this purpose. The serial data is stored in a shift register, from which it is immediately transferred to the set point memory. But whenever the front panel “ENTER” switch is pressed, the contents of the set point memory is replaced by data from the front panel code switch.

The low-speed digital-to-analog converter is of proprietary integrating type. Its conversion cycle consists of four phases. During phase 1, the integrator integrates an adjustable input voltage for a length of time that corresponds to the set point data. After that, the integrator is stopped and its voltage is transferred to a sampling low-pass filter. Time used for this second phase is constant. During the third, or calibration phase, integration is continued for a third period of time, which depends on the set point data. The final integration result is compared with a calibration reference voltage and depending on the comparison result, the integrator input is either increased or decreased until it has an exactly correct value.

Note that zero is a forbidden value for the set point - the integrator must be allowed to integrate for at least one clock -cycle (but preferably at least ten cycles).

6. INSTALLATION

MAINS VOLTAGE

IN ORDER TO MAINTAIN ELECTRICAL SAFETY, THE TS-530A MUST BE CONNECTED TO A GROUNDED MAINS OUTLET.

TS-530A units with serial number greater than 230 have a universal power supply which accepts input voltages from 90V to 250V and line frequencies from 50 to 60Hz. No user action is required with these units (older controllers have conventional power supplies, and voltage selection may be needed with them. Use their own manuals for this purpose).

INPUT Analog input is connected to a rear panel BNC socket. A coaxial cable for connecting the TS-530A to the AVS-47B Resistance Bridge is supplied with the controller. If another cable is used, its length should not exceed 50 cm.

The input should be taken from a low-impedance source, preferably less than 100Ω . The input current of the error amplifier will reduce accuracy if the source impedance is not low.

HEATER The heater should be floating in order to avoid any feedback from the controller output to either controller or thermometer input, which can occur if the heater current is allowed to flow via a ground path that is common with the input.

Two types of output connectors are provided, BNC and banana sockets. The jacket of the BNC socket is connected to the enclosure and the circuit ground. Also, the black banana socket represents both the circuit and safety ground. Regardless of which connector type you use, the cable shield must be connected to the TS-530A enclosure for good protection against EMI and electrostatic discharges.

The nominal output power ranges from $1\mu\text{W}$ to 1W are obtained when the heater resistance is 100Ω .

If $R_H < 100\Omega$ then it is equation $P = I_{\text{max}}^2 * R_H$ that indicates the maximum attainable power on each output range. I_{max} , in turn is calculated as follows:

$$I_{\text{max}} = 1V/R_s \quad (R_s = 10k, 3k16, 1k, 316\Omega, 100\Omega, 31.6\Omega \text{ or } 10\Omega \text{ for ranges } 10\mu\text{W}..1\text{W})$$

If $R_H > 100\Omega$ then power is limited by the maximum compliance voltage of the output. The TS-530A cannot supply more power than about $(9.5V)^2/R_H$ regardless of the range. Assume, for example, that the heater resistance is 500Ω . Heater current would be $1V/10\Omega=0.1\text{A}$ on the highest and $1V/31.6\Omega=31.6\text{mA}$ on the second highest range. These currents would rise the heater voltage up to 50 and 15 Volts, respectively, which are, of course, impossible. Therefore, $(9.5V)^2/500\Omega=0.18\text{W}$ is the maximum power on these ranges.

CONTROL POLARITY The TS-530A can be used with sensors having either a positive temperature coefficient (like Platinum and Rhodium-Iron sensors) or a negative coefficient (like Germanium and Carbon resistors, and Silicon diodes). Depending on which type of sensor is being connected, set the front panel dR/dT switch in corresponding position.

It is not necessary to remember the polarity of the sensor when looking at the error meter. A positive deflection means always that more power is needed to reach balance and that the integrator (if active) is working to increase output power.

7. RE-SCALING THE OUTPUT CURRENTS

7.1. WHY TO RE-SCALE

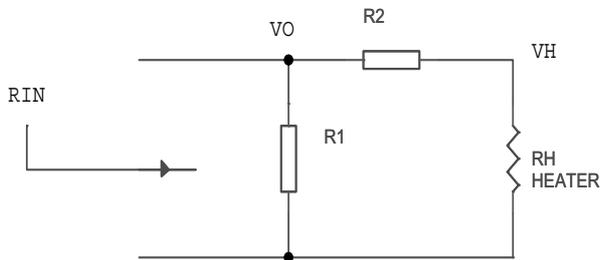
Re-scaling the output current may be desirable if the heater resistance is something else than the standard 100Ω , for which the full deflection of the power meter is calibrated. Alternatively, you may want to replace the standard set of power ranges from $1\mu\text{W}$ to 1W by a new set of ranges, say, from $0.1\mu\text{W}$ to 0.1W .

The following procedure replaces the method that was suggested in earlier TS-530A manuals. The old method required changing the current sense resistors inside the controller. Those resistors were unfortunately not very easily accessible and changing them was therefore an "academic" possibility.

We suggest, that the heater is made a part of a resistive network. Two room-temperature resistors are needed for scaling both the output power and the input impedance of the network. The TS-530A sees this impedance as the heater's resistance. If it sees 100Ω , the power meter behaves as it should: it shows full deflection when the output reaches 100% of the selected power range. The only difference is that all ranges must be thought as having been divided by the power scaling factor, which can be a convenient 10 for heaters between 10 and 1000Ω .

Instead of modifying the TS-530A, build the scaling network outside of the instrument. Small shielded component container boxes are with female and male BNC connectors are available e.g. from Farnell (manufactured by Pomona or Suhner).

7.2. CALCULATING THE SCALING RESISTORS



We need or use the following data:

- VO = maximum output compliance voltage of the TS-530A. Assume 10 volts.
 - VH = maximum voltage across the heater (will be calculated below)
 - PH = maximum heating power at full output (usually 0.1W)
 - RH = the resistance of your heater in the cryostat
 - RIN = heater resistance that the TS-530A sees (if it sees 100 ohms, the power meter works properly)
- All resistor values are in ohms.

The heating power is

$$PH = VH^2 / RH \text{ so that } VH = \sqrt{PH * RH}$$

On the other hand

$$VH = VO * RH / (RH + R2)$$

so that

$$1) \quad R2 = RH * (VO - \sqrt{PH * RH}) / \sqrt{PH * RH}$$

R1 must have such a value that makes the parallel connection of R1 and (R2+RH) equal to 100Ω ohms.

$$2) \quad R1 = 100 * (R2 + RH) / (R1 + R2 - 100)$$

Verify that

$$3) \quad RIN = R1 * (R2 + RH) / (R1 + R2 + RH) = 100$$

Note that PH=1W is possible only if RH=100Ω and R2=0, R1= infinite. In practice, use PH=0.1W. This value

can be used for scaling heater resistances between 10 and 1000Ω.

EXAMPLE:

RH = 250Ω and the maximum possible heating power of PH = 0.1W is suitable.

$$1) \Rightarrow R2 = 250\Omega$$

$$2) \Rightarrow R1 = 125\Omega$$

$$3) \Rightarrow RIN = 100\Omega$$

If you must build the resistors using parallel and series connections of values that are available, it is waste of effort to try to get an accuracy better than 1%. Similarly, if calculation suggests a value of greater than 10 kilo-ohms for R1, you can safely omit it for simplicity.

7.3. TUNING THE SYSTEM RESPONSE

Because in a low temperature system, thermal properties like heat capacitance and thermal conductivity may change drastically with temperature, it may be reasonable to use just a fast and simple way to find some working controller settings and to repeat this at various temperatures.

For example, following method can be tried. Select an output power range, which is assumed to provide sufficient control power. Using the TS-530A as a proportional controller, with no integrator and no derivation, increase gain until there is some 10 to 20% overshoot. Then add derivation, step by step, by increasing TD. This usually reduces overshoot, and it is often possible to get a quite satisfactory step response.

The function of the derivator is to provide additional frequency dependent gain. Input to the derivator is taken from error amplifier output, and therefore this gain can have an opposite effect on output than the proportional gain, which is the useful feature. If properly set, derivator allows one to use a higher proportional gain to make system faster and more accurate while keeping overshoot within acceptable limits. Unfortunately, a proportional-differential controller, while simple to tune, is not sufficiently accurate for many applications.

Because the DC-gain in the PD-mode is finite, and it cannot be further increased without making the system unstable, there will be a certain amount of control error between the desired set point and the temperature that the system actually reaches. This control error can be minimized, while still using PD mode, once the approximate heater power for this temperature is known. Use the POWER BIAS feature to apply a constant power to the heater, which is near to **but less** than the required control power. The correction that the PD circuit now has to make is much smaller and so will also be the control error.

It is not always possible to set the bias power and check frequently if it should be changed. Then the integrator can be switched on to cancel the **steady-state control error**. Integrator accumulates the existing error voltage, as long as there is any, and increases or decreases the heater power by an amount proportional to the accumulated charge. Ideally, the system will slew with exponential decay towards the set point and finally stay there, within some limits due to noise and integrator input errors.

Problem with the integrator is that it impairs the system stability, and very easily causes unacceptable overshoot. It is usually overshoot, not oscillation, that determines how short TI one can use. Try to make the integrator time constant shorter (this increases the integrating action), until overshoot is some 10%. Then verify that there is enough damping, i.e. system approaches steady state without prolonged oscillations. If damping is too low, reduce proportional gain slightly. Usually the result is not so awfully far from optimum.

The TS-530A integrator has been designed so that it is possible to change TI during control. Step response can be improved by first selecting a long TI to prevent unnecessary integration of error when it is large, and restoring final TI when the PD controller has done what it can. This is especially useful in applications involving a computer, where the above sequence can be easily automated.

NOTE: The derivator can provide a maximum of 40dB gain at 1Hz frequency. A combination of 60dB proportional gain and 100s derivator time constant will amplify noise coming with signal and set point voltage as well as from the error amplifier itself by a factor of 10^5 . Heater output will be noisy and control accuracy worse than with a shorter TI.

8. RECALIBRATION

8.1. WHY AND WHEN

The TS-530A and the AVS-47B are analog instruments, that can suffer from both zero offsets and scaling errors. The AVS-47B has a typical offset of 100-300 microvolts (equal to 1-3 display digits) between the front panel display and the analog output voltage. Usually the analog voltage is higher, but individual bridges differ due to component tolerances. The set point of the TS-530A can have both zero offset and scaling error, whereas the offset of the proportional amplifier is negligible. Because of these error sources, the two instruments can be slightly differently calibrated with the result, that the temperature control system does not settle exactly to the desired set point. This difference can change with time. It is, however, possible to calibrate the TS-530A very easily to conform to the calibration of the resistance bridge. Such a “relative calibration” works only with that individual bridge and therefore all new controllers use “absolute calibration” when they are shipped to customers.

Absolute calibration : All new units are calibrated against an external precision voltmeter, which means that the offset of the set point is adjusted to zero and the scale factor is adjusted to 1 (this means that set point data of 10000 produces an analog set point voltage of exactly 1.00000 Volts. This method is inferior to relative calibration, but it is used for new instruments, because it does not assume anything about the future use of the TS-530A.

Relative calibration : Both instruments are connected together with the analog input cable and the flat data cable. The AVS-47B is first switched to measure the calibration resistance on the 200 k Ω range, the offset of the set point is nulled. Then the bridge is switched to 200 Ω range and the scale factor of the set point is adjusted.

We **recommend**, that you check the system using the relative calibration method before important experiments, and recalibrate if necessary. Need for recalibration is also evident, if the steady-state readings of the bridge seem to be mainly higher or lower than the set point. If the resistance bridge and the TS-530A are of different ages, relative calibration is likely to be useful.

BOTH THE ABSOLUTE AND RELATIVE CALIBRATION, AS WILL BE EXPLAINED BELOW, REQUIRE OPENING THE TS-530A AND THEREFORE THESE OPERATIONS ARE ALLOWED ONLY FOR A QUALIFIED SERVICEMAN.

8.2. RELATIVE CALIBRATION

No external instruments are needed for calibrating the TS-530A for use with the AVS-47B Resistance Bridge.

Place the TS-530A on the top of the AVS-47B and open the top cover of the controller. Connect the two instruments together with the coaxial cable supplied with the controller (always use the ANALOG output of the AVS-47B, not DEVIATION). If the system is to be operated remotely, plug in also the data interconnection cable (this may change calibration slightly as it provides an additional ground path). Switch the bridge input to **CAL**, the range to **200k Ω** , the excitation to 3mV, and the TS-530A set point code switch to 10 and press <ENTER>. Let the system warm up for at least half an hour in its normal ambient temperature.

Adjust the OFFSET trimmer of the AVS-47B, if necessary, so that the display reads 000.10 (= 0.1 k Ω , there should be no need to do this if the bridge was recently self-calibrated). Switch then the TS-530A for 60dB proportional gain. If the ERROR meter is not exactly centered, use trimmer R419 (board TS530D*, the leftmost board) to null the error signal. The smallest division of the meter corresponds roughly to two display units of the AVS-47B (60dB gain).

Change the measuring range of the AVS-47B to **200 Ω** . Dial the TS-530A code switch to 10000 and press <ENTER>. The bridge should read 100.00 (if it does not, use the front panel SCALE trimmer for adjusting the display to 100.00). Use R410 (near to R419) for centering the ERROR meter again.

Now you have checked the self-calibration of the AVS-47B, and you have adjusted the TS-530A for the best set point accuracy of the control system.

9. COMPUTER CONTROL OF THE TS-530A

9.1. CONNECTING THE TS-530A AND AVS-47B TOGETHER

It is possible to control the TS-530A remotely through the AVS-47B resistance bridge, using either its primary interface alone, or the AVS47-IB two-stage GPIB interface option. For computer control, these two instruments must be connected together with a 37-way ribbon cable, which is supplied with the TS-530A.

If you need to monitor the internal signals of the TS-530A, then the default ribbon cable is not suitable, and you have to make a cable according to drawing 530conn.sch (APPENDIX E). A shielded 3 or 4 wire cable with the shield carrying digital ground is adequate. Keep the cable as short as possible, only a few tens of centimeters.

NOTE: This manual no longer describes use of the abandoned AVS12, DC900 nor AVS46-IB interfaces. If your bridge has been equipped with any of them, please contact Picowatt for getting old manuals.

9.2. INITIAL STATE AFTER POWER-ON

Regardless of whether the computer interface is connected or not, the initial state of the TS-530A after turn-on is such that all parameters are in their lowest states. Set point value may be random until the <ENTER> button is pressed. The instrument can be used manually as already described in this manual even when the computer interface is connected.

Note particularly that the integrator capacitor is reset and the integrator will start from zero as soon as it is enabled.

9.3. INITIAL STATE AFTER RESET COMMAND

LabView:

All parameters must be reset separately by setting them to 0 or to some other desired value. Users of LabView can do this with the aid of the TS530Cfg.vi virtual instrument that is downloadable from our WEB site.

AVS47-IB:

The TS-530A can be set to the reset state by commands

*RST
PONRST

These commands bring both the AVS-47B and the TS-530A to their initial power-on states. PONRST has the additional feature that it erases all scan parameters etc., except the RAM buffer of the AVS47-IB.

9.4. LABVIEW AND DIRECT PC INTERFACE

Direct PC Interface makes use of the computer's COMx: port. This alternative is supported only for PC:s that have a free standard serial communications port and run LabView 7.0 or higher. The TS-530A is programmed via the AVS-47B, which in turn is connected to the PC via the Picobus cable. Direct interfacing is described in an application note that is downloadable from our WEB site. Only one LabView Virtual Instrument, TS530Cfg.vi. is required for programming the TS-530A. This VI accepts the following input parameters:

SET POINT: The set point range is from 1mV to 4.2V. VI input is an integer from 10 to 42000. One digit means 100 microvolts.

PROPORTIONAL GAIN: VI input is an integer from 0 to 11, corresponding to approximate gains from 5dB to 60dB in 5dB steps.

INTEGRATOR "TIME CONSTANT" :

VI input is an integer from 0 to 15:

0: P or PD control modes. Integrator stays at zero.

1-9: Time constant 2, 5, 10, 20, 50, 100, 200, 500 or 1000 seconds

10: Latched: Integrator is disconnected from the error signal and retains its last value (some drift may take place). This mode can be used temporarily after a large change in set point in order to reduce overshoot.

11: P or PD control modes. Integrator stays at zero.

15: Shorted: The **error signal** is nulled. The output power does not change, if error signal is shorted to ground when the system is in steady state. In a steady state, both the proportional and derivative terms are zero and the output power is determined by the integrator alone. The effect of this mode is to feed the last known good power to the heater. Sooner or later this power will turn out too low or too high for maintaining the desired temperature, and therefore this mode is to be used only temporarily. Typical use of this mode is to allow quick measurement of other temperature



sensors with the AVS-47B (see also Simultaneous Thermometry and Control).

DERIVATOR GAIN: VI input is an integer from 0 to 7 corresponding to derivator time constants 0s (no derivation), 1s, 2s, 5s, 10s, 20s, 50s and 100s.

POWER BIAS: VI input is an integer from 0 to 5 corresponding to power bias of 0, 20, 40, 60, 80 or 100 percents of selected heater range's full output.

HEATER POWER RANGE: VI input is an integer from 0 to 7:
0: Heater is off
1-7: Power ranges 1, 10, 100uW, 1, 10, 100mW and 1W. Ranges are for a 100 ohm heater.

9.5. COMMAND REFERENCE FOR THE AVS47-IB

Command separator: ; (semicolon).
Command terminator is marked by <CT> in the following.
It means

- ASCII 10 decimal (<LF> =linefeed, <NL>=newline), or
- ^END = end-of-identify (physically one of the 24 GPIB signal leads), or
- both together

NOTE: All numeric parameters are shown in decimal format.

These are commands only - no queries

SPT[1..42000]<CT> set point. unit=100μV

PRO[0..15]<CT> proportional gain (0=5dB, 11=60dB, 15=error short)

ITC[0..11]<CT> integrator time constant (0,11=reset, 10=hold)

DTC[0..7]<CT> derivator time constant

BIA[0..5]<CT> power bias. unit 20% of full range

POW[0..7]<CT> power range

The following items can be read by giving first the command and issuing the query after two or three seconds.

SPV<CT>, SPV?<CT> Measure Set Point Voltage Command, Set Point Voltage query.

HTV<CT>, HTV?<CT> Measure Heater Output Voltage Command, Heater Output Voltage query.

HTI<CT>, HTI?<CT> Measure Heater Output Current Command, Heater Output Current query.

HTP<CT>, HTP?<CT> Measure Heater Output Power Command, Heater Output Power query.

The command initiates the necessary measurements of analog voltages, which takes some time because of the slow A/D converter. The result is read to computer by the query, which works fast.

9.6. SET POINT

Set point command is

SPTn , n= [1..42000]

In decimal notation the set point ranges from 1 to 42000 times 100μV. This command overrides any previously given manual set point. A front panel LED indicator shows whether the manual or remote set point is currently being used by the TS-530A. Do not use n values lower than 10.

NOTE: The TS-530A does not provide means for reading the remote set point value back to the computer. If your computer program is such that set point can be given directly from keyboard, you must take care of storing the current value. For the same reason, the computer cannot find out if the ENTER button has been pressed and manual set point activated. Do not mix manual and remote operation unless you know what you are doing.

You can read the analog set point voltage via the AVS-47B, however, this voltage may differ slightly from the digital set point number.



9.7. PROPORTIONAL GAIN

Twelve logarithmically spaced gain values are available. Use the command

PROn

The parameter n is selected as follows

n	decibels	gain
15	-	0; error forced to zero
14	60	1000
10	55	560
9	50	316
8	45	180
7	40	100
6	35	56
5	30	31
4	25	18
3	20	10
2	15	6
1	10	3
0	5	1.8

9.8. INTEGRATOR TIME CONSTANT

Nine logarithmically spaced integrator time constant values are available. In addition, the integrator can be latched (hold-state) to retain the accumulated charge, and it can be reset at both ends of the parameter range.

ITCn

parameter n is selected as follows:

n	TI
11	reset (PD -mode)
10	hold (TI = ∞)
9	1000 s
8	500 s
7	200 s
6	100 s
5	50 s
4	20 s
3	10 s
2	5 s
1	2 s
0	RESET (PD -MODE)

9.9. DERIVATOR TIME CONSTANT

Seven derivator time constant values are available, and can be selected by command

DTCn

n	TD
7	100 s
6	50 s
5	20 s
4	10 s
3	5 s
2	2 s
1	1 s
0	no derivation

9.10. POWER BIAS

There are five evenly spaced discrete bias power levels that can be selected by command

BIA n

n	BIAS POWER
5	100% of full range output power
4	80%
3	60%
2	40%
1	20%
0	0

NOTE: Because the TS-530A has been linearized in terms of output power, changing bias power by one step will always increase or decrease heating power by an equal amount regardless of the present heater current level.



9.11. POWER RANGE

The TS-530A has seven remotely selectable output power ranges with one decade steps in power. In addition, the output can be remotely disabled by selecting a zero range (default state after power-on and the *RST and PONRST commands).

POW _n	
n	POWER RANGE
7	1W
6	100mW
5	10mW
4	1mW
3	100μW
2	10μW
1	1μW
0	output disabled

NOTE 1: The above power values apply for a TS-530A in standard configuration and with a heater resistance of 100Ω.

NOTE 2: The actual maximum heating power into a 100Ω load may be little less than 1W, depending on component spread.

10. SIMULTANEOUS THERMOMETRY AND CONTROL

The AVS47-IB Computer Interface makes it possible to use a system consisting of one AVS-47B and one TS-530A for both thermometry and temperature control.

The idea here is to control the temperature in the usual way for some time, then disable the control by latching the integrator and nulling the error signal. There is no active control now, but the heater is heated by a constant power, which is determined solely by the charge accumulated in the integrator. If the system was initially in balance, its temperature will remain quite (but not perfectly!) stable for a limited time.

Once the integrator has been disabled, there is some time available for switching the AVS-47B to measure other sensors. After having done this, the control is enabled again.

The actual procedure is rather complicated, and it is described in the AVS47-IB manual in detail. This feature is not available in the set of LabView virtual instruments.

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APPENDICES

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B: DATA CONNECTOR PIN ASSIGNMENTS

C: LAYOUT DRAWINGS AND CIRCUIT SCHEMATICS

DECLARATION OF CONFORMITY

Manufacturer's name: RV-Elektronikka Oy Picowatt

Manufacturer's address: Veromiehentie 14
FIN-01510 VANTAA
Finland

declares that

Product Name: Model TS-530A
Temperature Controller

with options: no options

conforms to the following Product Specifications:

EN 50 081-1: Generic emission standard, Part 1: Residential, commercial and light industry.

EN 50 082-1: Generic immunity standard, Part 1: Residential, commercial and light industry.

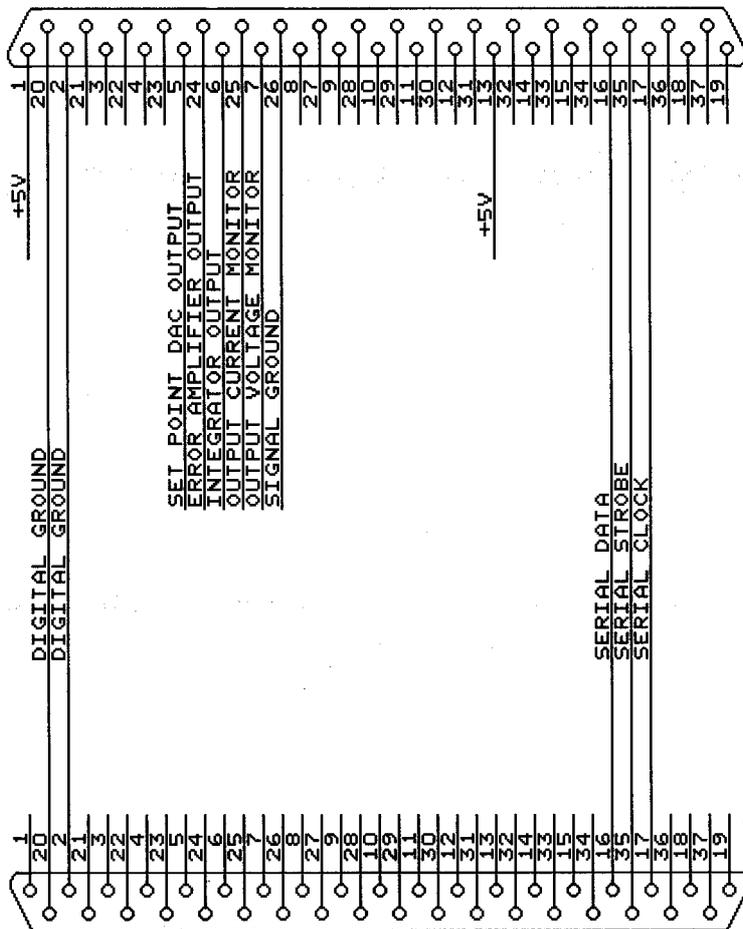
EN 61 010-1: Safety requirements for electrical equipment for measurement, control and laboratory use.

Additional information: The intended use of this product is controlling temperature using a resistance bridge as the thermometer at very low temperatures, where the resistive sensor must be measured using ultralow excitation current. Therefore, immunity against radiated RF fields has been deemed irrelevant, and conformity to EN50081-1 in this respect has not been verified.

Vantaa, February 1, 1997

RV-Elektronikka Oy Picowatt


Reijo Voutilainen
President



AVS-47

PROGRAMMING OUTLET

TS-530A

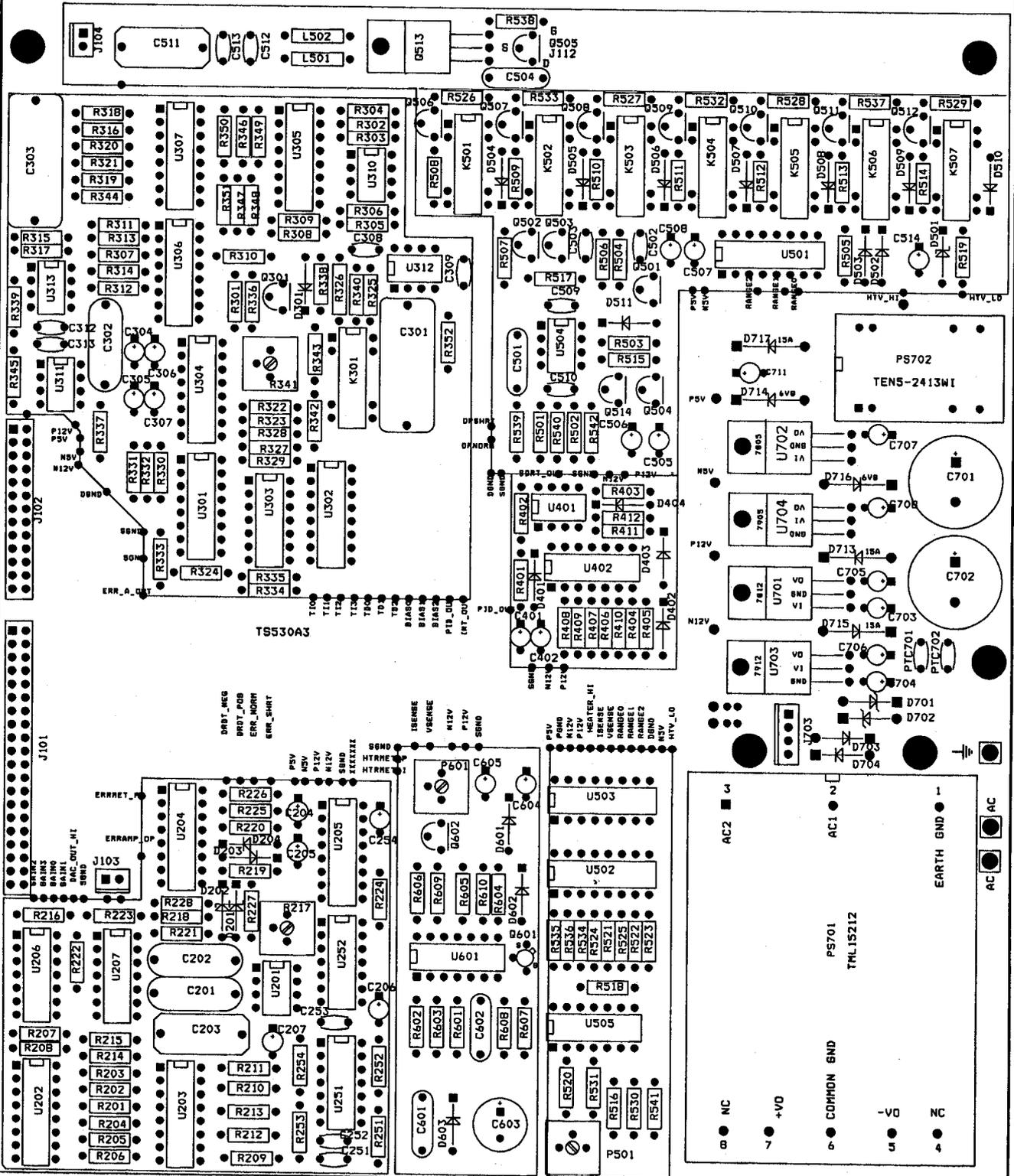
INTERFACE CONNECTOR



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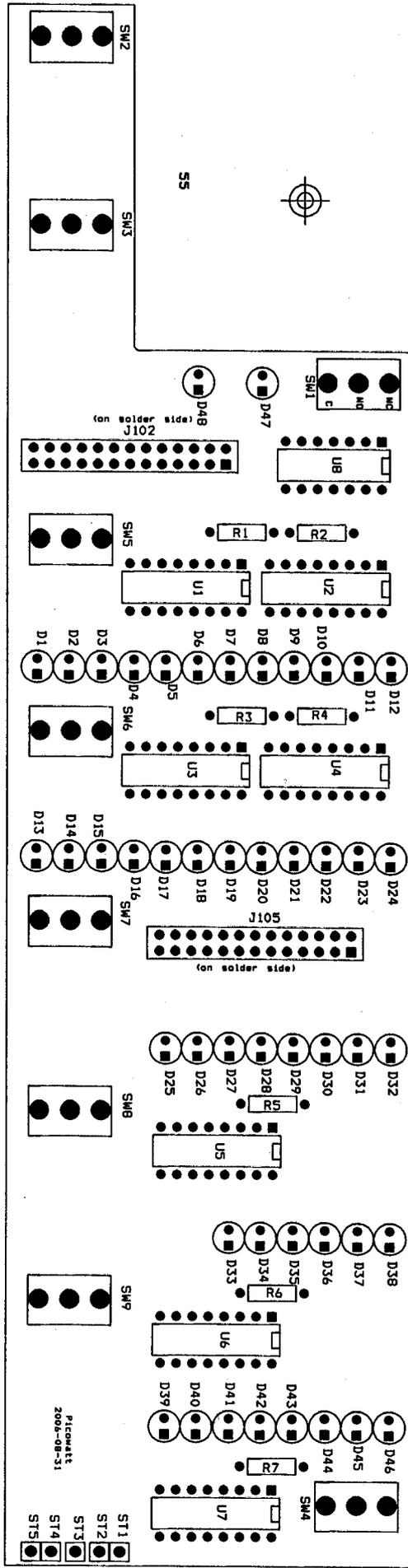
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 2008-04-11: switching mode power supply
 2008-04-11: dc/dc converter for heater
 2008-05-20: gerber output
 2008-05-22: new gerber output

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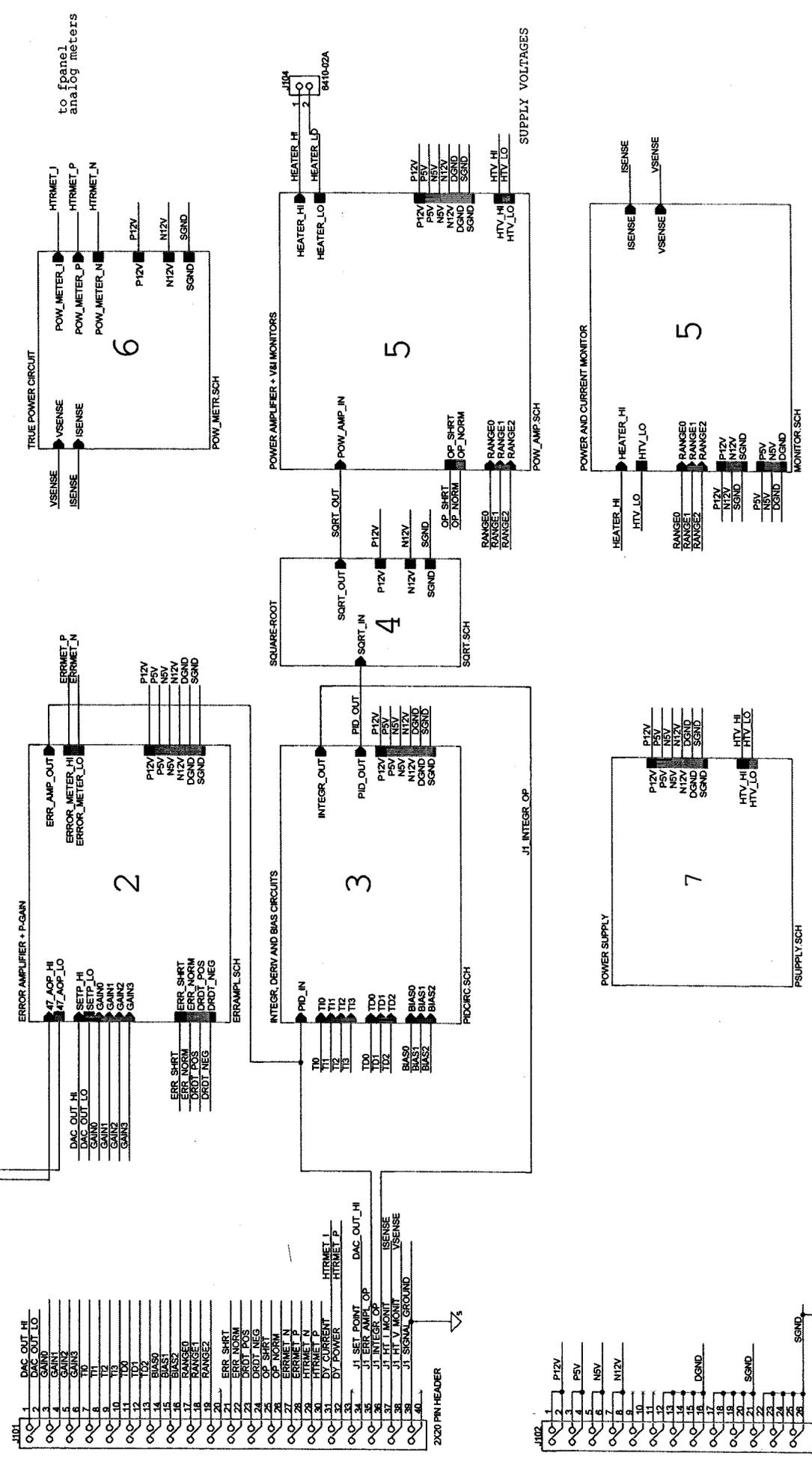
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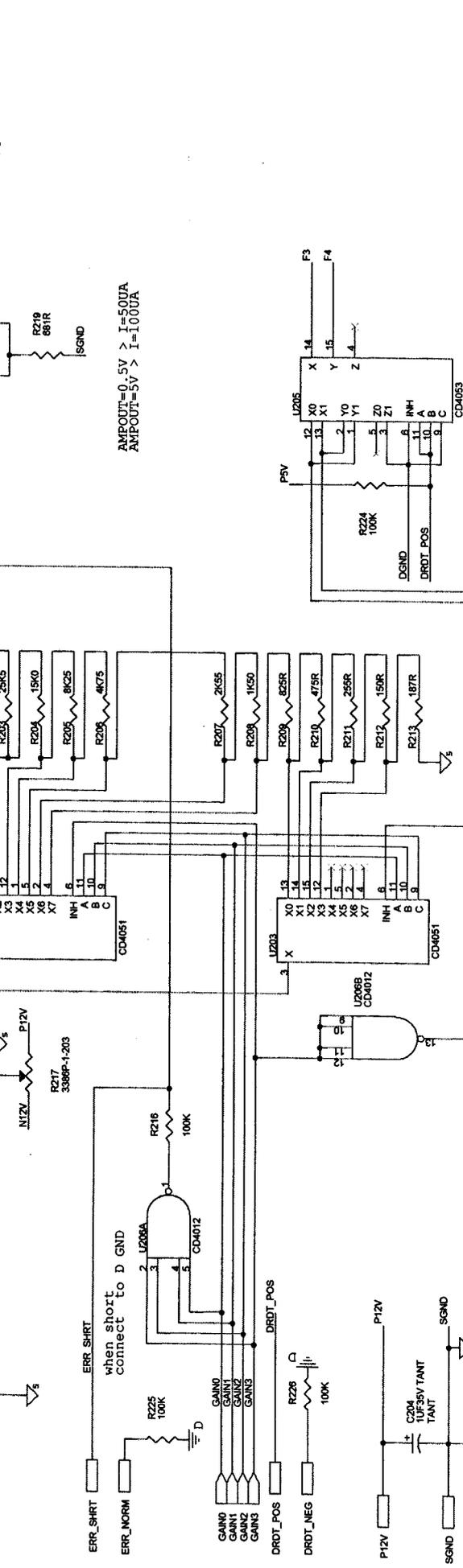
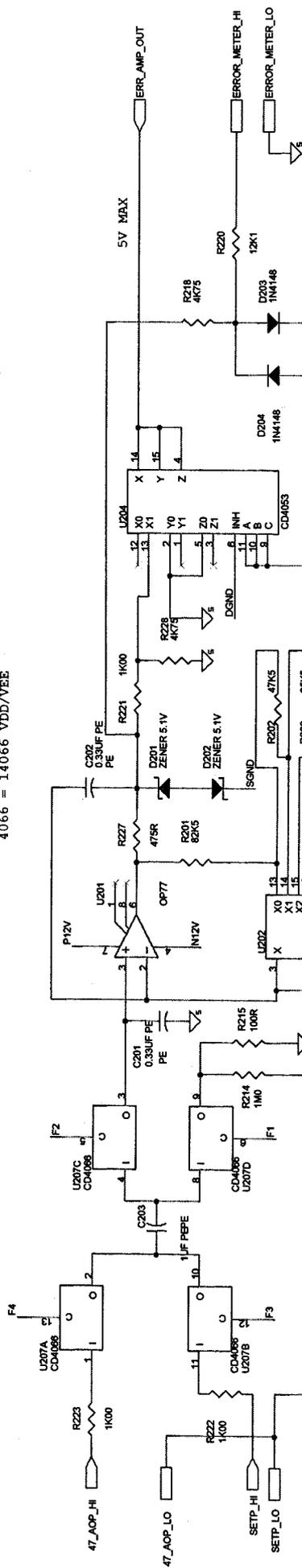
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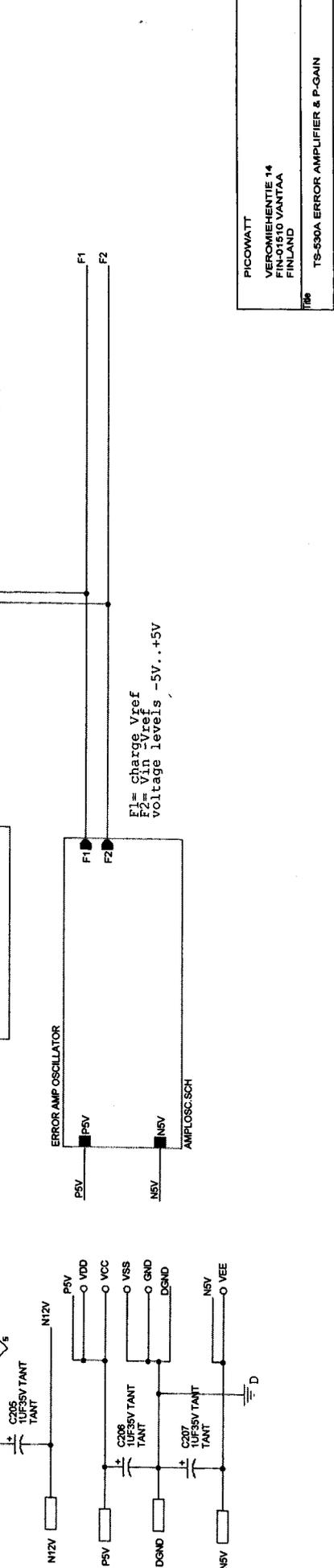


G=SGND

4066 = 14066 VDD/VBE



AMP/OUT=0.5V > I=500UA
 AMP/OUT=5V > I=1000UA



F1= Charge Vref
 F2= Vin -Vref
 voltage levels -5V..+5V



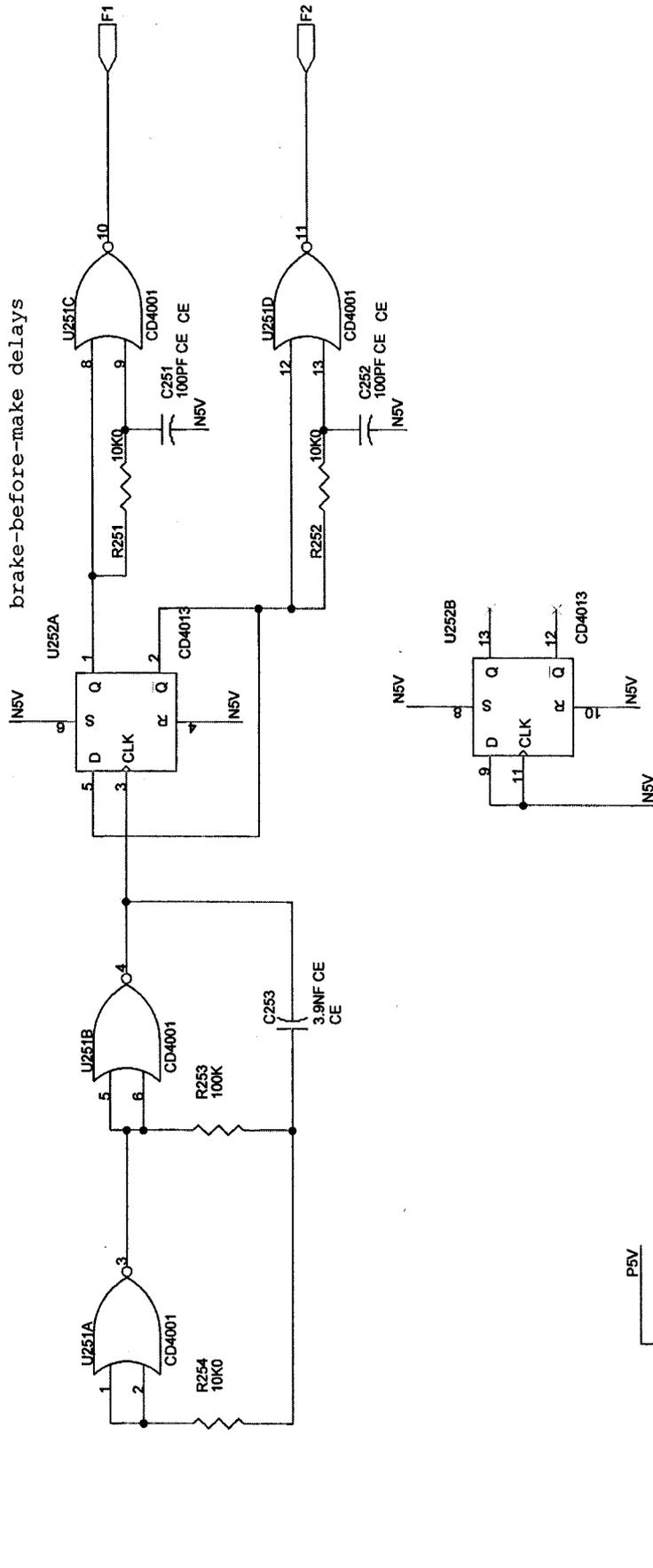
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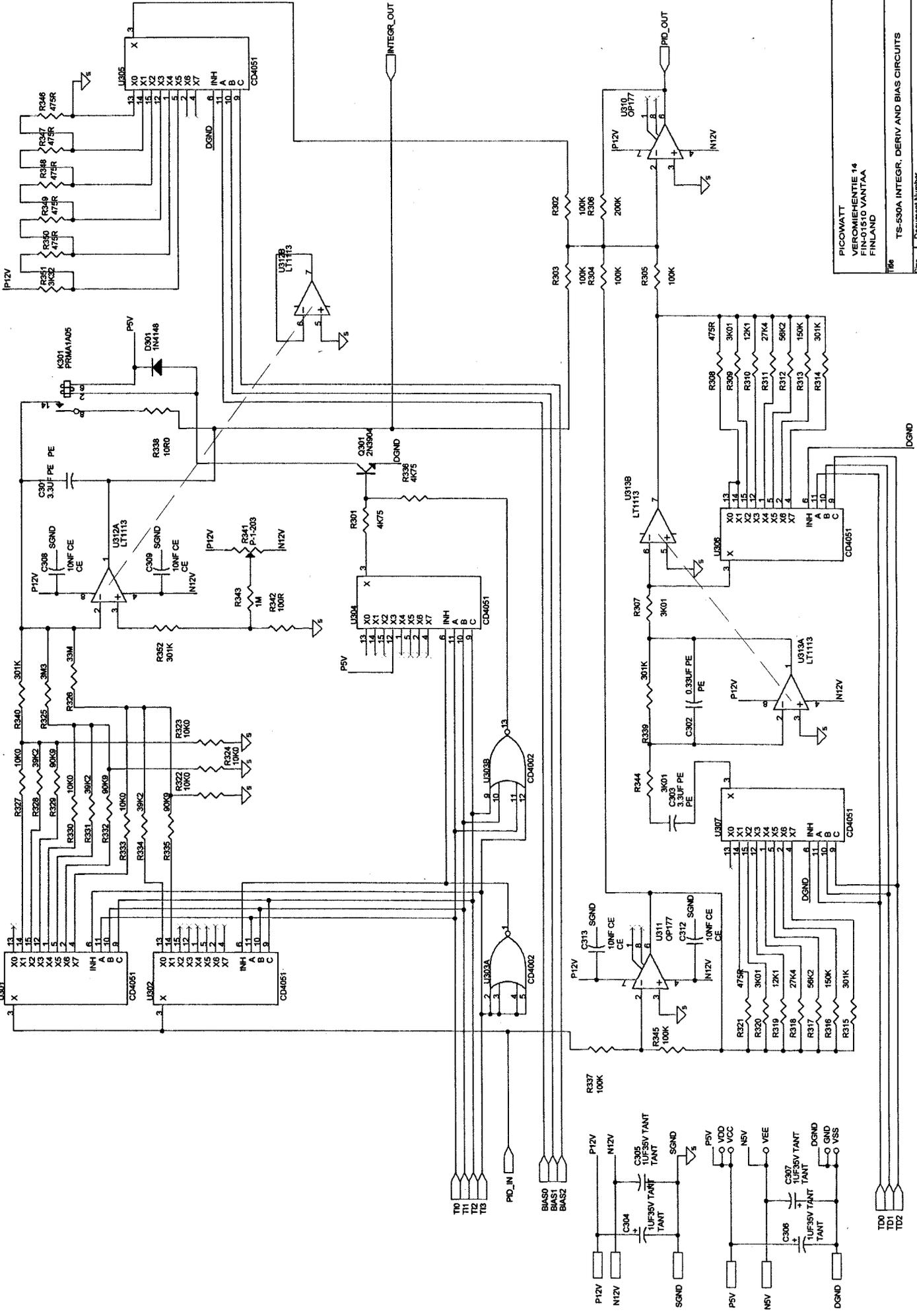
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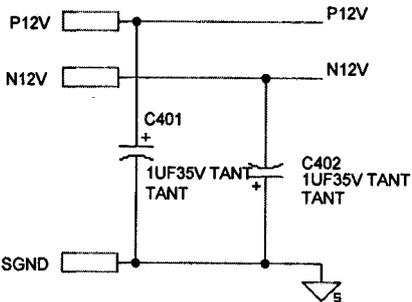
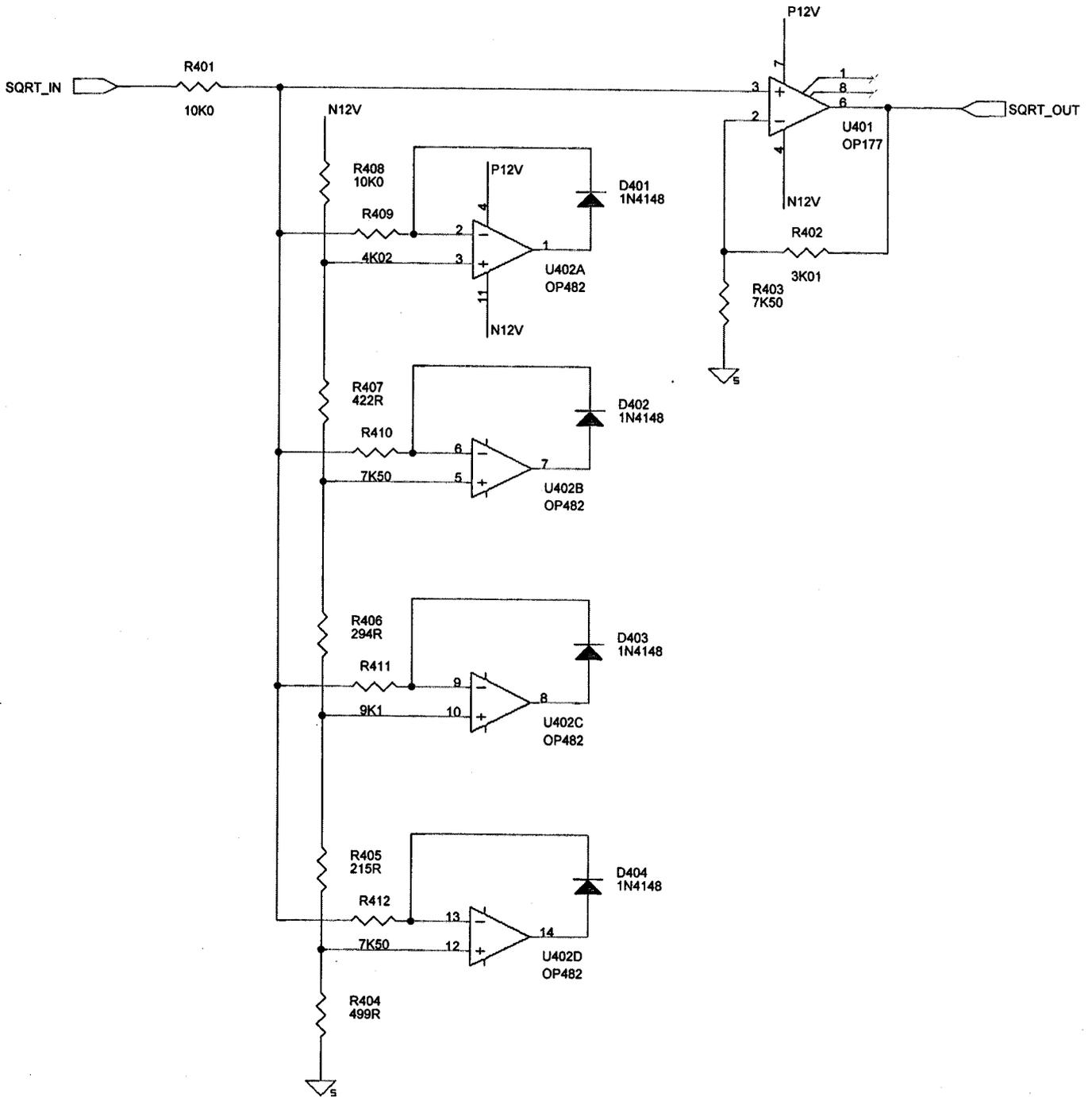
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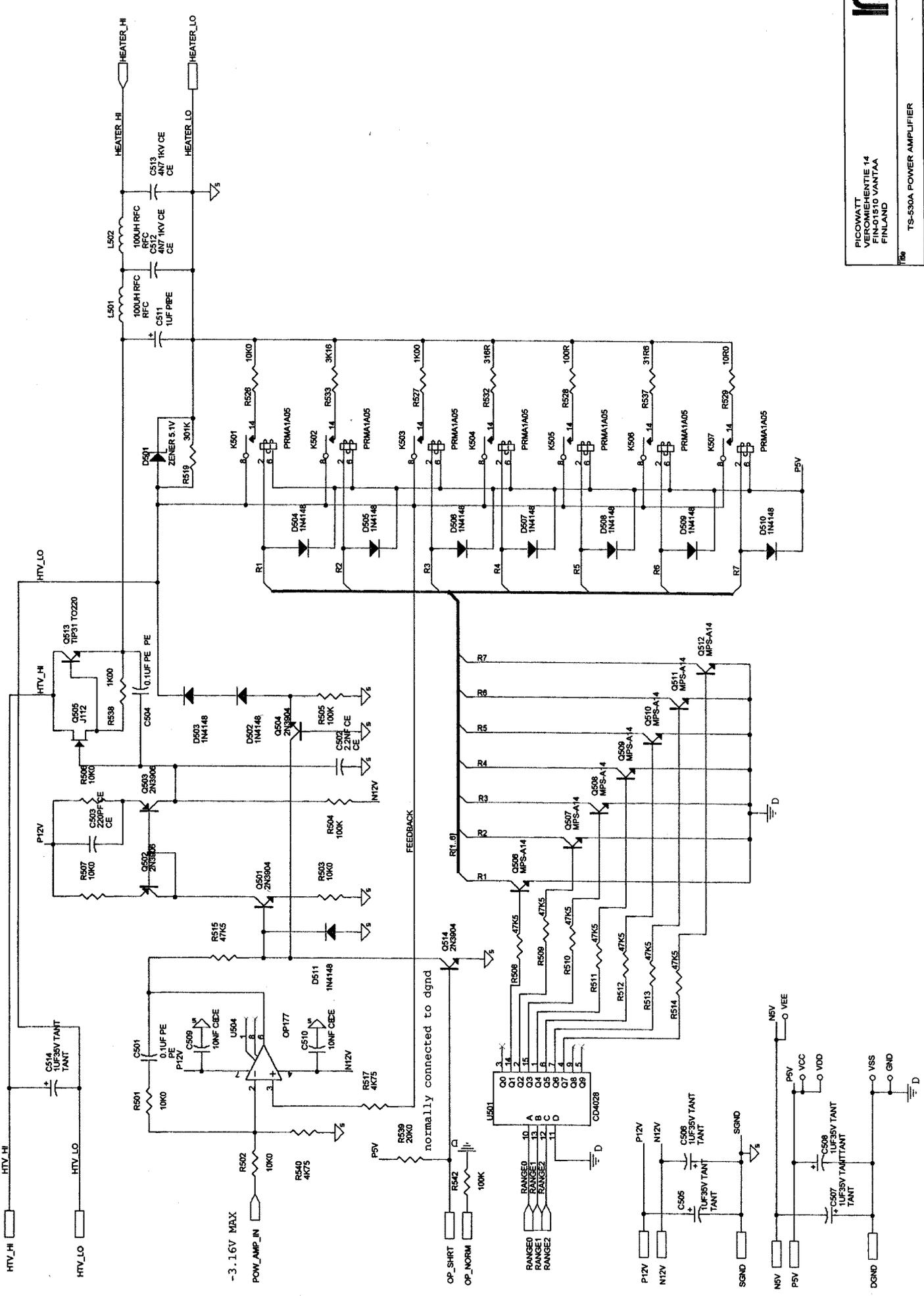


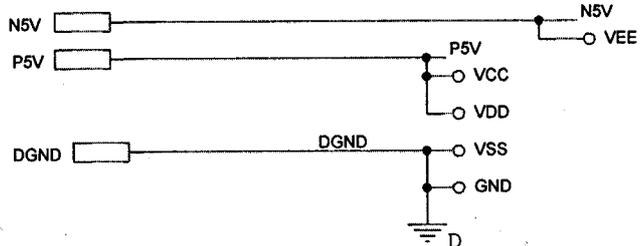
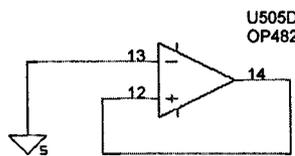
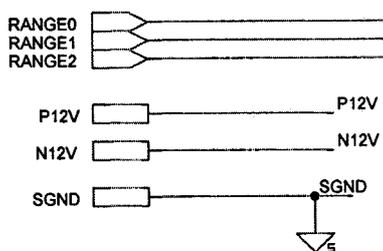
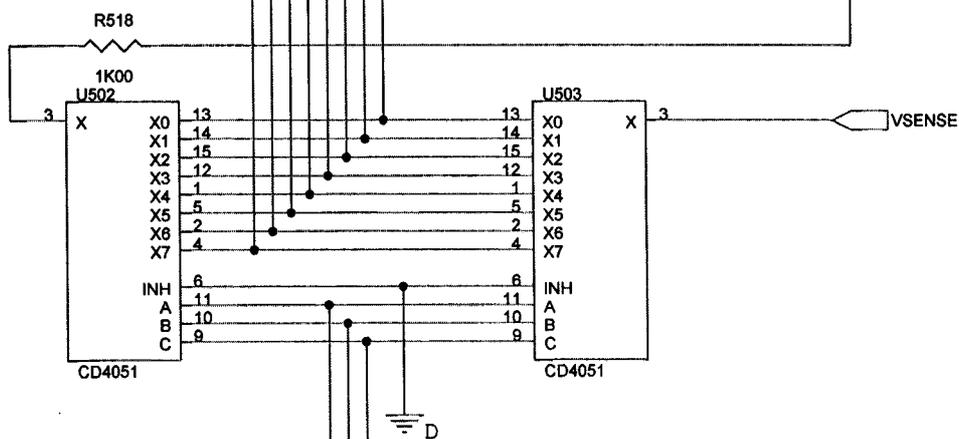
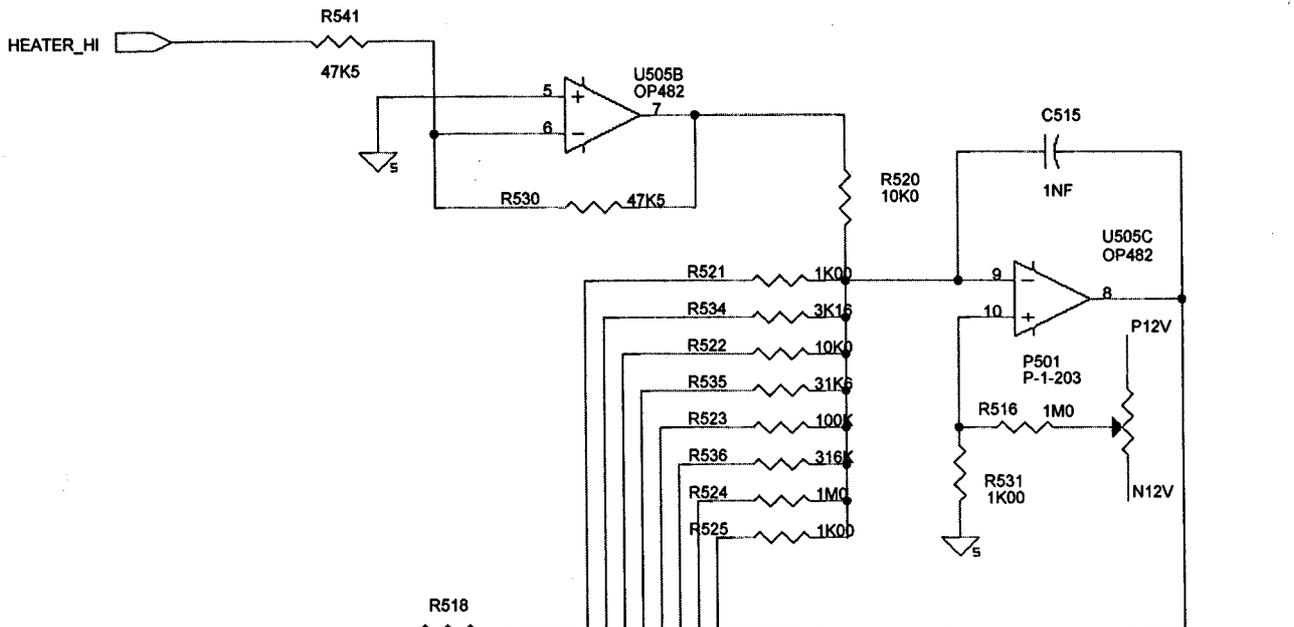
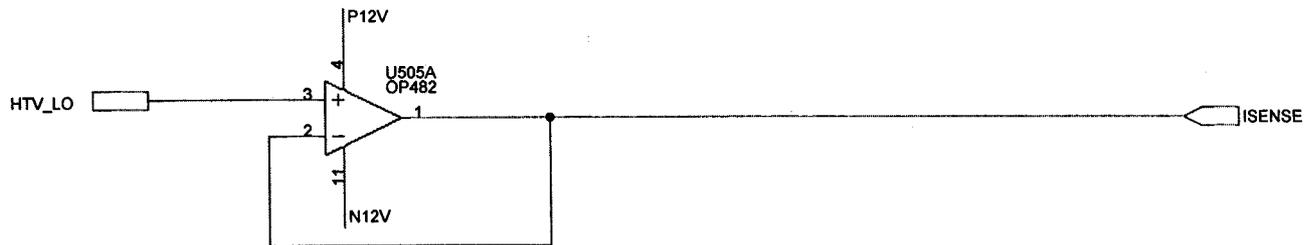
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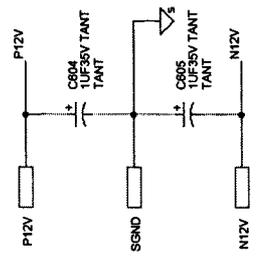
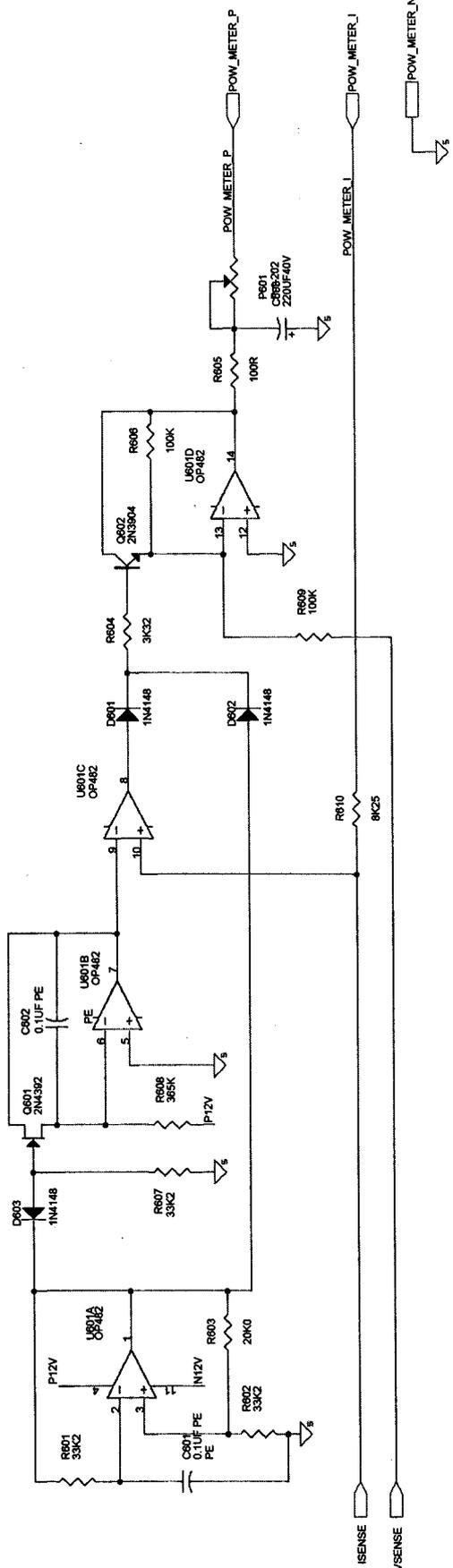


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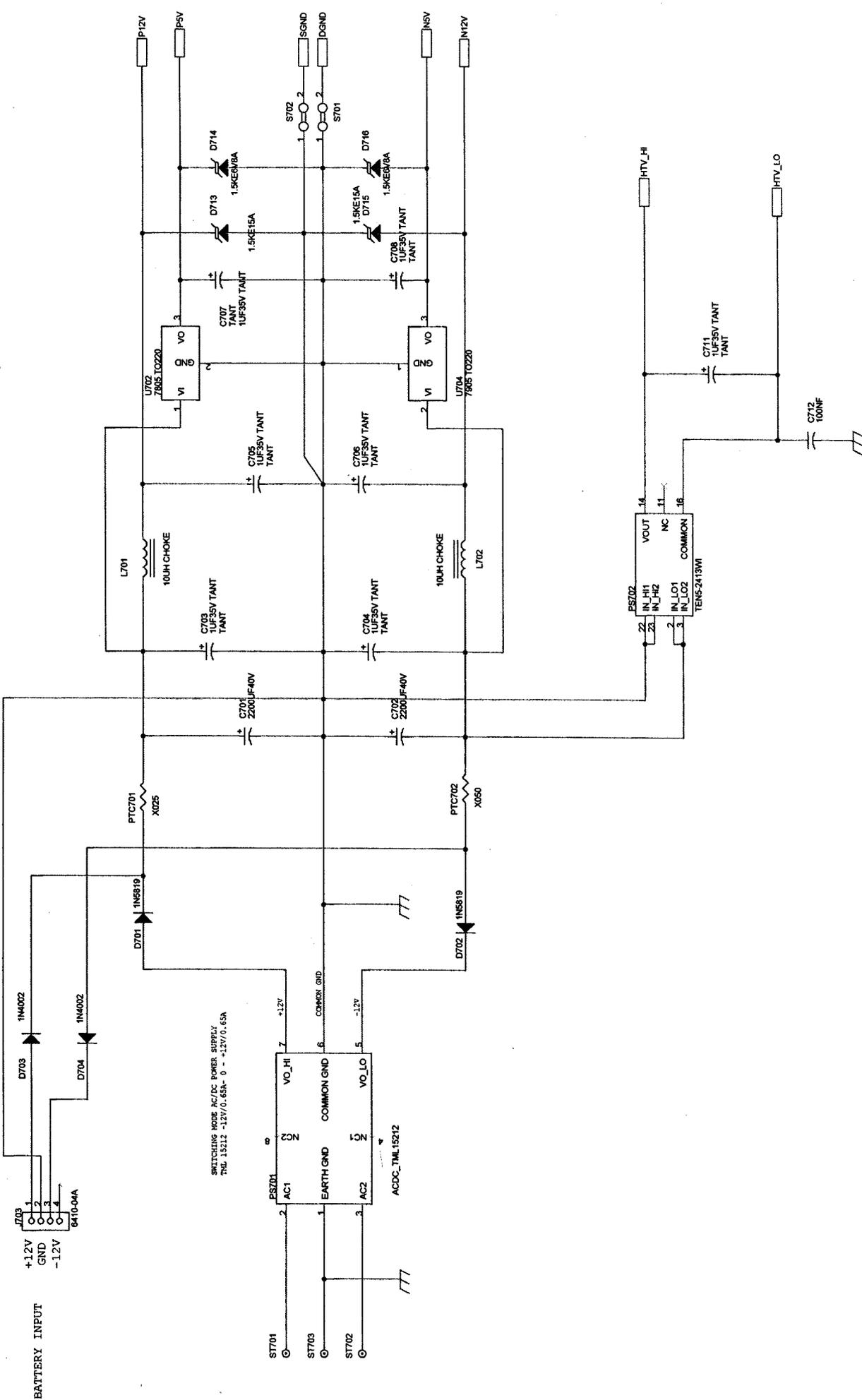
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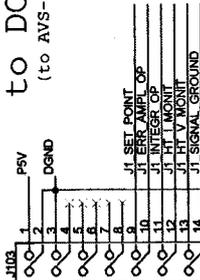
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SWITCHING MODE AC/DC POWER SUPPLY
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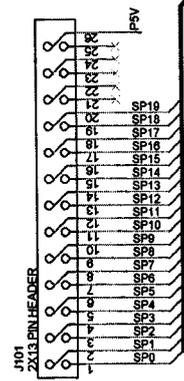
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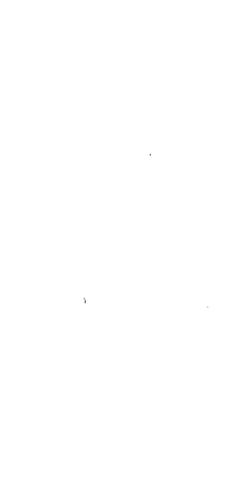
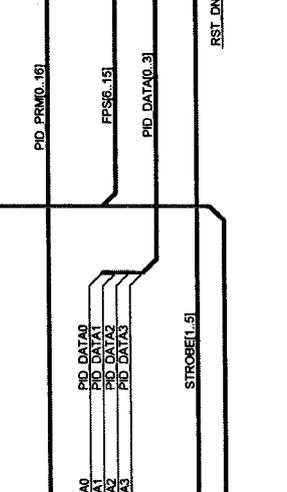
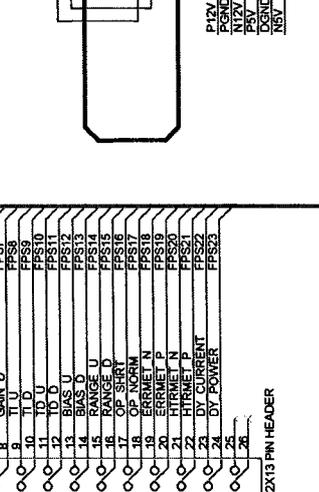
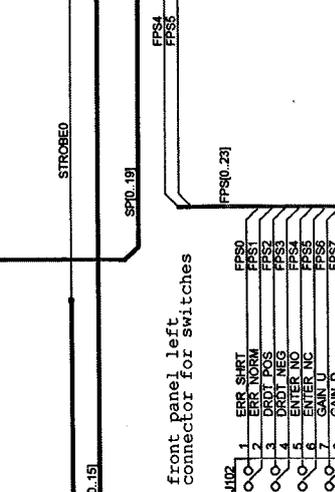
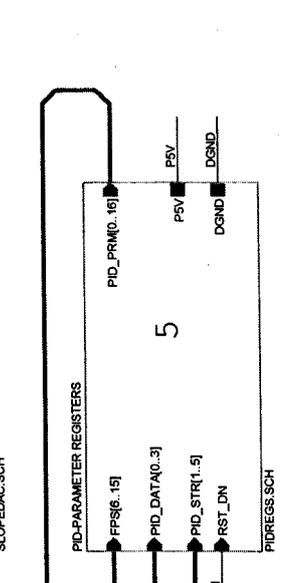
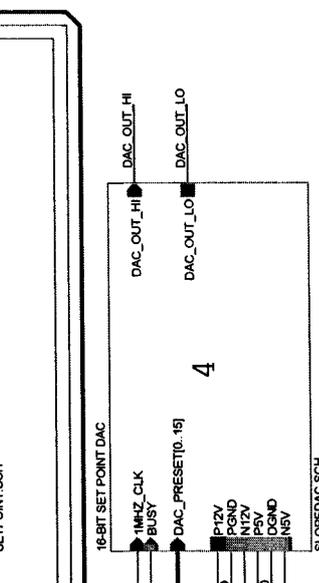
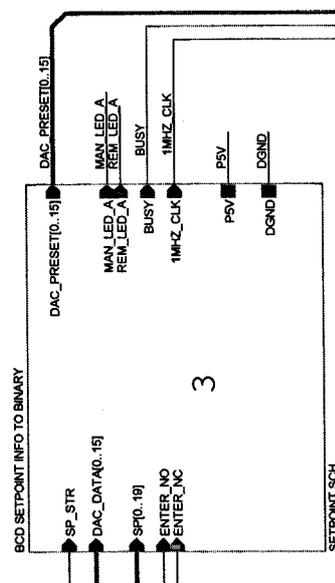


J1 SET POINT
J1 ERR AMPL OP
J1 INTEGR OP
J1 HI L MONIT
J1 HI V MONIT
J1 SIGNAL GROUND

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TO SET POINT THUMBWHEELS



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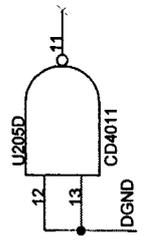
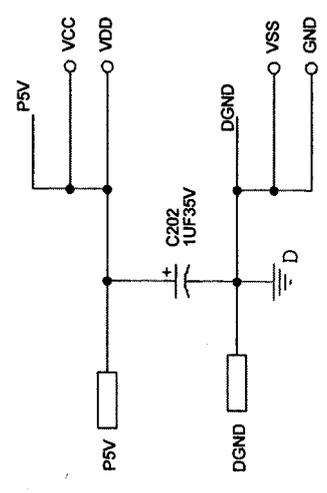
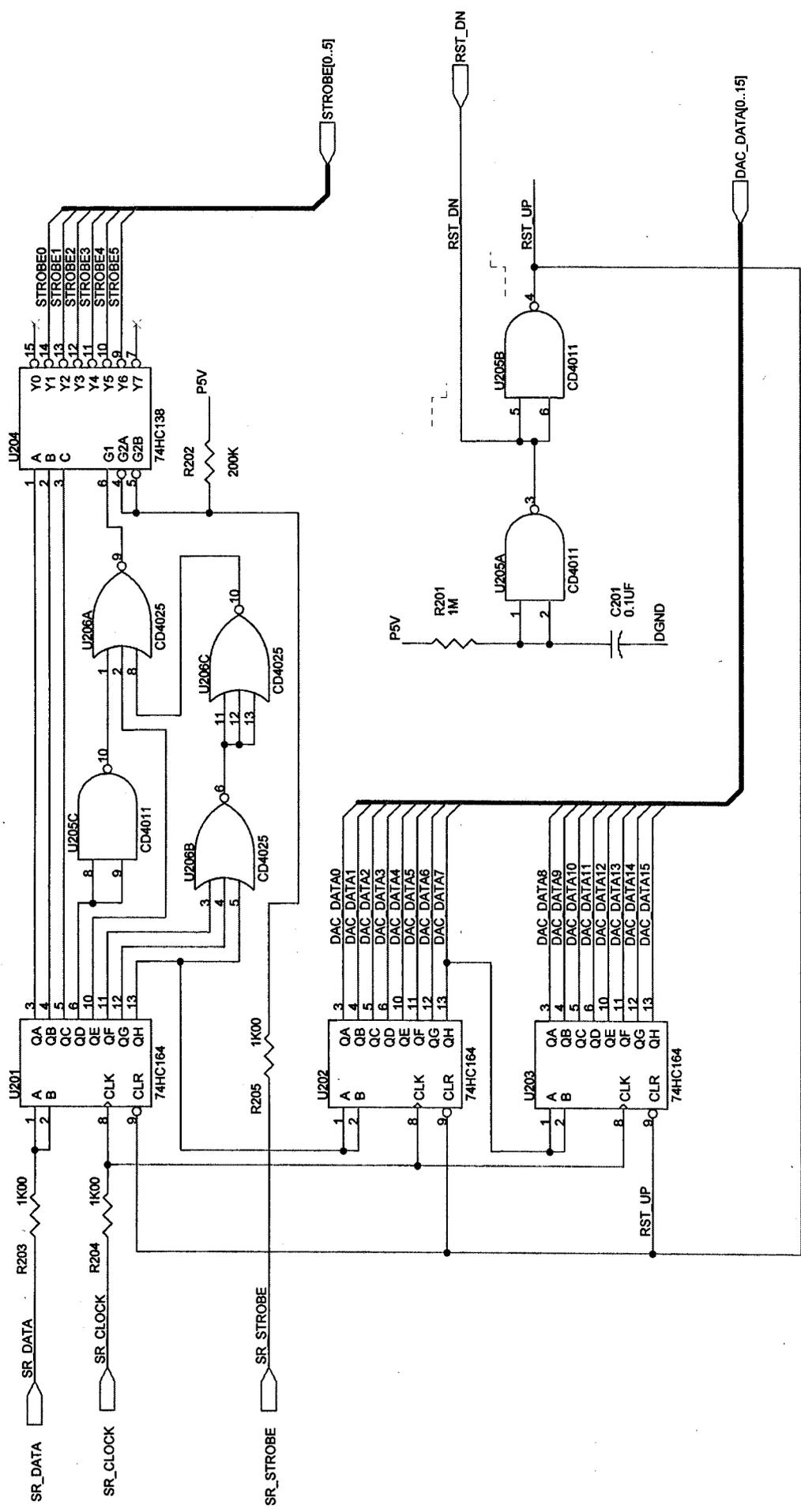
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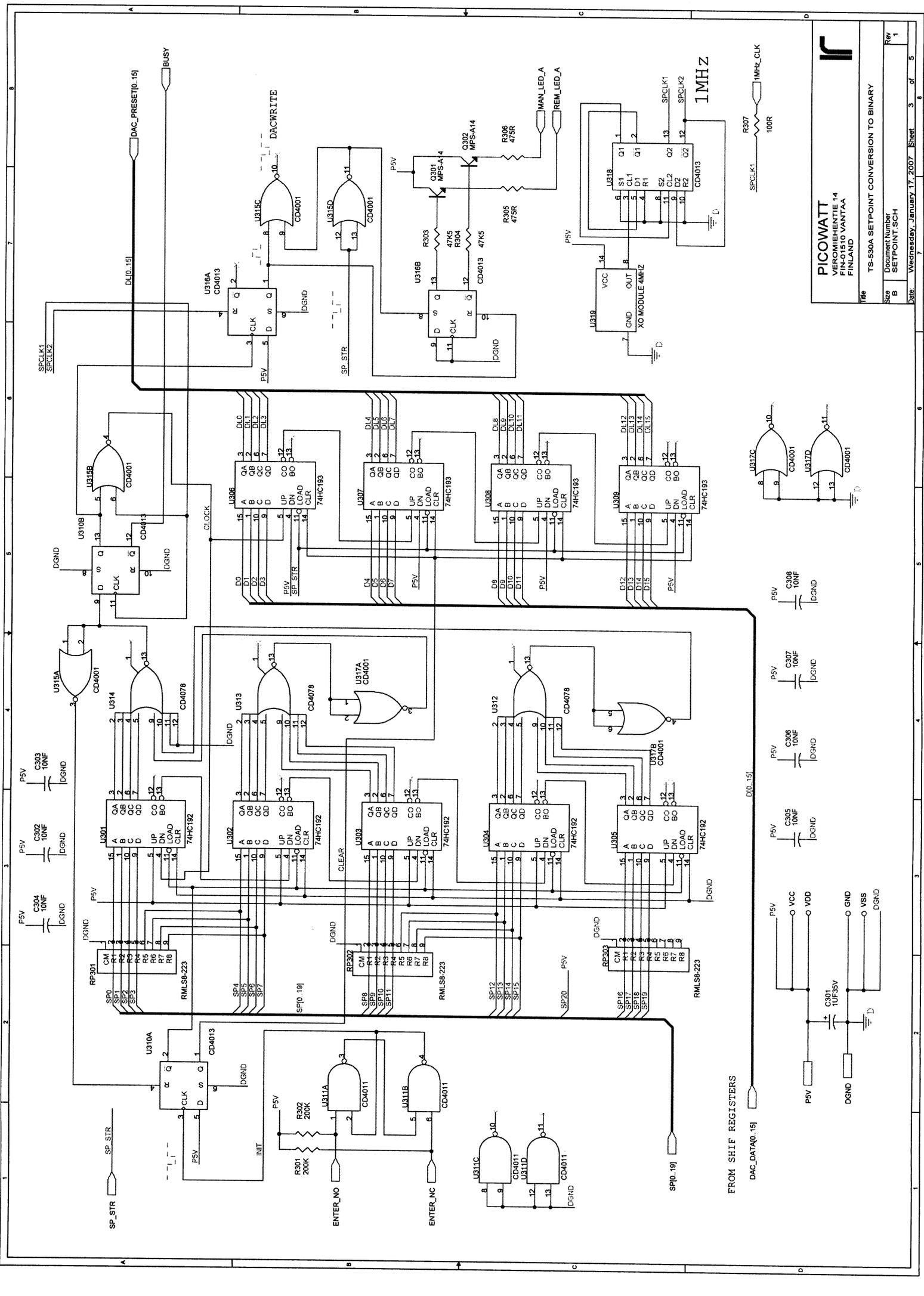
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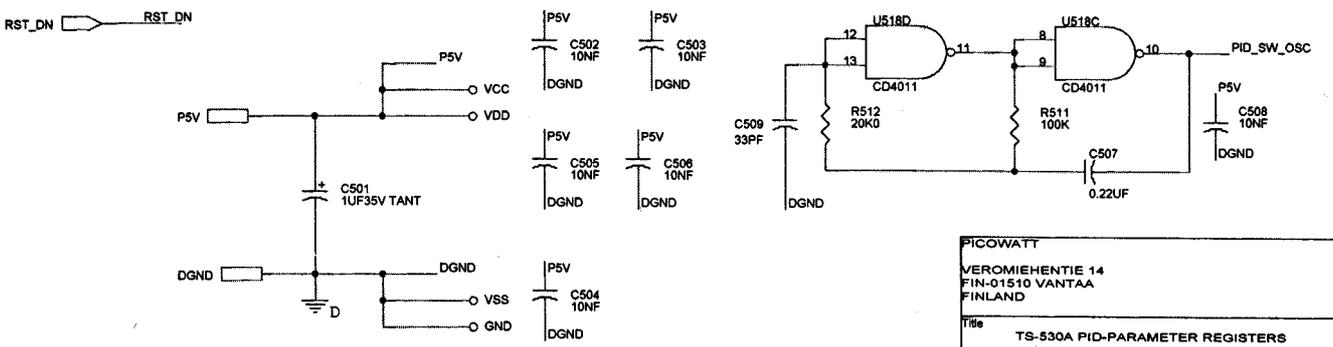
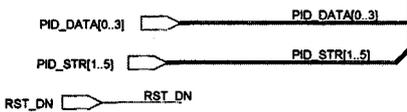
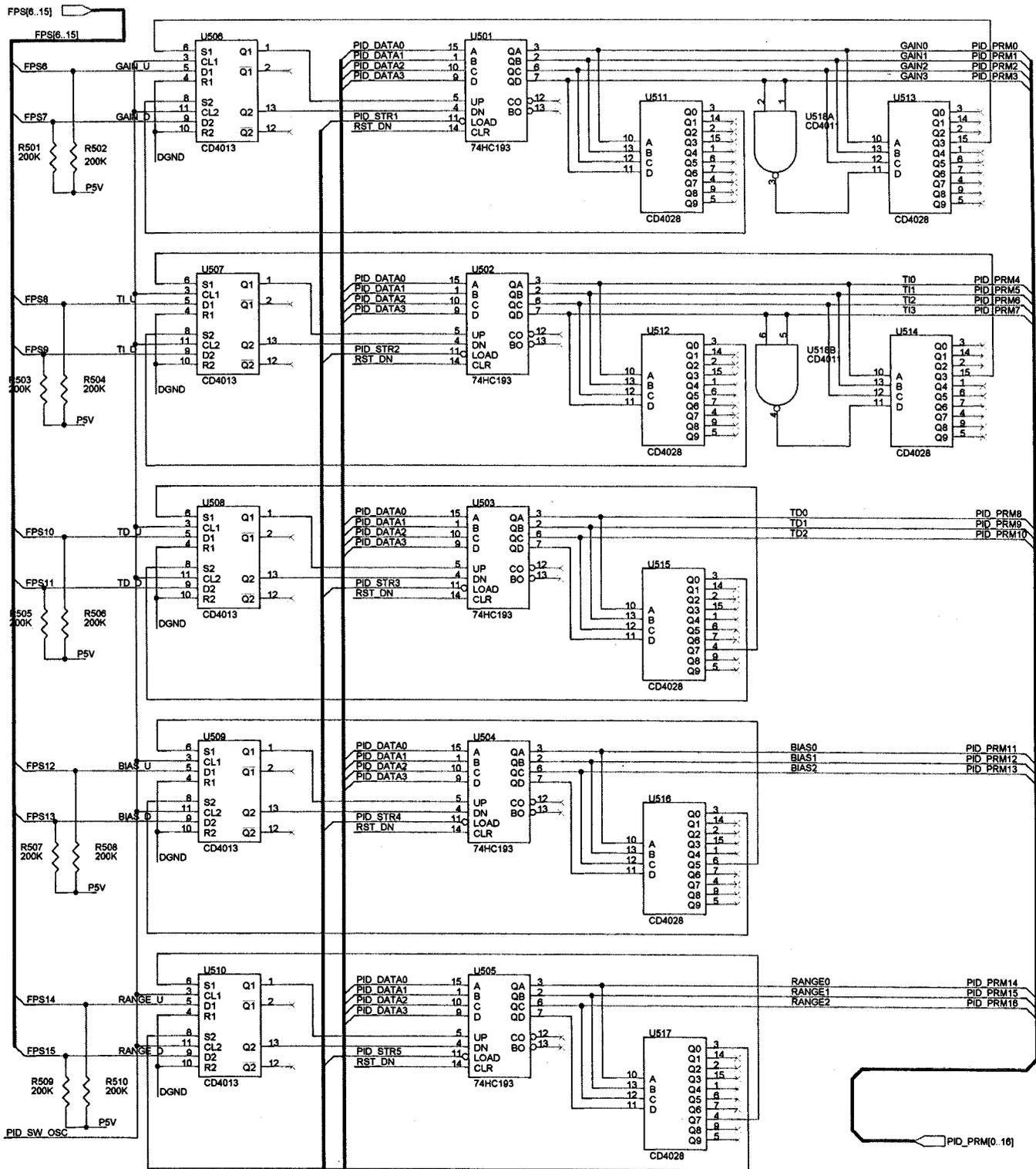
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 Date: Wednesday, January 17, 2007 Sheet: 3 of 5



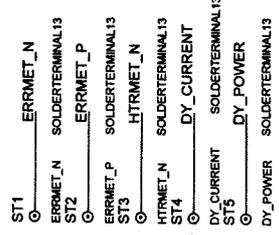
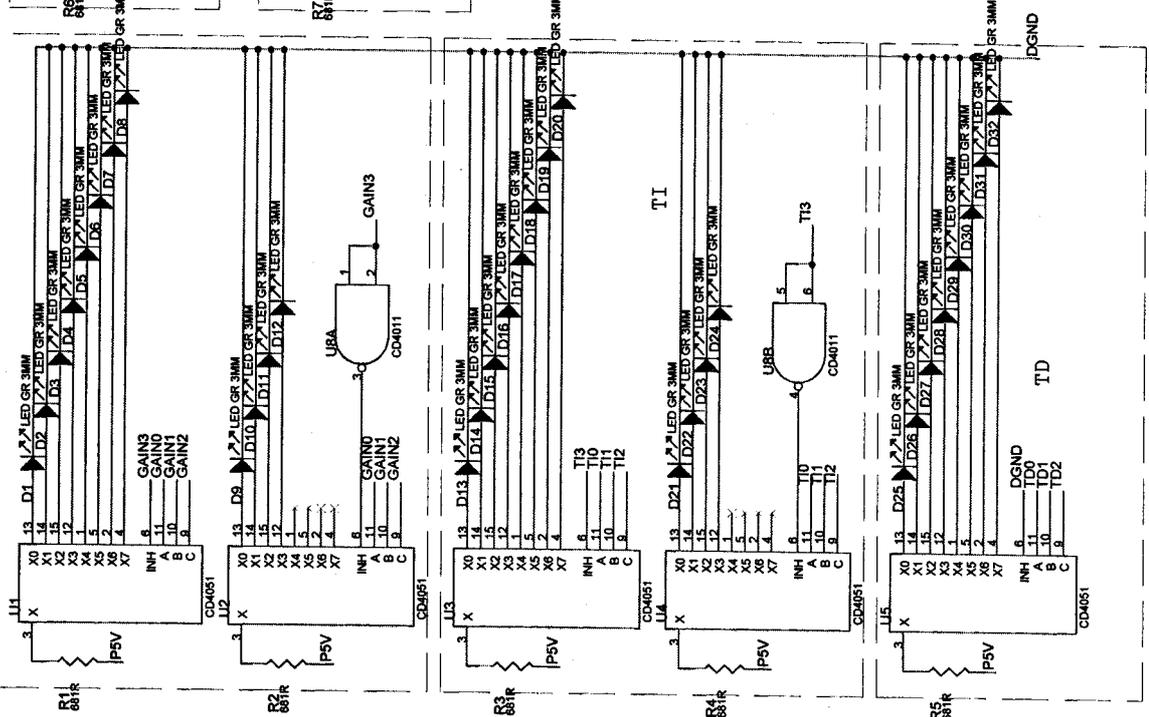
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Title: **TS-530A PID-PARAMETER REGISTERS**

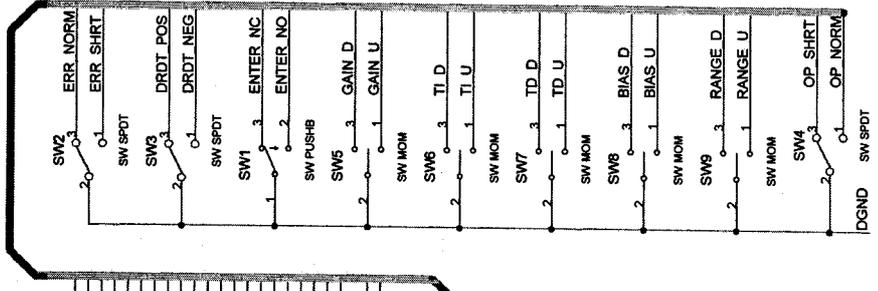
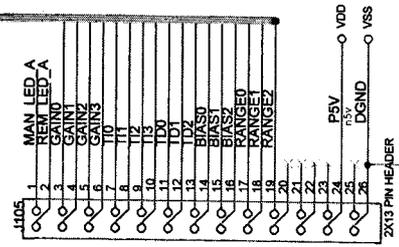
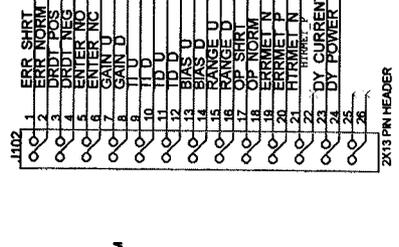
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GAIN



- ST1 ○ ERRMET_N
- ERRMET_N SOLDERTERMINAL13
- ST2 ○ ERRMET_P
- ERRMET_P SOLDERTERMINAL13
- ST3 ○ HTRMET_N
- HTRMET_N SOLDERTERMINAL13
- ST4 ○ DY_CURRENT
- DY_CURRENT SOLDERTERMINAL13
- ST5 ○ DY_POWER
- DY_POWER SOLDERTERMINAL13



RV-Elektronikka Oy
Veroniehentie 14
SF-01510 VANTAA
FINLAND