105A WATTMETER

MAINTENANCE MANUAL

Infratek

6. THEORY OF OPERATION

6.1. Introduction

This section presents an overall functional description of the 105A, followed by detailed circuit description. The description is supported by the schematic diagrams in section 9.

6.2. Overall Functional Description

The functional block diagram of the 105A is shown in Figure 6.1.
The basic signal path flows from left to right. The inputs are sensed at the input terminals, scaled, converted, directed to the A/D converter circuit, the digital representation transmitted via the internal bus to the digital controller, and sent to the display.
The current amplifier and the voltage amplifier constitute the "front end" of the wattmeter. The current amplifier senses the current in the current sensing resistors and produces a proportional signal for all functions. Its output is applied to the rms converter and the watt converter which both produce an equivalent dc voltage. The voltage amplifier senses the voltage in the devider circuit. The amplifier output is applied to the voltage rms converter, and also to the watt converter.
The multiplexer selects one out of three signals and presents it to the A/D converter.
The microprocessor (digital controller) controls the operation of virtually every part of the 105A. It configures the instrument for each function and range, triggers the A/D converter, controls the multiplexer, reads the appropriate latches, calculates the results, sends data to and reads data from the display controller, and communicates with the IEEE-488 Interface.
The main power supply provides supply voltages to all parts of the instrument including the display.
All outputs of the 105A are isolated from the main electronics. Shock hazards are eliminated.

6.3. Detailed Circuit Description

The following paragraphs give a detailed circuit description of the functional blocks in Figure 6.1. The descriptions follow the part designations of the schematic diagrams of section 9. Pins are designated by the respective integrated circuit (e.g. U101-7 for U202 pin 7).

6.4. Current Amplifier

The voltage drop across the current sensing resistors is amplified in U1. The gains are 660/66/6 gain 660 if amplifier U1 is set by relay S5. Similarly, S6 sets gain 6 and gain 66.
The output U1-10 is decoupled in U2 and then applied to the rms converter U3 and the multiplexer U101. The input signal is AC or AC+DC coupled by relay S6. U2 performs phase correction at high frequencies.

6.5. Voltage Amplifier

The voltage from the input devider R23, R24, and R25 is amplified in U4. The gain switching (100, 10, 1) is accomplished by relays S1, S2, and S3, and the AC- and AC+DC coupling is controlled by relay S4.

6.6. RMS Converters

U3 and U6 are analogue computing rms converters. The AC- or DC input signal at pin 13 is converted to a DC signal which would produce the same power as the input signal. The outputs of the rms converters are always positive. The components around U6 are used for signal low pass filtering. The time constant of the low pass filter is approximately 0.5 seconds.

6.7. The Watt Converter

U102 and the four amplifiers U103 comprise the watt converter. The current signal output at U2-6 and the voltage signal output at U5-6 are applied via the autozero multiplexer U101 to the analogue computing watt converter U102. U102 formes the product of current and voltage and feeds a current proportional to the product to amplifier U103-12,13,14. Its output is a voltage proportional to instantaneous power. U103-3,2,1 performs low pass filtering, its output is a voltage proportional to average power. U103-5,6,7 is a signal inverter. U103-9,10,8 together with U101 generates the autozero signal to control the watt converter null. U101 samples the watt converter output with zero input and stores the error signal in C102.

6.8. A/D Converter

The four signals Ir (rms current), Ur (rms voltage), and Pp (positive power) are selected by multiplexer U105, fed to amplifier U107, and are in U108 digitally converted. U108 is controlled by the microprocessor U201. U201 reads the A/D output via the data bus D0...D7. The multiplexer is controlled by latch U106.

6.9. Recorder Output Drivers

The signals for the recorder outputs are generated by the three amplifiers U104-(1,2,3),(5,6,7), and (8,9,10). These signals are fed to connector J101. The signal Pm at J101 is used for the broad band recorder output (option 05).

6.10. Digital Controller

U201 does all the controlling of the digital components. It reads the program from U203 and U204, it stores data in U205 and 206, it addresses the digital circuits, and finally, it performs the computing required.

6.11. Decoder

U208, U209, U210, U10, U11, and U12 are used for circuit addressing. They address memory space U204-U206, the key board encoder/display driver U207, the A/D converter U108, and the latches U8, U106, U109, and U306 through U308.

6.12. Key Board Encoder and Display Driver

U207 scans the 5 front panel controls S300 through S304 and when a key is depressed is its number stored in U207. U207 then sends an IRQ to U109-3. The digital controller reads the data from U207 and takes appropriate action.
U207 also sends display data to the decoders U301 and U302. It performs the multiplexing of the five digits including the decimal points. U303 and U304 are high voltage drivers for the vacuum fluorescent display.

6.13. Led Drivers

U306, and U307, are the drivers for the 16 front panel Leds. The three latches are addressed by U210. The data are sent from the microprocessor via the data bus.

6.14. Power Supply

The power supply provides the outputs +5V, +15V, +30V, +(7-8)V, 3.3V, and the isolated output +5V, and -5.6V.
The +15V supply is for the analogue circuits, the +5V is for the digital circuits, the +30V is for the display drivers, the 3.3V for the vacuum fluorescent display, and the +5V/-5.6V for the isolated outputs (recorder and interface). VR401 through VR405 are voltage regulators.

6.15. Isolated IEEE-488 Interface (Option 01)

To avoid hazardous potentials at the interface output a bidirectional bus isolator is put between the 105A and the interface output circuit.
The potential isolation is achieved by the bus isolators U602 through U605. U601 and U606 are bidirectional bus transceivers on the 105A input side, and U607 and U608 are the transceivers on the 105A output side. J602 is connected to the interface connector J501. The interface controller U503 manages the signal flow between 105A and external system controller. U501 and U502 are bus transceivers to communicate with the external interface controller. U504 is the address latch. On 105A start-up, its contents is read and stored by the microprocessor.

6.16. Energy Converter (Option 02)

The energy converter determines the time increment for the energy computation. The time increment is derived from the microprocessor clock.

6.17. Recorder Output for Arms, Vrms, and Watt

The three signals proportional to Arms, Vrms, and Watt are generated by the quad operational amplifier U104. The signals are taken off connector J101 and transmitted to J801 on the recorder output print. The DC current isolator T801 receives a current proportional to Arms and reflects this current to the output side. The voltage drop across the output resistor network is adjusted to be 3Vdc at full scale current range.
Similarly, the DC current isolator T802 transmits Vrms to the output side and T803 transmits Watt to the output side. The three output signals are galvanically isolated from the 105A input and main electronics and also galvanically isolated from each other. Only positive currents can be transmitted to the output.

6.18. Broad Band Recorder Output

The broad band recorder output transmits the signal proportional to instantaneous power to the 105A output. The isolation amplifier U801 accomplishes signal isolation. The output side of U102 receives its supply from the DC/DC converter comprised of Q801-Q805, T804, and voltage regulators VR801, VR802.

NOTE: The broad band recorder output and the IEEE-interface have common potentials. The Lo-side of the recorder output is approximately 5.6V below IEEE-488 interface ground.
When using both, the interface and the recorder output, make sure that the external equipment does not short this potential difference.

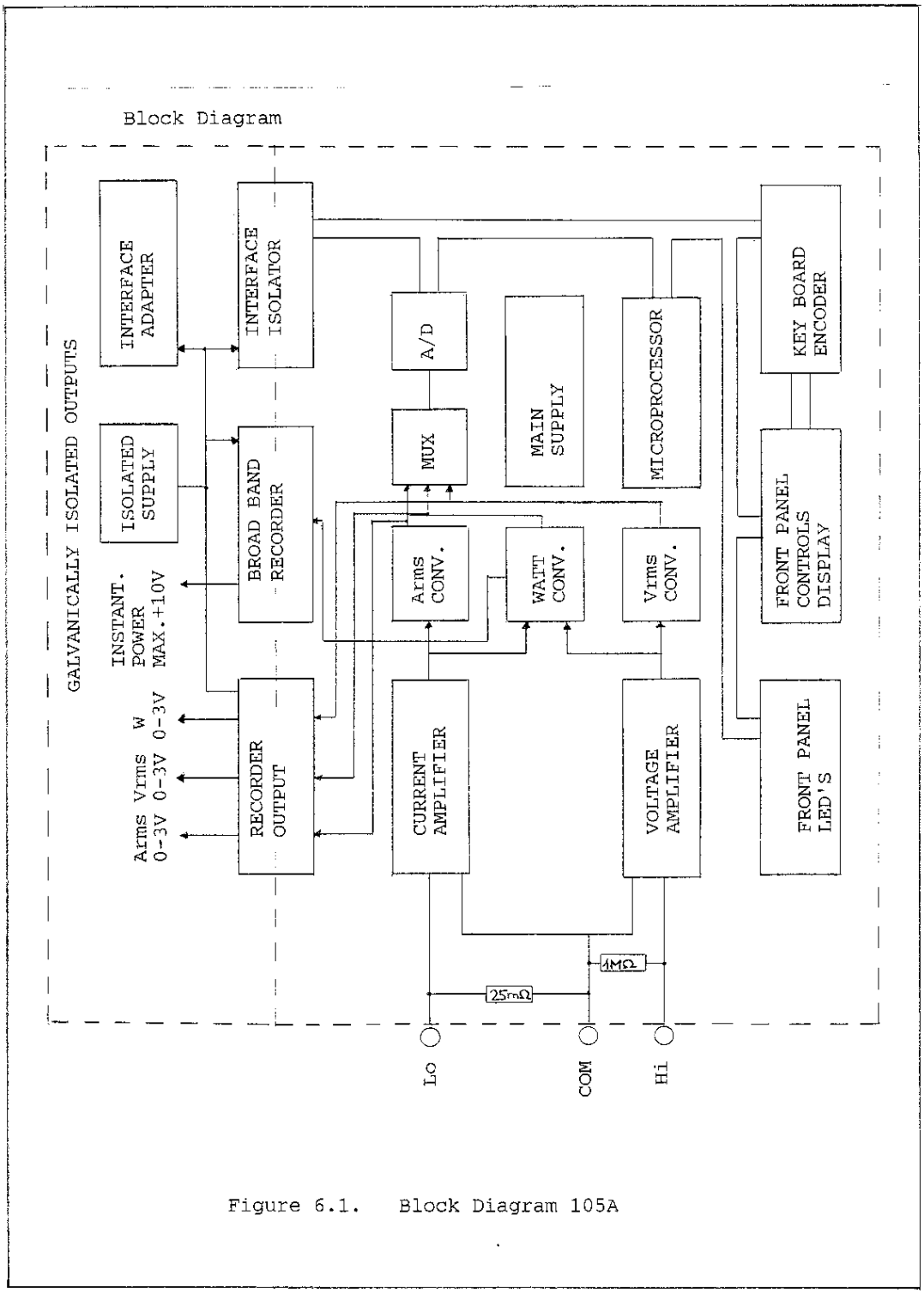


Figure 6.1. Block Diagram 105A

7. MAINTENANCE

WARNING: These service instructions are for use by qualified personnel only. To avoid electric shock, do not perform any procedures in this section unless you are qualified to do so.

7.1. Introduction

This section presents maintenance information for the 105A. This section also includes an alignment procedure and a calibration procedure.

7.2. Disassembly Procedure

WARNING: To avoid electric shock, remove the power cord and test leads before disassembling the instrument.

7.3. Top Cover Removal

Remove all screws along the top edge of the case.
Remove the top cover.

7.4. Circuit Board Location

The main circuits including the options are located on the main printed circuit board assembly. The options are installed on spacers and connected to the main PCA by cables.
Parts of the display, all Led drivers, and all function control switches are located on the front panel PCA.
The rear panel assembly carries the line transformer, the line selection switch, and the input connectors.

7.5. Main PCA Removal

The main printed circuit board assembly is attached to the side panels by 8 spacers (4 on each side).
Loosen the 8 screws from the bottom which attach the main PCA to the side panels. Remove all cables and lift the PCA out of the case.

7.6. Alignment Procedure

To attain maximum accuracy, the 105A must be properly aligned before calibration. Measure all offsets with respect to current amplifier ground potential.
Allow 10 minutes warm-up time before proceeding to the next steps.

7.7. Current Amplifier DC Offset Adjustment

1. Select AC+DC-Coupling, 1A current range.
   Adjust P3 for 0mV at U2-6.
2. Select AC+DC-Coupling, 25A current range.
   Adjust P4 for 0mV at U2-6.
3. Repeat steps 1 through 2 until readings converge.

7.8. Voltage Amplifier DC Offset Adjustment

1. Select AC+DC-Coupling, 120V range, short input terminals together.
   Adjust P8 for 0mV at U5-6.
2. Select AC+DC-Coupling, 480V range.
   Adjust P9 for 0mV at U5-6.
3. Repeat steps 1 through 2 until readings converge.

7.9. Watt Converter Offset Adjustment

1. Select AC-Coupling, 120V range, 25A range.
   Apply 120Vrms/130Hz to voltage input.
   Adjust P102 for minimum AC voltage at U103-14 (use oscilloscope).
2. Select AC-Coupling, 1A range, 480V range.
   Apply 1A/130Hz to current input.
   Adjust P101 for minimum AC voltage at U103-14 (use oscilloscope).
3. Repeat steps 1 through 2 once or twice.
4. Check offset voltages at:
   U103-14, Offset, maximum +3mV
   U103- 1, Offset, maximum +3mV
   U103- 7, Offset, maximum +5mV

7.10. Calibration Procedure

For calibration a wide range of voltages and currents are required. For the whole calibration procedure use 130Hz sinusoidal signals. Select AC-Coupling.

1. 1A, 120V, Watt calibration:
Select 1A- and 120V range. Apply 1A and 120V to the 105A input.

1.1. Switch the CAL switch S201 to the front position, wait 1 second and press the current range button. The calibration factor for the 1A range is now displayed. Switch S201 back to its rear position. All current ranges are now calibrated.

1.2. Switch S201 to the front position, wait one second and press the voltage range button. The calibration factor for the 120V range is now displayed. Switch S201 back to its rear position. All voltage ranges are now calibrated.

1.3. Apply 0.1A/12V to the 105A input.
The current and voltage readings should be within +0.1 % (on 1A/120V ranges). Adjust P105 if deviations are greater than 0.1 %.

1.4. If the setting of P105 had to be changed, repeat steps 1.1. and 1.2.

1.5. Power calibration. Select 1A/120V ranges and apply 1A/120V at 130Hz and 0 degree phase shift between current and voltage.
Switch S201 to front position, wait 1 second and press the "W" control. The calibration factor for Watt is now displayed. Switch S201 back to its rear position. Power for all ranges is now calibrated.

1.6. Apply 0.1A/12V. The display should be 1.2W +0.1 %. Deviations can be adjusted with potentiometer P104. If large adjustments are necessary, repeat step 1.5.

NOTE: All calibration factors are approximately 1.

7.11. Troubleshooting

The 105A is designed to be efficiently maintained and repaired. Some integrated circuits are socketed. Most of the troubleshooting can be done with basic electronic troubleshooting equipment such as a multimeter and an oscilloscope. The troubleshooting of the digital section is probably most efficiently done by exchanging the (socketed) integrated circuits.

7.12. Initial Troubleshooting Procedure

When a problem occurs in the 105A, first verify the problem is actually in the instrument. If the problem occurs when the instrument is in a system, check to see if the same problem exists when under local control. If the malfunction does not involve the IEEE-488 option or the recorder output option, remove the options from the instrument before proceeding.
A failure in the instrument may cause the 105A to display random patterns or nothing at all. If in addition, none of the front panel Leds are lighted, start troubleshooting by checking the power supply for proper levels and for oscillations.
If all of the supplies are working correctly, check the 1MHz clock of the microprocessor. Check the "CAL" switch, it must be set to the rear position.

7.13. Digital Section Troubleshooting

If a problem occurs with front panel Leds, check the decoder U210, and the latches U306, U307, and U308.
If a problem occurs with the vacuum fluorescent display, check U209-7, U10-10, U11-8, U207, U301, U302, U303, and U304.
If a problem occurs with the microprocessor, check U201, U203, U204, U205, and U206.
If a problem occurs with gain selection, check U7, U8, U9-6.
If a problem occurs with the front panel controls, check U207, U301, and U305.
When an installed option is not recognized by the 105A, check 109.
If the watt converter exhibits an unstable null, the error could be in the integrated circuit U106.
When no data, or false data are displayed, check the reference at pin 10 of U108, or replace U108.

7.14. Analog Section Troubleshooting

Monitor the outputs U1-10 and U4-10 and switch ranges. Amplifiers U2 and U5 have a gain of 1. The rms converters U3 and U6 convert an AC input signal to a positive output signal (pin 6/14).
If an error occurs in the watt converter, check the output U103-14. To a sinusoidal current and voltage input, the signal at U103 14 must be a sinusoidal signal of twice the input frequency. In addition, this signal is offset with its minimum at 0V (positive watt input and no phase shift between current and voltage).
If an error occurs in the watt converter autozero, check the multiplexer U101 and U103-8.

7.15. Power Supply Troubleshooting

Check the rear panel fuse. If none of the supply voltages is present, check the input section of the transformer. If just one of the supply voltages is not present, check the appropriate voltage regulator.

7.16. Recorder Output Troubleshooting

If one of the recorder outputs Arms, Vrms, or Watt is not operative, check U104. For full scale display, the voltage at R137, R138, and R139 must be 3V. If these voltages are correct, check the DC current isolators T801-T803.
If a problem occurs with the broad band recorder output, check U801. Check the supply voltages +12V at the output side of U801.

7.17. IEEE-488 Interface

Check the supply voltages at the bus isolator input side and output side. Check the voltage levels at the address selector switches R501-R508 and make sure levels correspond with the address selector switches. Check the 1MHz clock signal at U608-13. Proceed by replacing integrated circuits U601, U606, U607, U608, U501, U502, U503, and U504.

7.18. Energy Converter Troubleshooting

If a problem occurs in the energy converter, check U701, U702, and U703.

8. LIST OF REPLACEABLE PARTS

Main PCA

C1, C18	Cap., Cer., 100pF, 5%, 100V
C2, C19	Cap., Cer., 1000pF+33OpF, 5%, 100V
C3, C20	Cap., Polyst., 100pF, 1%, 63V
C8, C25	Cap., Cer., 68pF, 5%, 100V
C16	Cap., Cer., 1000pF, 5%, 100V
C7, C24, C104	Cap., Polypr., 1nF, 5%, 100V
C4, C5, C21, C22, C14, C15 C31, C32, C102, C103, C109 C112, C113, C404	Cap., Polypr. 100uF, 5%, 100V
C17	Cap., Cer., 390pF, 5%, 100V
C6, C23, C12, C13 C29, C30, C105, C106	Cap., Polypr., 220nF, 5%, 100V
C9, C10, C11, C26, C27 C28, C101, C107, C108 C110, C111, C203, C204, C402 C406, C408, C410	Cap., Tant., 1.5uF, 35V
C201, C202	Cap., Cer., 22pF, 5%, 100V
C401	Cap., Electrol., 4700uF, 25V
C403, C405, C407, C409	Cap., Electrol., 1000uF, 40V
C411	Cap., Electrol., 100uF, 35V
D1-D14	1N4148, Si Diode
D406, D407	WO2, Bridge Rectifier
D401-D405	1N4002, Si Diode
J101, J202, J203	2-Row-Connector 14 pin
J201, J204	2-Row-Connector 20 pin
P1, P6	Pot., 5kOhm, Bourns 3296W
P2, P7	Pot., 200 Ohm, Bourns 3296W
P3, P11, P8, P9	Pot., 100kOhm, Bourns 3296W
P4, P10	Pot., 2kOhm, Bourns 3296W
P5	Pot., 1kOhm, Bourns 3296W
P101-P105	Pot., 500kOhm, Bourns 3296W
Q1	ZTX450, Si Trans. npn
R1	0.01Ohm Dale, 50W, 1%
R2	10Ohm Dale, 10W, 1%
R3-R22, R24-R40 R101-R139, R201-R204	M.F.Resistor, 1%, 0.4W, 250V
R23	Res., Phil, VR68, 5%, 1W, 7000V
S401	Voltage Range Selector
S1-S9	Relay FBR22D06P, FUJITSU
T401	Line Transformer 105A
U1, U5	AMP05FX, Amplifier PMI
U2, U5, U107	OP43GP, Amplifier PMI
U3, U6	AD637J, RMS Converter
U101, U105	DG212, Analog Switch MAXIM
U102	RC4200A, Raytheon
U103	TL074BC, Quad Amplifier
U104	OP400FY, Quad Amplifier
U106, U109, U8	74HC373, Octal Latch

U7	SN75423, Relay driver
U108	HADC574ZCC, 12bit A/D Converter
U201	MC6809C, Motorola
U202	74HCT245B, Bus Transceiver
U203, U204	2764, 8k EPROM
U205	6116P, RAM
U206	2804, EEPROM
U207	P8279, Key Board Encoder
U208, U209	74HC138, Decoder
U9, U10	74HC04, Hex Inverter
U11, U12	74HC32, Quad OR
U210	74HC08, Quad AND
VR401,405	LM340T-5, 5V Regulator
VR402,403	LM340T-15, 15V Regulator
VR404	LM7915CT, -15V Regulator
Z1, Z3	8.2V Zener, O.5W
Z2, Z4, Z102	12 V Zener, 0.5W
Z101	9.1V Zener, O.5W
Z401	15V Zener, 0.5W

Display PCA

D303	1N4148 Si Diode
J302	2-Row-Connector 14 pin
J301	2-Row-Connector 20 pin
LD301-316	GL-3NG5 green/GL-3PR5 red, LED
RN 301-RN302	9x100Ohm Resistor Network
S300-304	Print Switch ITT KSA
U301	74HC259E Latch
U302	74LS248N Decoder BCD/7 Segment
U303, U304	MSL 912 VFD Driver
U306-307	74HC373 Octal Latch
VFD1	Vacuum Fluorescent Display FUTAB 6-LT-15C
T301	npn-Transmitter 3904

Various Parts

MP01	Rear Panel assembly
MP02	Front Panel
MP03	Power Switch 10A/250V
MP04	Case 105A, KM7

Options

Bus Isolator PCA	
C601, C602	Cap., Polypr., 1nF, 100V
C603	Cap., Tantal, 1.5uF, 35V
J601, 602	2-Row-Connector 20 pol.
Q601	2N3904, npn Si Transistor
Q602	2N3906, pnp Si Transistor
R601-603	M.F.Resistor, 1%, 0.4W, 250V
U601, 606, 607, 608	74HC245, Bus Transceiver
U603-605	N1600, Quad Bus Isolator
U602	N1601, Dual Bus Isolator

IEEE-488 Interface PCA

J501	Cable Assembly, Interface to Isolator
J502	Cable Assembly, Interface to 24 pol. Amphenol
J503	Cable Assembly, Interface to Address Switch
R501-508	M.F.Resistor, 4.75k, 1%, 250V
U501-502	MC3447L, Line Driver
U503	MC68488, Interface Adapter
U504	74HC373, Octal Latch

Energy Converter PCA

J701	2-Row-Connector, 14 pol.
U701	74HC373
U702	74HC4040
U703	CD4020

Recorder Output PCA

C801, 802, 805, 806 C813, 814	Cap., Polypr., 100nF, 5%, 100V
C803, C804	Cap., Cer., 270pF, 5%, 100V
C807, 811, 812	Cap., Tantal, 10uF, 35V
C808, 809	Cap., Cer., 22pF, 5%, 100V
C810	Cap., Polypr., 1nF, 5%, 100V
D801-804	EGP10D, Fast Recovery Diode
D805	1N4148, Si Diode
J801, 802	2-Row-Connector 14 pol.
P801	Pot., 20kOhm, Bourns 3296W
P802	Pot., 1kOhm, Bourns 3296W

P803-805	Pot., 200Ohm, Bourns 3296W
Q801, 804	ZTX109C, npn Transistor
Q802	ZTX452, npn Transistor
Q803	ZTX552, pnp Transistor
Q805	IRF510, MOSFET Power Transistor
R803-816	M.F.Resistor, 1%, 0.4W, 250V
T801-803	DC Current Isolator
VR801	LM78L12, +12V Regulator
VR802	LM79L12, -12V Regulator
Z801	BZX55C15, 15V Zener
Z802	BZX55C56, 56V Zener

9. SCHEMATICS DIAGRAM

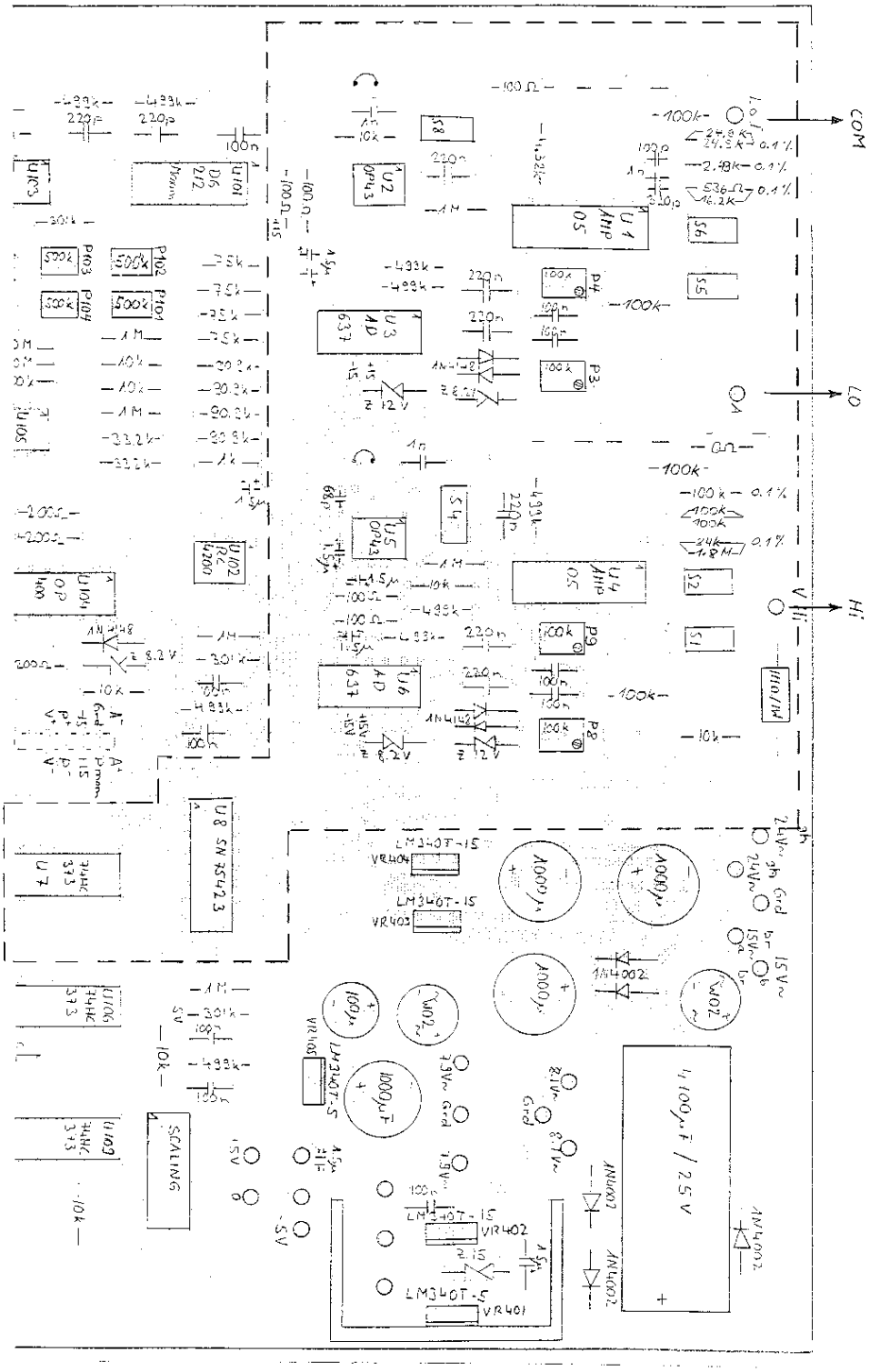


Figure 9.1. Voltage- and Current Amplifier PCA

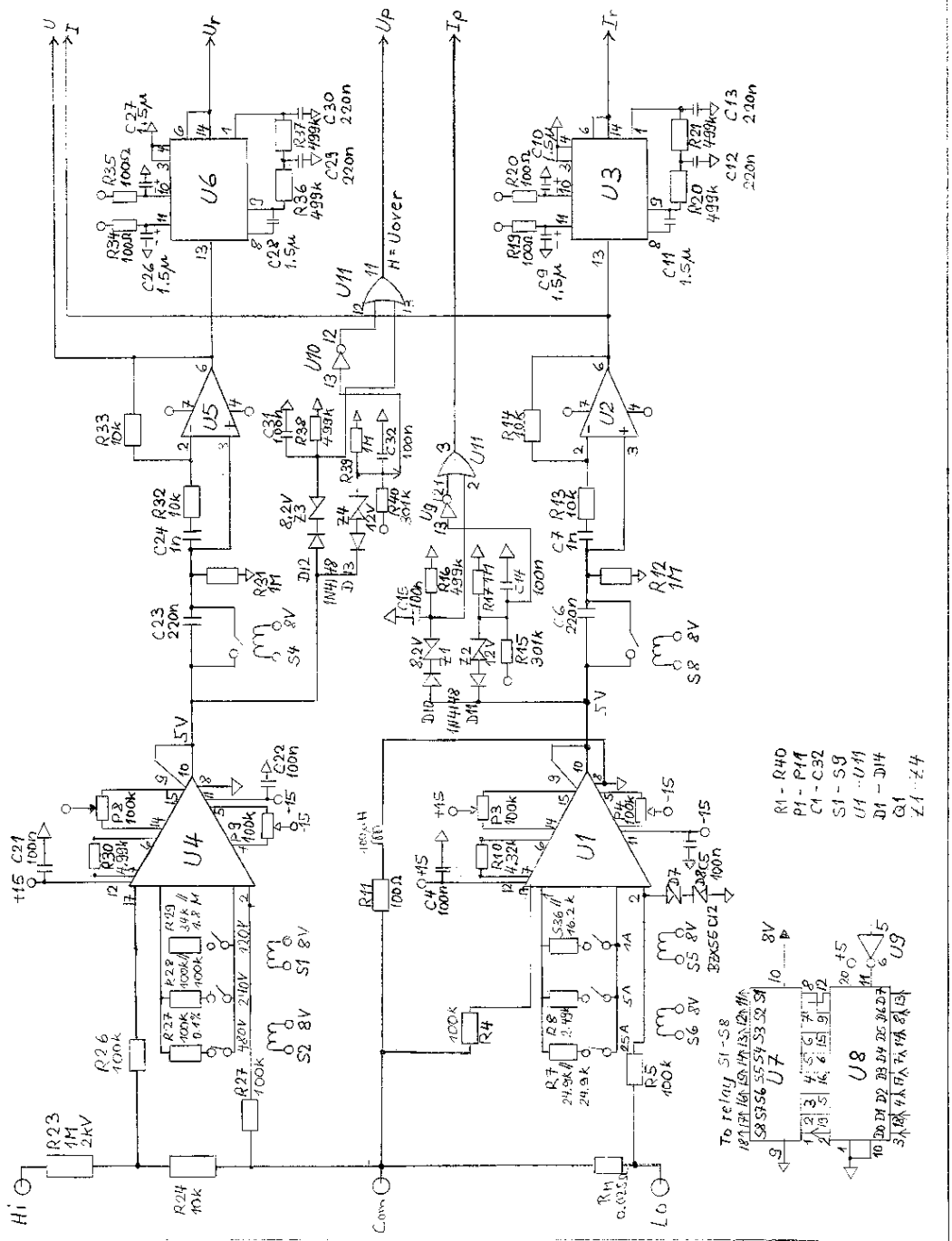


Figure 9.2. Voltage- and Current Amplifier PCA

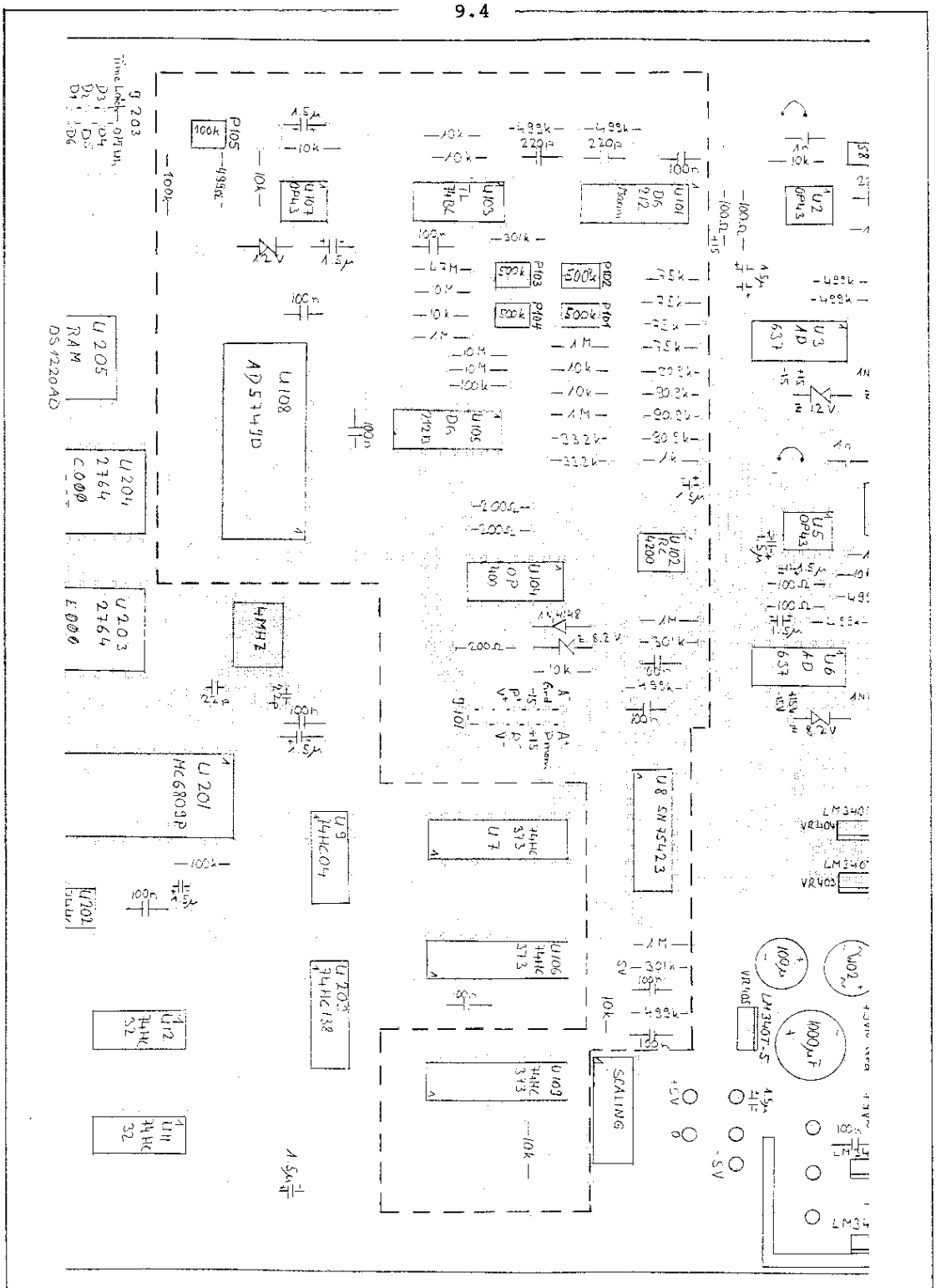


Figure 9.3. Watt- and A/D Converter PCA

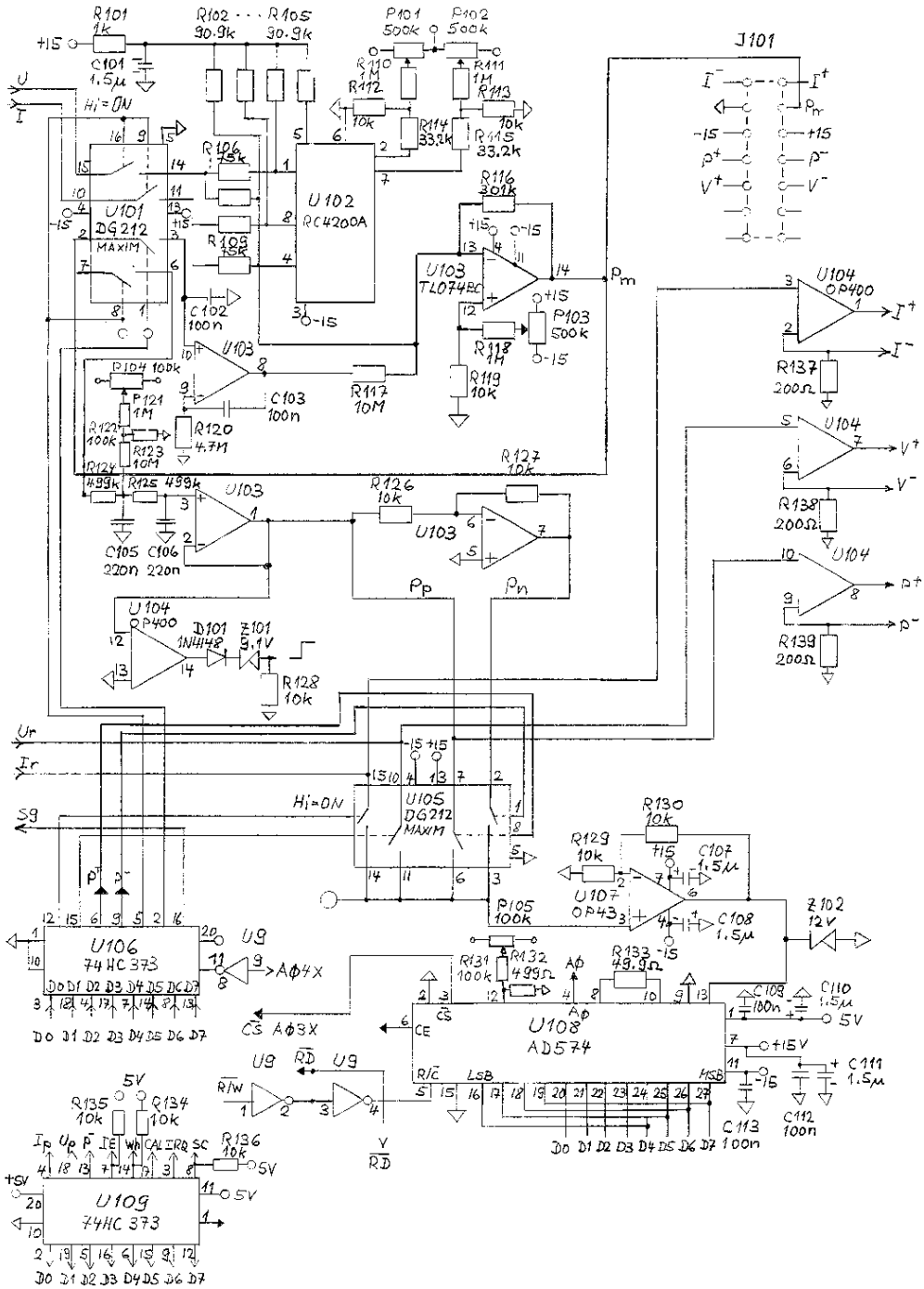


Figure 9.4. Watt- and A/D Converter PCA

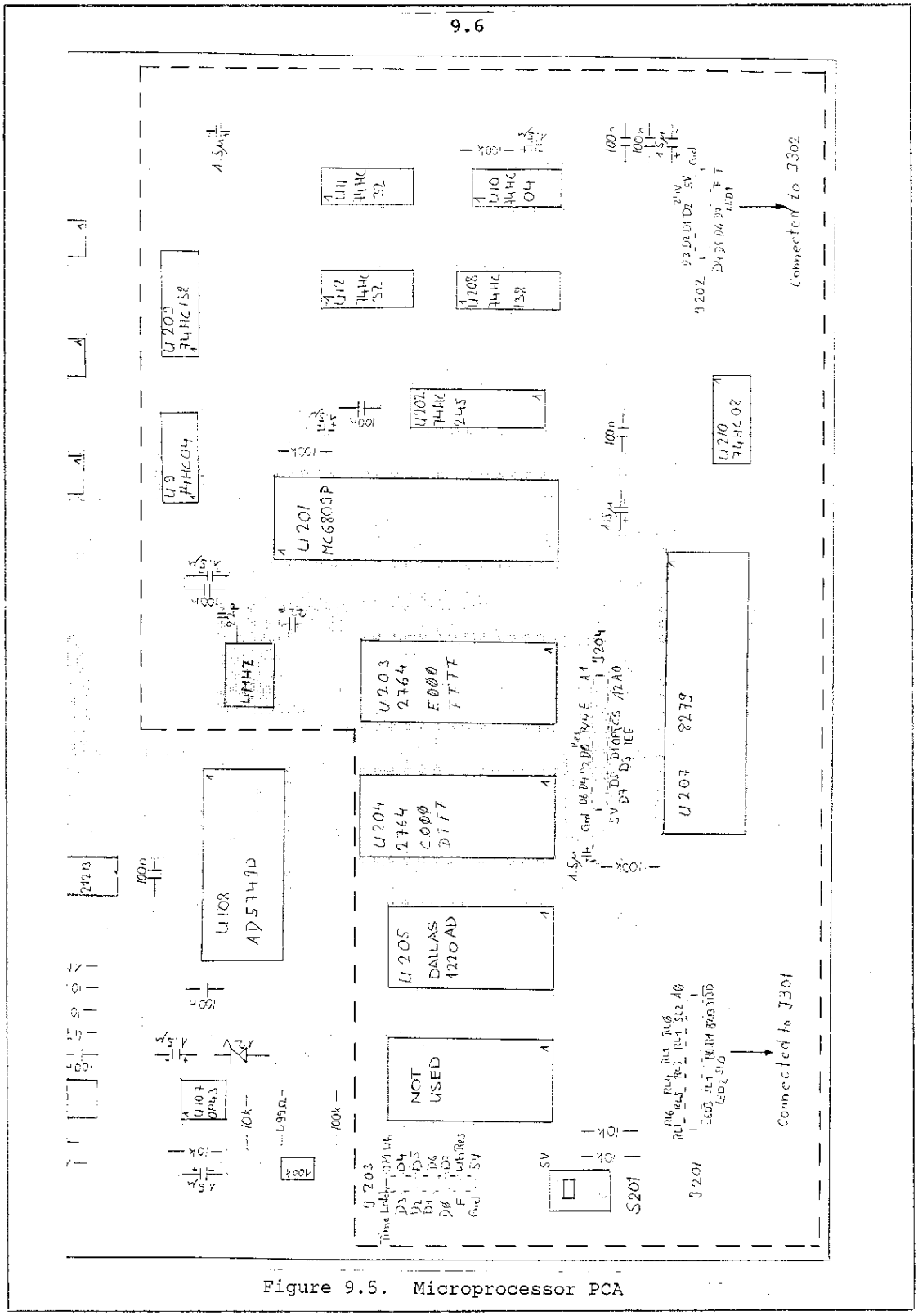
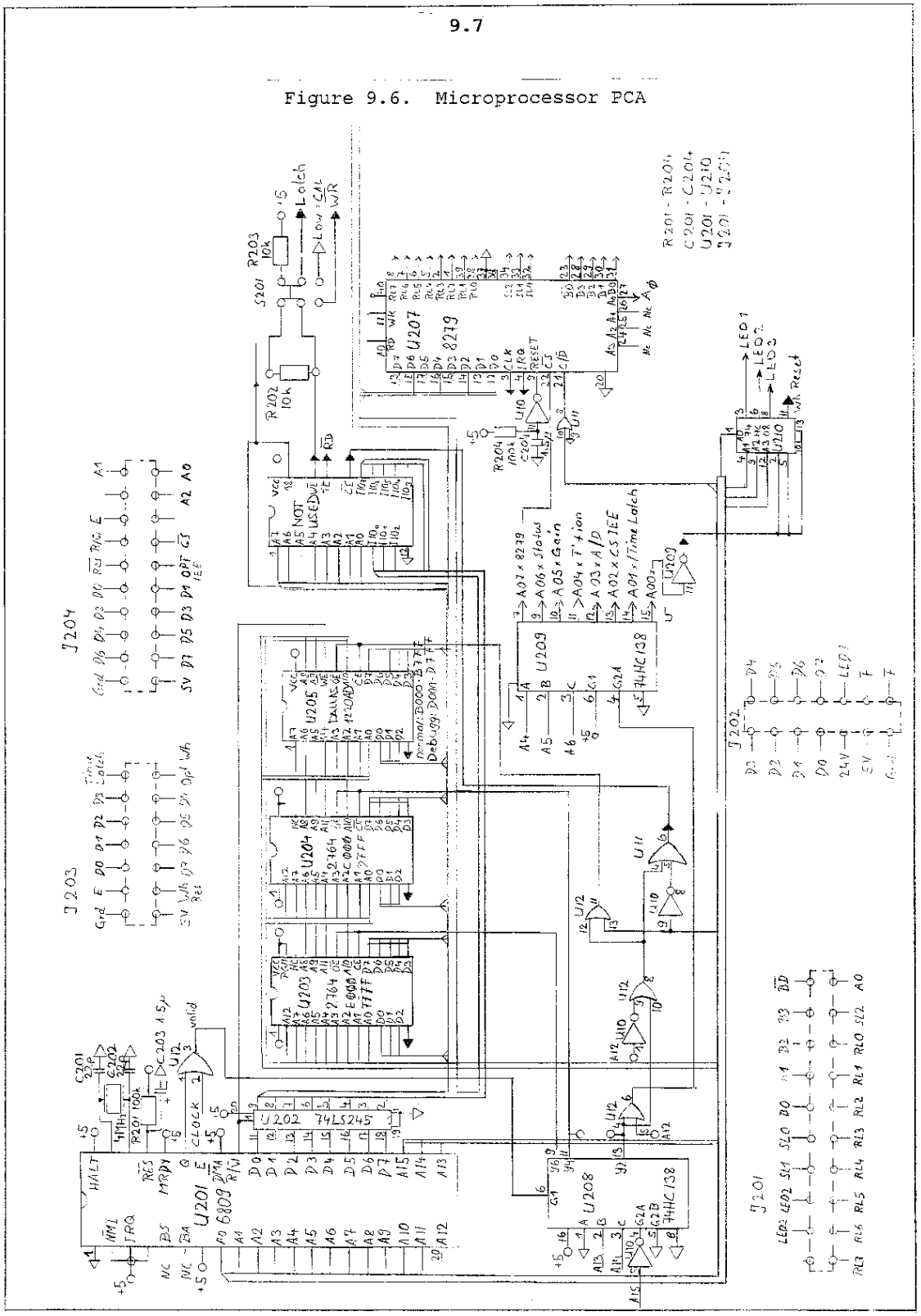


Figure 9.5. Microprocessor PCA

Figure 9.6. Microprocessor PCA



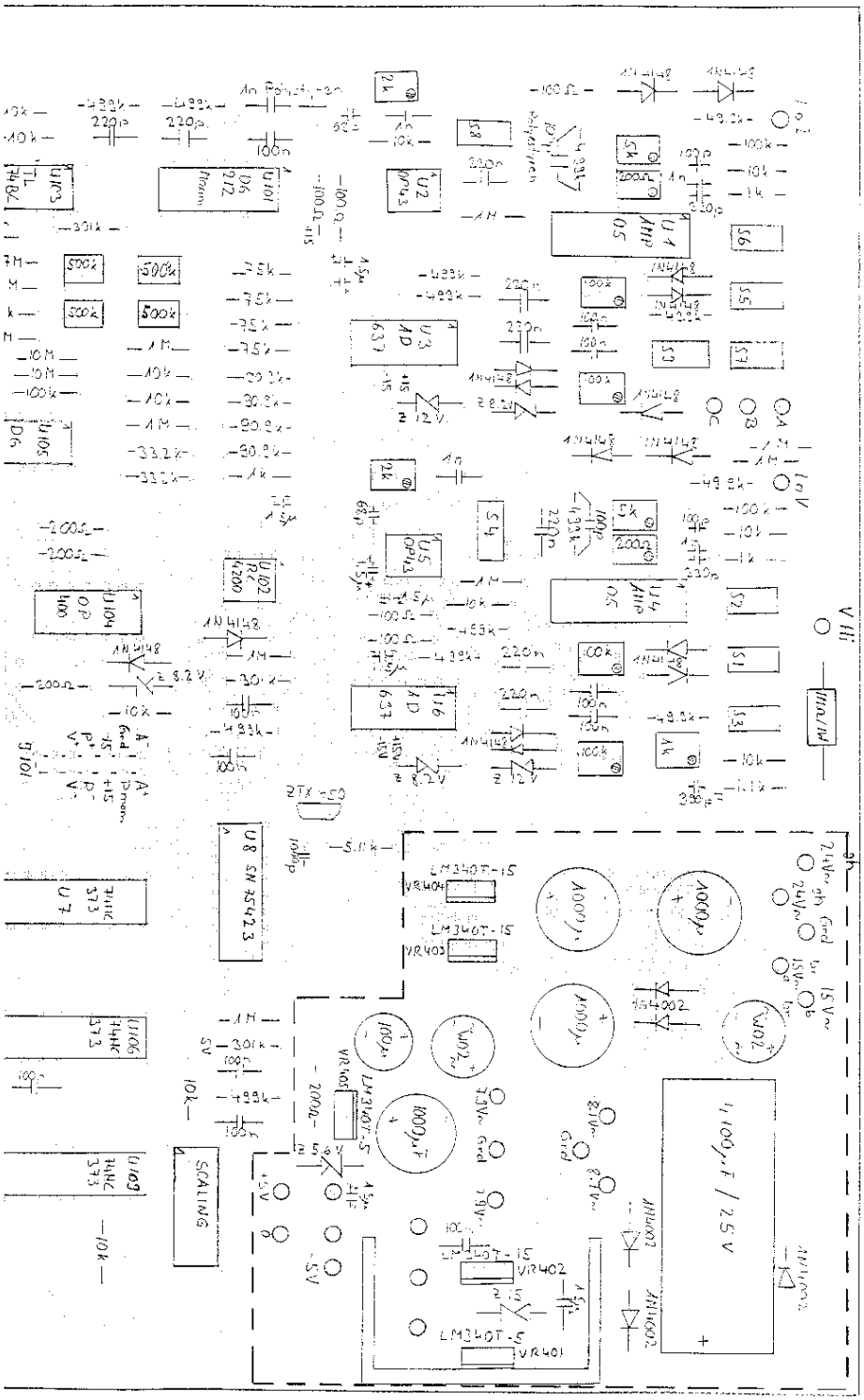


Figure 9.7. Power Supply PCA

C 401 - C 411
S 401
VR 401 - VR 405
D 401 - D 405
Z 401

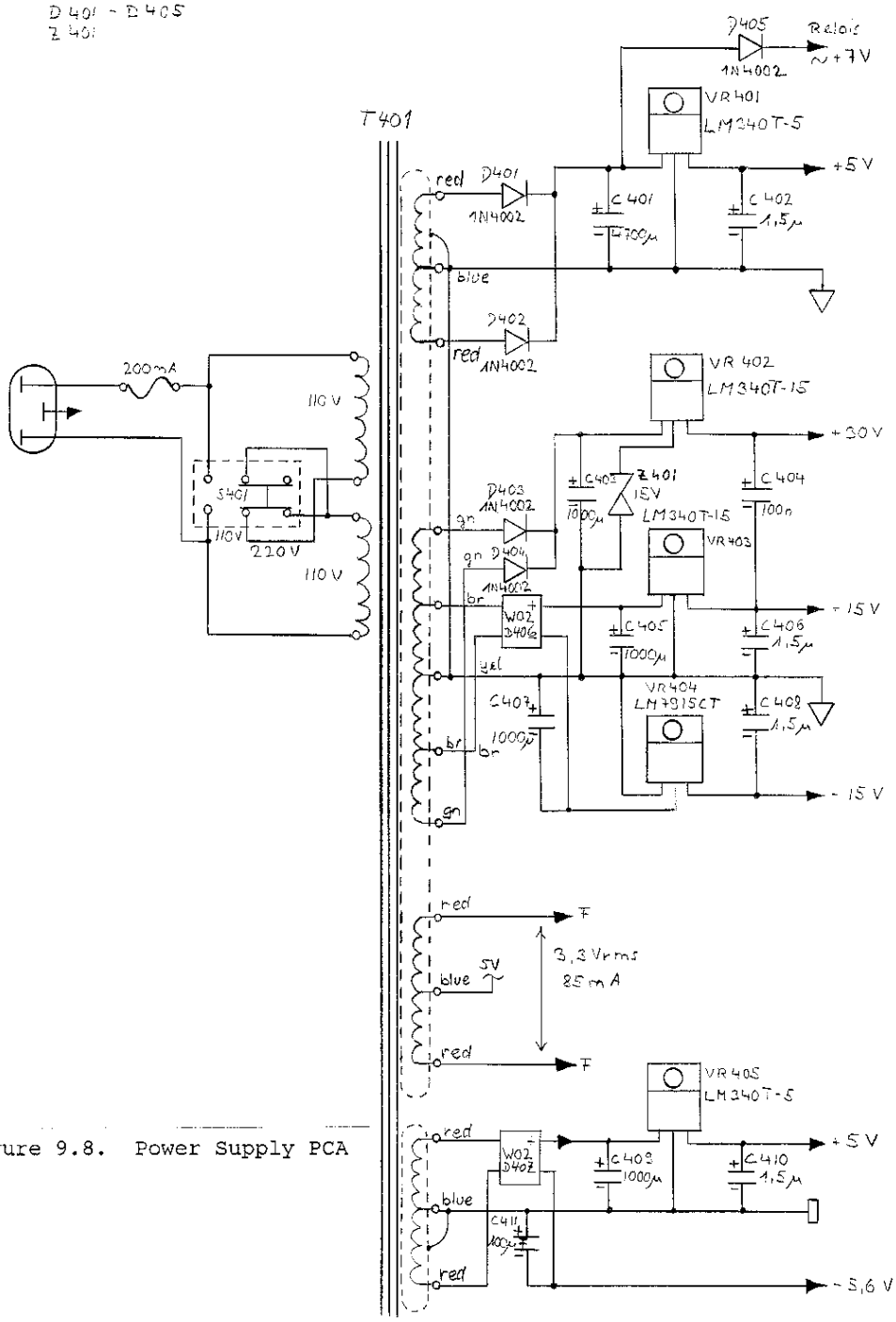
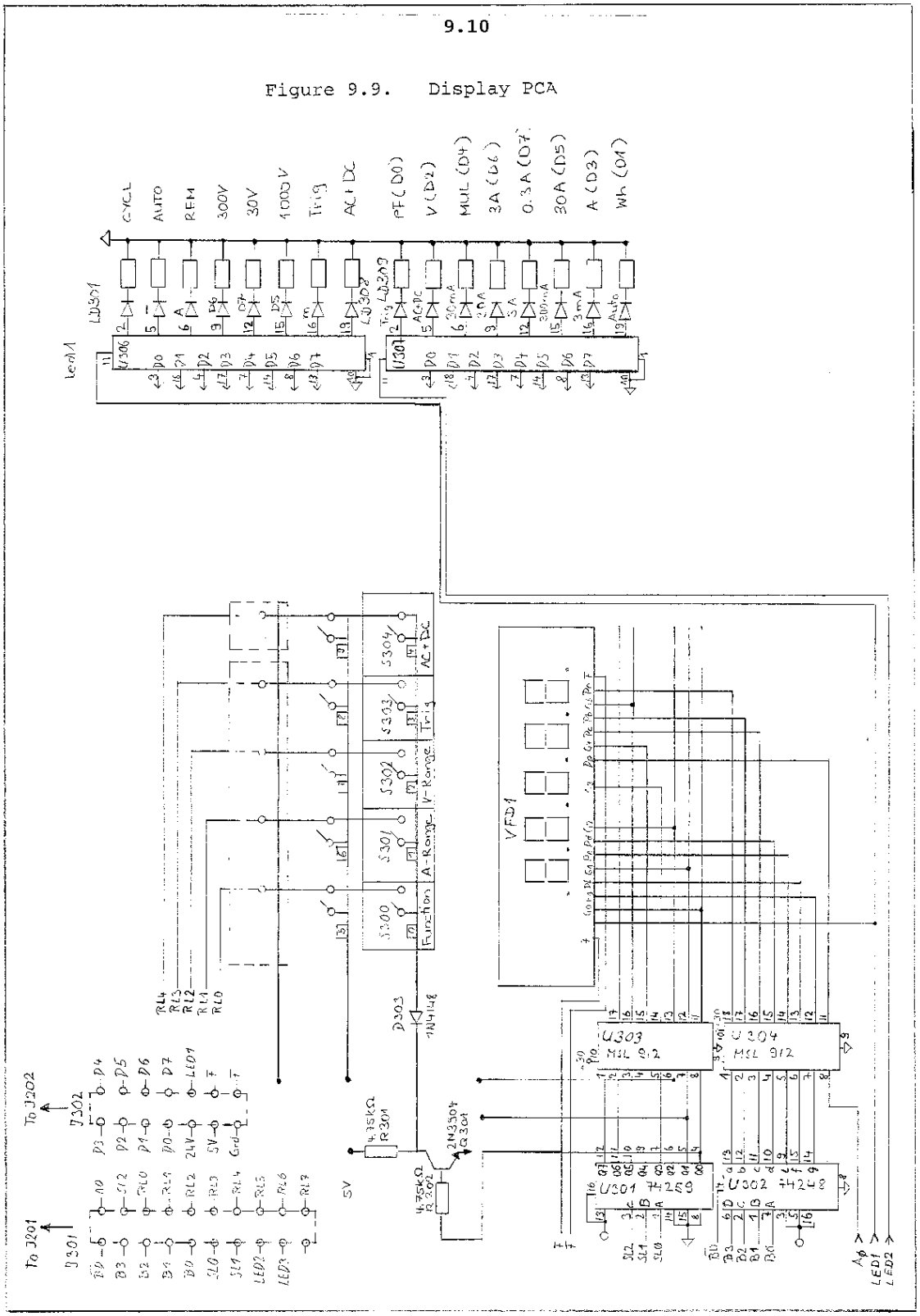


Figure 9.8. Power Supply PCA

Figure 9.9. Display PCA



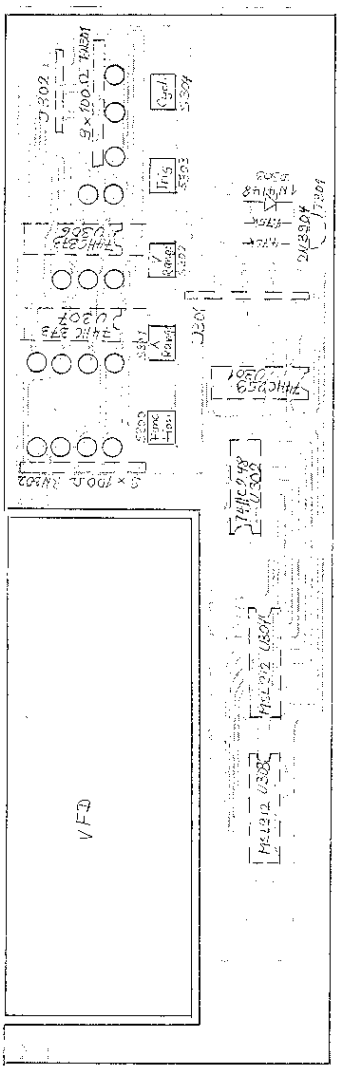
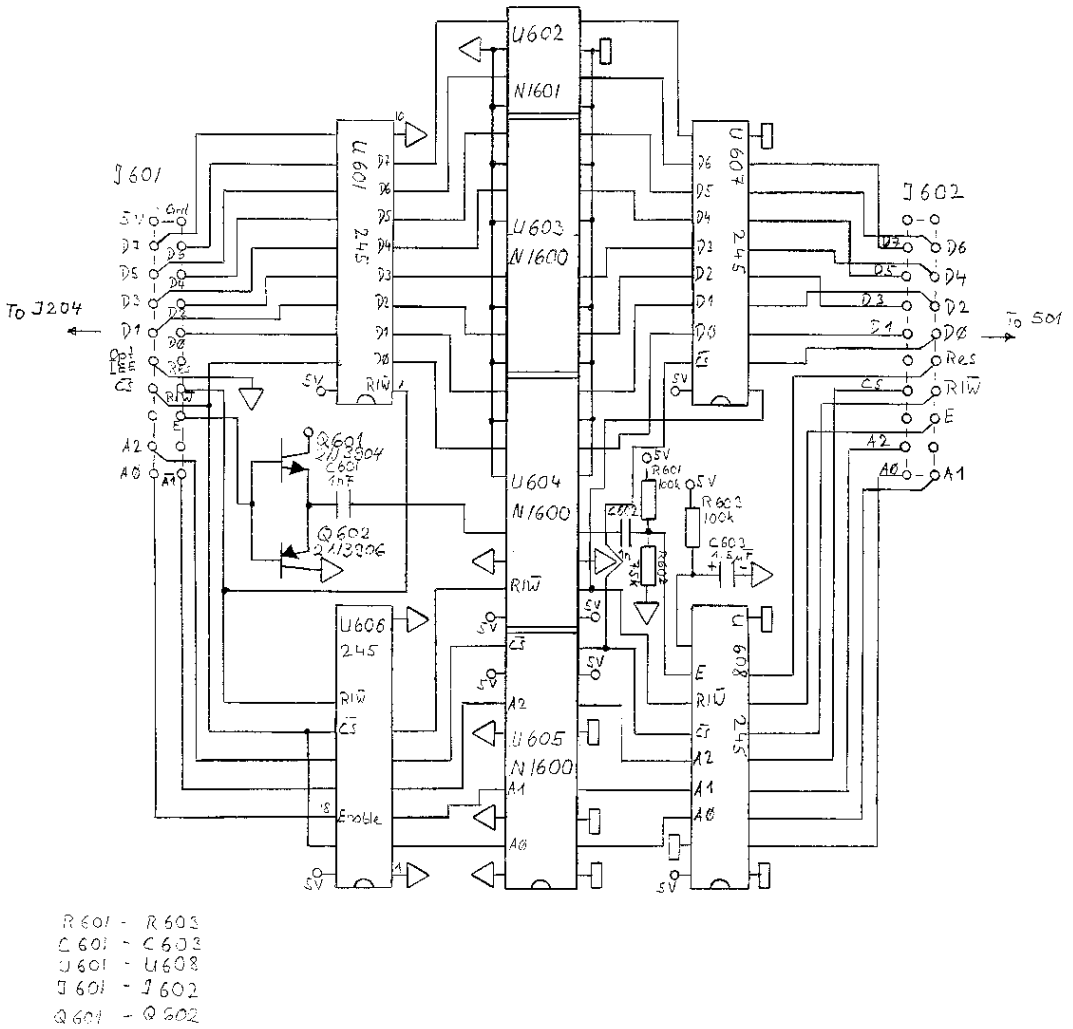


Figure 9.10. Bus Isolator PCA



R601 - R603
C601 - C603
U601 - U608
J601 - J602
Q601 - Q602

Figure 9.11. Bus Isolator PCA

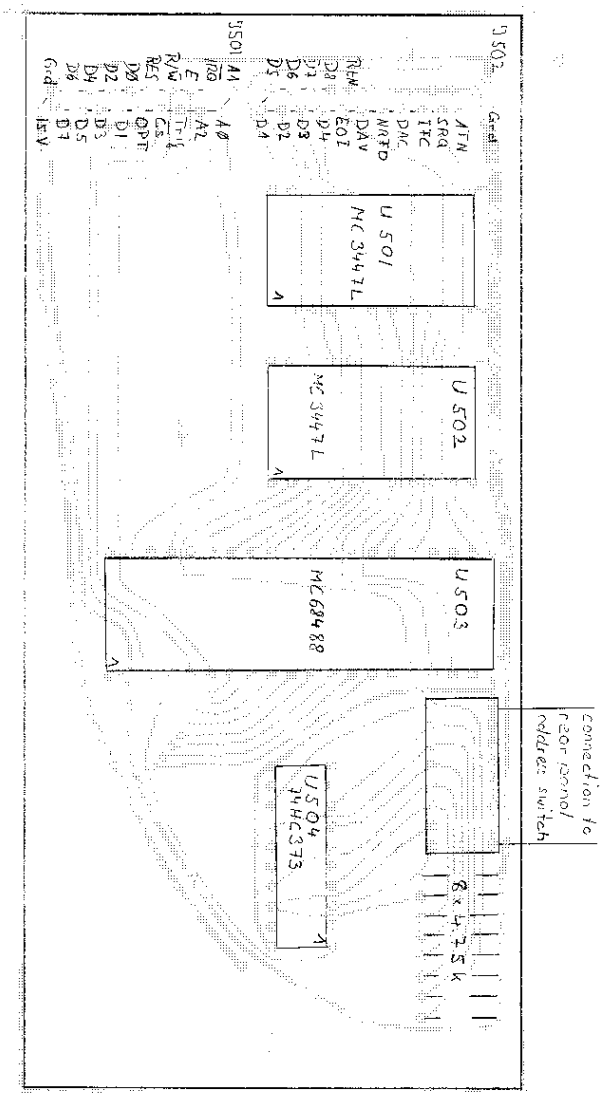


Figure 9.12. IEEE-488 Interface PCA

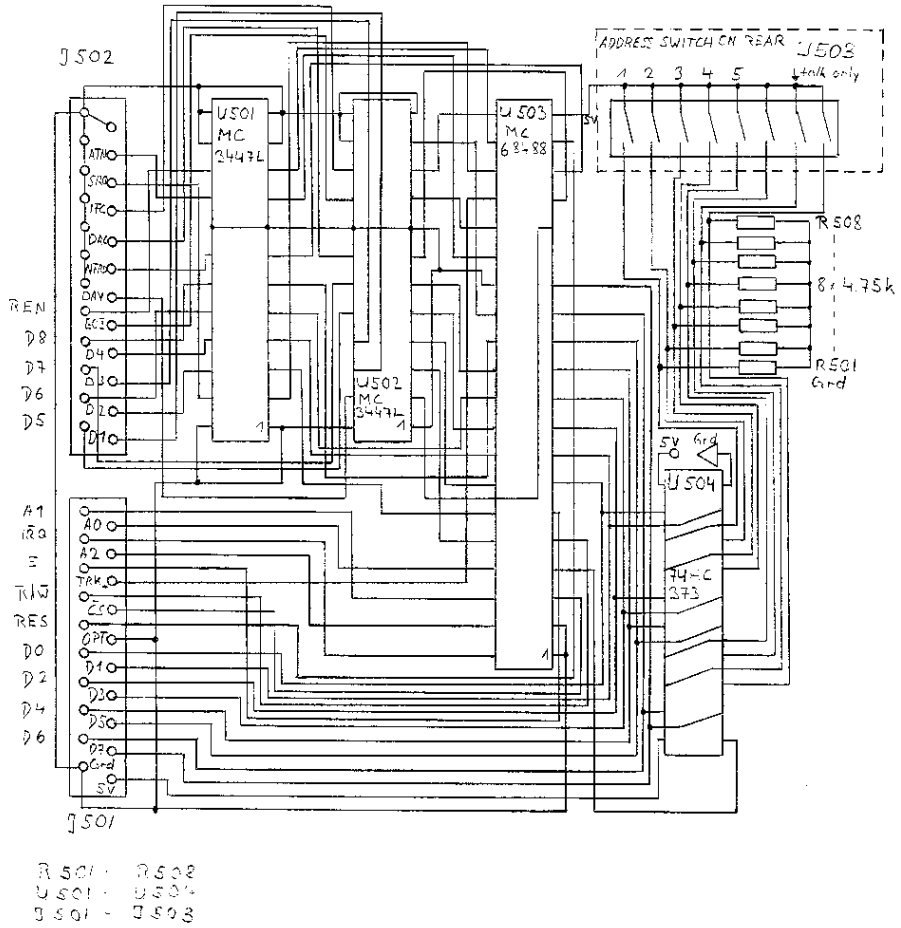


Figure 9.13. IEEE-488 Interface PCA

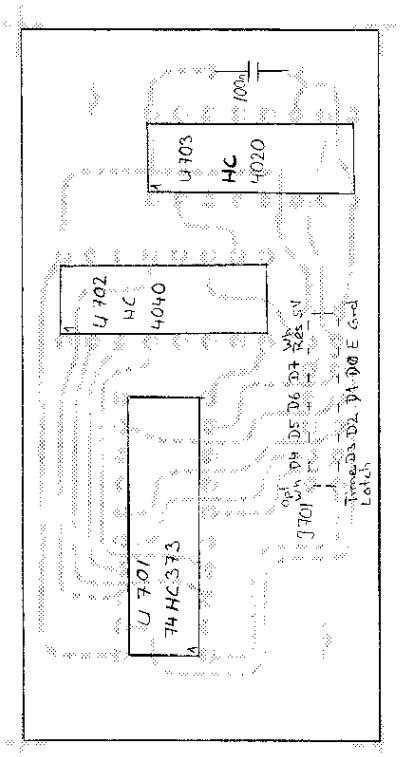
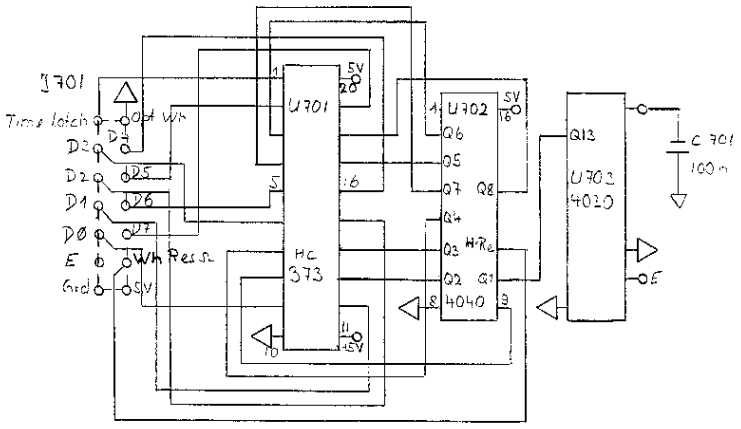


Figure 9.14. Energy Converter PCA



C 701
U 701
U 701 - U 703

Figure 9.15. Energy Converter PCA

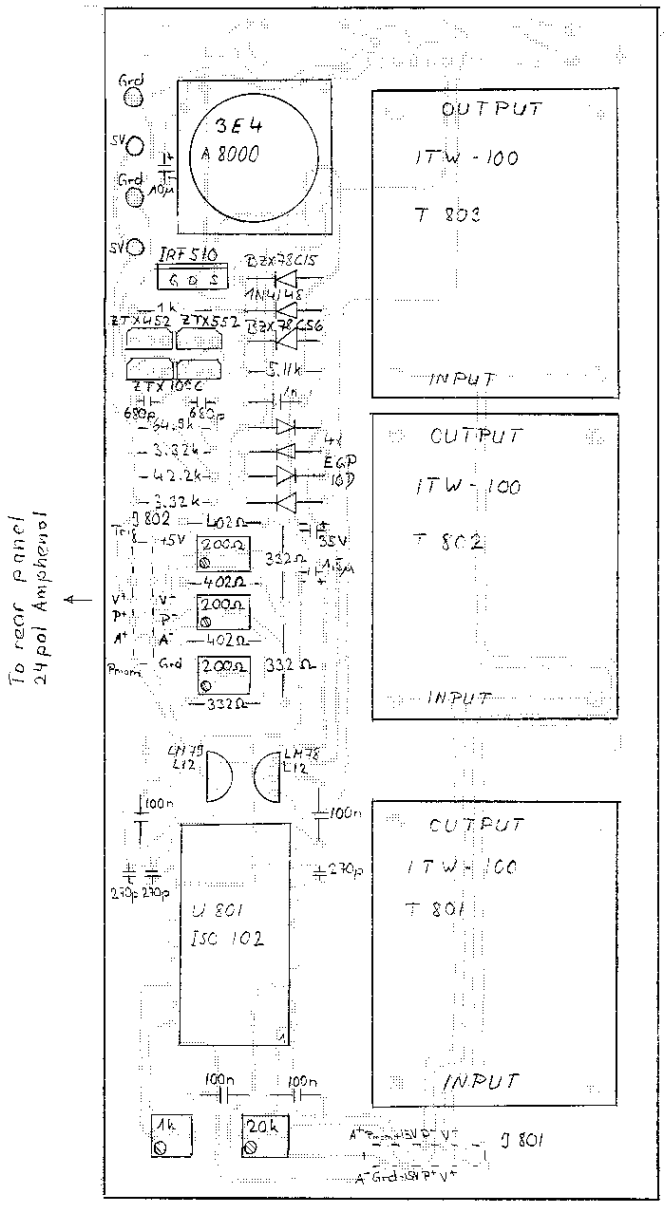
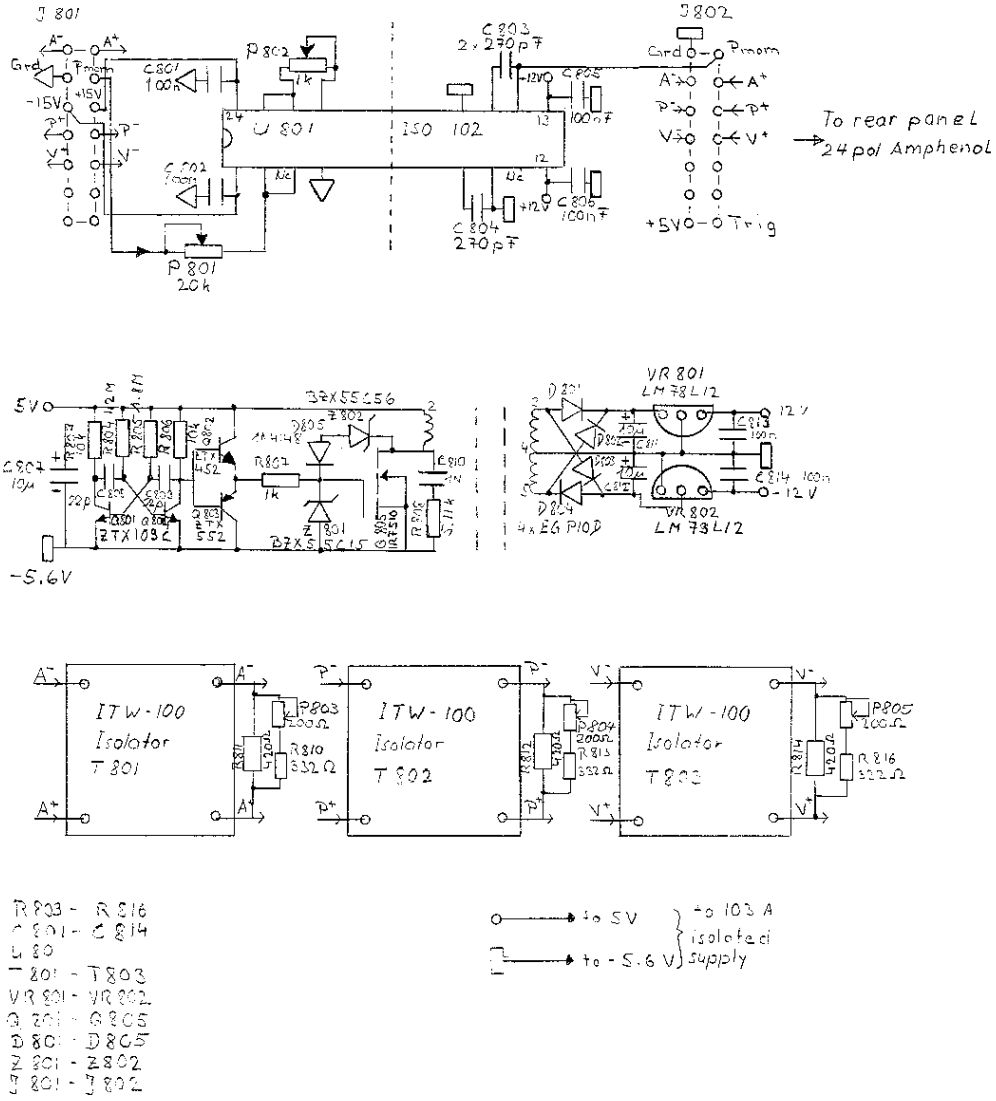


Figure 9.16. Recorder Output PCA



R 803 - R 816
C 801 - C 814
L 80
T 801 - T 803
VR 801 - VR 802
Q 801 - Q 805
D 801 - D 805
Z 801 - Z 802
J 801 - J 802

Figure 9.17. Recorder Output PCA