NEUROTHERM

RADIO FREQUENCY

LESION GENERATOR

MODEL NT 1100

Service Manual

1.0 CONTENTS

1.1 List of Figures

2.0 WARNINGS AND CAUTIONS

Warning indicates a potentially harmful situation to yourself or others.

HAZARDOUS ELECTRICAL OUTPUT: The equipment is for use **ONLY** by qualified medical personnel.

Do **NOT** under any circumstance perform any testing or maintenance on the equipment while it is being used on a patient.

Do **NOT** use extension cords or adapters of any type. The power cord and plug must be intact and undamaged.

Should the power cord or plug become cracked, frayed, broken of otherwise damaged, it must be replaced immediately.

If the equipment has in any way suffered mechanical damage it should be returned to the Supplier for Inspection and Test before further use.

Unplug the power cord before cleaning or service.

The operator should not perform any servicing of the equipment. Any servicing should only be carried out by qualified personnel.

EXPLOSION HAZARD: Equipment not suitable for use in the presence of a flammable anaesthetic mixture with air or with oxygen or nitrous oxide.

ELECTRIC SHOCK HAZARD: Always turn the equipment off before cleaning and **DO NOT** allow **ANY** fluid to enter the ventilation holes or sockets.

ELECTRIC SHOCK HAZARD: Do not touch any exposed wiring or conductive surface, while cover is off and the equipment is energised. The voltage present when the electric power is connected to the equipment can cause injury or death. **Never** wear a grounding wrist strap when working on energised equipment.

FUSE REPLACEMENT: For continued protection against fire hazard, replace only with same type and rating of fuse as displayed on the rear Serial Number Plate.

IMPROPER LINE VOLTAGE: The voltage selector on the mains input socket is factory set and should not be changed by the user. The serial number plate shows the correct mains input voltage for the machine and the rating of the fuses to be used in the mains input fuse holder. An incorrect voltage setting may result in Neurotherm malfunction and potential damage.

2.0 WARNINGS AND CAUTIONS (continued)

A CAUTION indicates a condition that may lead to equipment damage or malfunction.

Servicing of the equipment in accordance with this service manual should never be undertaken in the absence of proper tools, test equipment and the most recent revision of this service manual which is clearly and thoroughly understood.

When repairing circuit boards, great care should be taken in handling boards as all boards contain static sensitive devices. Before servicing a board, ground yourself and the relevant tool to discharge any accumulated static charge by wearing a wrist strap and placing the board on a static mat. If a board has to be returned, use anti-static bags or containers.

The tests and repairs outlined in this manual should only be attempted by trained personnel. Unauthorised service may void the warranty of the unit.

Check the voltage rating on the rear Serial Number Plate before connecting the equipment to AC Mains Power. The equipment must never be operated at the wrong mains voltage.

Use insulated tools when adjusting the internal controls on the equipment.

When cleaning the outer casing or display panel of the equipment do not use abrasive agents or solvents.

To reduce risk of electrical shock do not remove back panel of generator. Refer servicing to qualified personnel.

3.0 INTRODUCTION AND APPLICABILITY OF THIS MANUAL

3.1 Introduction and applicability of this manual

This service Manual (Document No. R1000) gives the information required to maintain and repair the Neurotherm Radio Frequency Lesion Generator Unit, Model NT1100. The main body of this manual deals with the present production revision of the equipment. Differences between equipment revision are summarised in Section 3.2. Section 3.3 lists the technical changes made to the equipment.

The revision of the whole equipment is changed if such technical changes are made which make some spare parts incompatible with earlier units. The initial equipment numbering, as shown on the rear Serial Number Plate contains no revision letter (e.g. Serial No. NT1100-7020-05) however later revisions will contain a revision letter (e.g.Serial No. NT1100-7020-05 Rev A). If the whole machine is upgraded such that early machines cannot be easily amended, then the upgraded machines will start from a nominated serial number as indicated in Section 3.2.

Within the equipment, function units such as Printed Circuit Boards will be changed or updated from time to time, these may or may not introduce a revision of the whole equipment. Each printed circuit board contains an identity number and a serial number of the board together with the issue number - designated by a letter. The initial issue letter was A for all Boards. In all cases the spare parts order code is also the Board Identity Number and Issue Number (e.g. RF 102E).

In order to understand this manual it is necessary to have a complete understanding of the function and operations of the Lesion Generator Machine. This information can be obtained from the Operators Manual which contains full operating instructions.

3.2 Summary of Equipment Revision Changes

Initial production revision of this equipment – Model NT1100

Initial production DEC 2005

Start from
NT 1100 – 7007-05

From
NT1100 – 7150 – 06 (May 2006)
Metal Rack used and all cards in rack were changed to move components away from guides

3.3 Summary of Board Revision Changes

3.3.1 Revision A – All Boards NT1100

Initial production revision of this equipment

Power Supply Board	RF100C
Fuse Board	RF101C
Impedance Board	RF102C
Stimulate Board	RF103C
RF Power Amplifier Board	RF104C
RF Voltage and Current Board	RF105B
Temperature Board	RF106C
Interlock Board	RF107C
Front Panel and Connection Board	RF109B
Interface Board	RF110C
Computer Motherboard	RF111B
Card Rack Backplanes	RF115A and RF116A

3.3.2 Revision B – Boards in rack

Fuse Board	RF101D
Impedance Board	RF102D
Stimulate Board	RF103D
RF Voltage and Current Board	RF105C
Temperature Board	RF106D
Interlock Board	RF107D
Interface Board	RF110D
Card Rack Backplanes	RF115B and RF116B

3.4 Manual Updates

3.4.1 Neurotherm Radio Frequency Lesion Generator Unit Manual Changes

This is the NT 1100 Manual applicable to the machines from serial numbers shown below:-

Issue No.	From Serial No	Page	Change	Date
	NT1100 – 7007-05		As issued	DEC 2005
2	NT1100 – 7150-06			JUNE 2006

3.4.2 Record of Manual Updates carried out

Update Number	Carried out by Name	Date
2	Howard Clarke	June 2006

4.0 GENERAL DESCRIPTION AND PRINCIPLE OF LESIONING

4.1 Specifications

SIZE:

Width	400 mm (15 ¾”)
Height	300 mm (11 ¾”)
Depth	415 mm (16 ½”)

WEIGHT:

12.5 kg (28 lbs)

ELECTRICAL:

EUROPE	230 Volts 50Hz Fused 1 Amp on live and neutral
USA/CANADA	110 Volts 60Hz Fused 2 Amp on live and neutral

Voltage change via rear connector

Power Consumption 150 watts

The power supply is built to Class 2 standard. The mains transformer and all mains related parts are doubly insulated from the Main Enclosure. The mains transformer has separate isolated bobbins for mains and low voltage windings. Thermal fuses (rated to fail at 125°C) are fitted into all primary and secondary windings.

The machine is not connected to mains earth (class2).

STANDARDS:

This instrument complies with

EN60601-1:1997
IEC60601-1-2:1993
IEC60601-2-2:1998
IEC60601-2-10: With Canadian deviations

With respect to electrical shock, fire and mechanical hazards only in accordance with UL60601-1, IEC60601-1, CAN/CSA C22.2 No.601.1 and IEC 60601-2-2

IMPEDANCE

Measuring frequency		53KHz (± 3KHz)
Measuring source voltage		Less than 500 mV AC
Measuring Display		50-2000 ohms (one ohm resolution)
Accuracy		±5%
Features	(a)	Internal 500 ohm Test Resistor
	(b)	Impedance in all Lesion Modes and in Stimulation Mode when stimulation is off
	(c)	Audible Tone available where frequency varies with impedance over full impedance range (50-2000 ohms). Audible tone is adjustable and mutable.
	(d)	Warning on screen if impedance is less than 50 ohms or greater than 2000 ohms.

STIMULATION MODE

Signal Shape		Biphasic square wave with negative edge leading. This wave is available in a variety of frequencies and widths.
Output Range	Voltage	0-5v ± 3% for motor frequencies (2Hz and 5 Hz) 0-3v ± 5% (Default) for all other frequencies 0-0.5v ± 10% for all other frequencies
	Current	0-10mA±5% 50-2000 ohms 0-6mA± 5% 50-2000 ohms 0-1mA± 5% 50-2000 ohms
Pulses Rates	Motor	2 or 5 Hz (Default 2Hz)
	Sensory	10,20, 50, 75, 100, 150, 180, 200 Hz (Default 50 Hz)
Pulse Rate Accuracy		± 3%
Pulse Widths		0.1, 0.2, 0.5 and 1.0 mS (Default 1.0 mS)
Pulse width Accuracy		± 5% for 0.2, 0.5 and 1.0 mS ± 15% for 0.1mS

Features	(a) Hardware and Software lockout if voltage / current control not initially set to zero. (b) Warning on screen if stimulation control is not initially at zero. (c) Flashing LED on front panel indicates machine is delivering stimulation pulses. (d) Stimulation Test Socket is provided on front of machine to interface with the standard stimulation test kit. (e) Various screen displays for displaying amplitude of each stimulation procedure.

LESION MODE

RF Waveform	480 KHz ± 5% Sinusoidal
Power Output	Continuously variable. Maximum power output 30 watts ± 5% into 200 ohms. Power is displayed in certain Lesion Modes.
Voltage Display on screen	0-99RF volts (RMS)
Current Display on screen	0-999RF milliamps (RMS)
Self Test	150 ohm dummy load resistor built into machine
Lamp Indicator	LED flashes when Lesion Power is being delivered.
Temperature Range	Selectable 50-90°C for Thermal Lesion (Default 80°) Selectable in 5° C steps in initial screen set ups Selectable in 1°C steps when in Lesion Mode using "Temp up and Temp down" buttons.
Time	Selectable 0:30 to 10:00 mins (Default 1:00 minute) Selectable in 30 seconds steps in initial screen set ups Selectable in 1 second steps when in Lesion Mode using "Time up and Time Down" buttons
Special Temperature Profiles	A series of fixed temperature/time profiles are programmed into the generator: P1, P2, P3. The user can also program a custom profile with the following characteristics: Start Temperature 50-60°C (Default 50°C) Step Time 00:10 to 3:00 mins (Default 2 mins) Step Rise 1°C or 5°C (Default 5°C) Final Temperature 65° - 90° C (Default 65°C) Final Dwell Time 1:00–10:00 Minutes (Default 4.00 mins

Lesion Start	Lesion starts as soon as temperature is within 5°C of desired temperature.
Auto Mode	With Lesion Power Control off, the procedure can be carried out under Automatic control by pressing the "Auto start" button. The temperature will ramp up at 8°C per second and time will start when the measured temperature is within 5°C of desired temperature. The lesioning can be stopped at any time by pressing the "Auto Stop" Button.
Display	Temperature is displayed against time as a curve on the screen together with a display of "Measured temperature" and "Time to completion of lesion". RF Lesion power (or voltage and current) together with impedance are also displayed.
Audible Indicator	An alarm tone (with a volume adjustment) will indicate the end of the procedure.

PULSE RF MODE

In pulsed mode the waveform is pulsed rather than continuous.

Pulse Widths	5ms, 10ms, 20ms, 50ms (default 20 ms)
Pulse Frequencies	1Hz, 2Hz, 5Hz, (default 2 Hz)
Temperature Range	Selectable in 42-65°C range, (default 42°C)
Time	Selectable 00:30 to 20:00 minutes (default 2:00 mins)
Set Volts/ Current	Pulsed RF can be carried out in Auto Mode at fixed voltage or current. Voltage range 30-70 Volts (default 45 Volts) Current range 50-350 mA

PULSE DOSE MODE

In Pulse Dose Mode the numbers of Pulses of Pulsed RF are counted. Pulse Dose Procedures are carried out in Auto Mode.

Set Temperature	42°C
Pulse Counts	120-1200 count (Default 240 counts)
Rate	2Hz
Width	20 mS
Set Voltage Range	30-70V (Default 45V)
Set Current Range	50-350 mA

MULTIPLE PROBES

The Neurotherm can be operated with 1,2 or 3 probes. When in Stimulation Mode each probe is selected by the operator for Stimulation. In RF Lesion, Pulse RF or Pulse Dose Mode the generator energises all connected probes in a time interlacing method. In multiple probe operation not all pulse rates are available.

Features

(a) Hardware and Software lockout if RF Power Control not initially set to zero.
(b) Warning on screen if RF Control is not initially set to zero or if Auto is selected and RF control is not off.
(c) LED Flashes on front panel to indicate machine is delivering power.
(d) Three output sockets to accept a variety of probes, (including cordotomy (optional extra)) and enable multiple probe peration.
(e) Hardware lockout if temperature exceeds 95°C.

MAJOR FEATURES

Touch Screen Operation – User interface set up and software control via TP 400 processor.

Windows CE4.2. NET Operating System.

12.1" LCD Sceen with Back lighting and wide antiglare visibility.

Printer Support	Via Bluetooth adaptor internally fitted.
Remote Mimic Screen	Optically isolated running over CAT5 Cable to External TFT screen up to 300 metres.
Storage Device	USB Memory Stick for downloading log files.
Service Ports	Only accessible by service engineers for keyboard + mouse.

Any equipment connected to rear sockets must comply with IEC60950 and IEC60601-1

Use only parts supplied by Neurotherm Ltd. Any other parts will void the warranty and may cause danger to the patient.

Earth Leakage

1	Enclosure leakage current Normal Reverse Single fault condition Normal Reverse	 40 microamsps 40 microamsps 40 microamsps 40 microamps	 100 microamps 100 microamps 500 microamps 500 microamps
2	Patient leakage current Normal (AC) Reverse (AC) Single fault condition Normal (AC) Reverse AC)	 5 microamps 4 microamps 7 microamps 7 microamps	 100 microamps 100 microamps 500 microamps 500 microamps
3	Patient Leakage current Normal (DC) Reverse (DC) Single fault condition Normal (DC) Reverse (DC)	 4 microamps 4 microamps 4 microamps 4 microamps	 10 microamps 10 microamps 50 microamps 50 microamps
4	Patient Auxiliary Leakage Current Normal (AC) Reverse (AC) Single Fault Condition Normal (AC) Reverse (AC)	 4 microamps 4 microamps 6 microamps 6 microamps	 100 microamps 100 microamps 500 microamps 500 microamps
5	Patient Auxiliary Leakage Current Normal (DC) Reverse (DC) Single Fault Condition Normal (DC) Reverse (DC)	 4 microamps 4 microamps 4 microamps 4 microamps	 10 microamps 10 microamps 50 microamps 50 microamps
6	Patient Leakage Floating Type Normal Reverse Single Fault Condition Normal Reverse	 27 microamps 27 microamps 36 microamps 35 microamps	 5000 microamps 5000 microamps 5000 microamps 5000 microamps

Environmental Conditions

7	Transport	Temperature Humidity Pressure	-10°C to 70°C 0-95%RH 140-760mmHg	Non-Condensing (0-12,200 metres) (0-40, 000ft)
8	Storage	Temperature Humidity Pressure	10°C to 60°C 10 to 80% RH 520-760mmHg	(0-3000 metres) (0-10,000ft)
9	Operating	Temperature Humidity	10°C to 40°C 10 to 80% RH	

Figure 4.1 Output Power/Load Resistance Curve

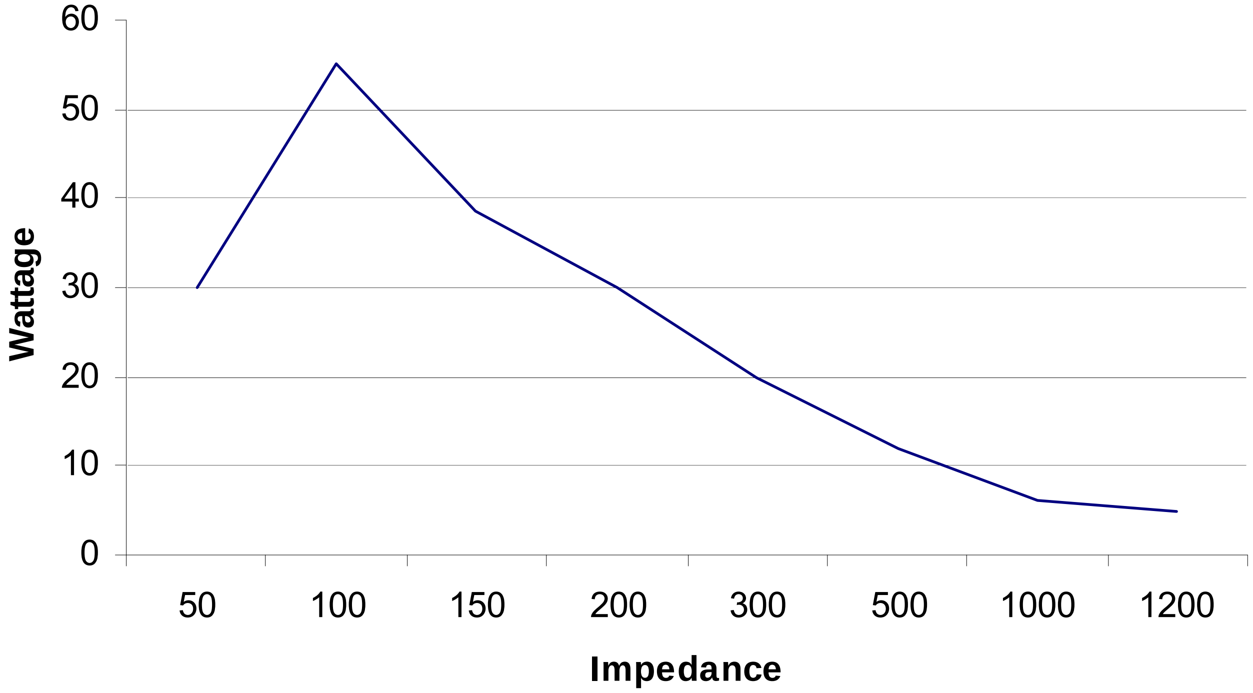
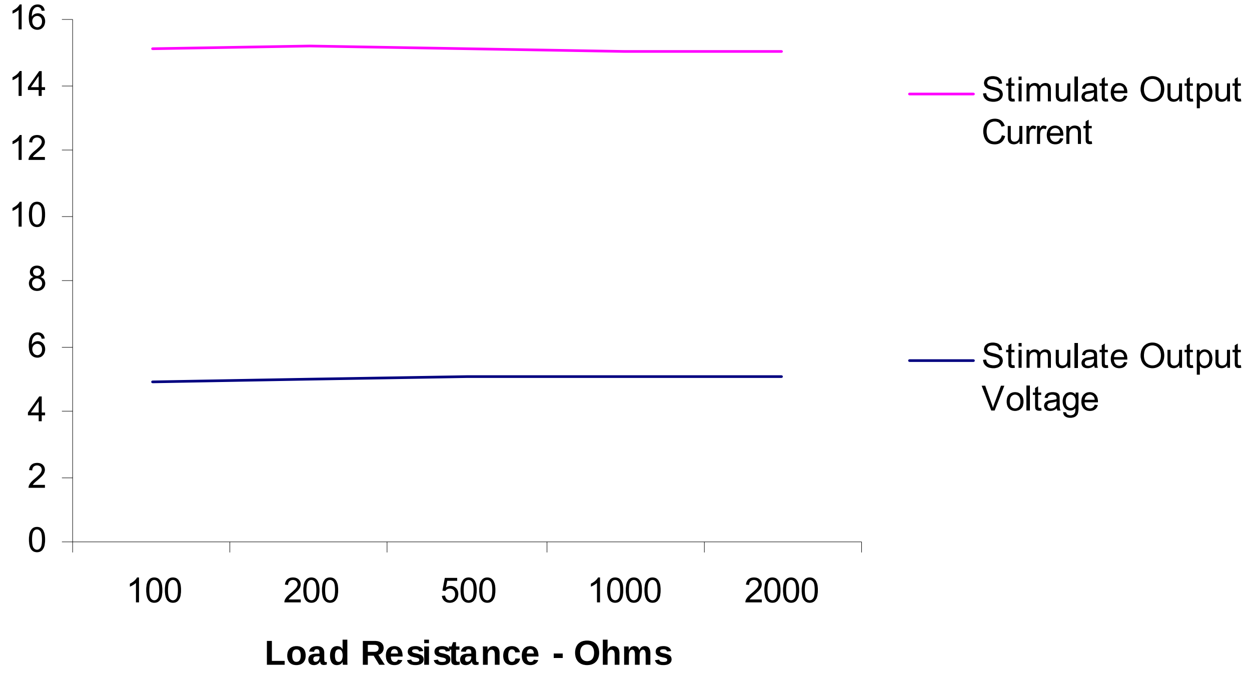


Figure 4.2 **Typical available Stimulation Output Voltage / Load Resistance and Stimulate Output Current/Load Resistance**

Load Resistance	Stimulate Output Voltage (5v Constant Voltage)	Stimulate Output Current (10mA Constant Current)
0		
100	4.88	10.2
200	4.98	10.2
500	5.04	10.1
1000	5.05	10
2000	5.07	9.84



4.2 Principles of Lesioning

4.2.1 The basic physical principles of radiofrequency ablation

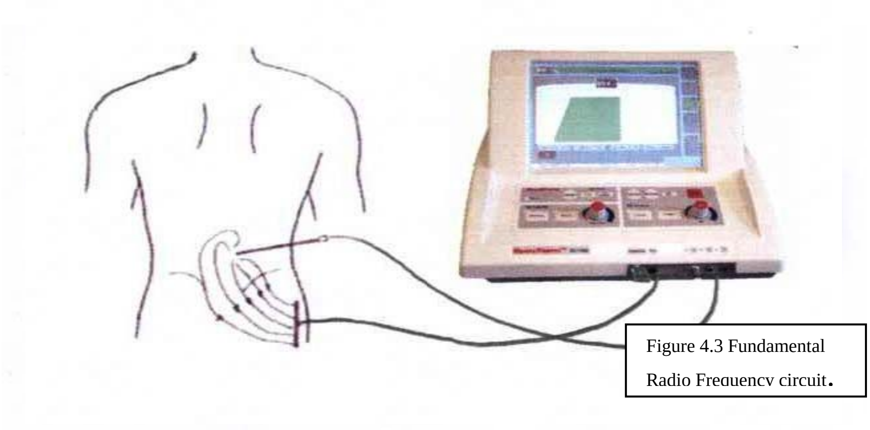


Figure 4.3 Fundamental Radio Frequency circuit.

Figure 4.3 shows the fundamental radiofrequency circuit. The RF lesion generator or power source provides a source of RF. It is connected by wires to 2 electrodes: one inserted into the body, referred to as the active electrode; another in contact with the surface of the body, referred to as the dispersive electrode. This is the so-called monopolar configuration. The RF voltage causes current to flow through the wires, through the electrodes, and to the patient's body. The patient's body is a conductive electrolytic media, and thus the patient's body becomes part of the RF circuit. This current spreads out from the electrodes and flows through the electrolytic tissue medium of the body. The active and dispersive electrodes have a similar physical role in delivering and receiving the current, but functionally, because of their differing areas, they have very different effects with regard to the RF heating process.

The active electrode with its smaller surface area has much higher field densities in the tissue adjacent to it. This higher field density causes significant heating near the active electrode surface. The dispersive electrode has a much larger area, and, as a consequence, the field density is much lower in the tissue adjacent to it. This results in a lower radiofrequency heating effect, and thus if the dispersive electrode is large enough no appreciable heating will occur near it. In fact, a large area surface plate to join to the skin with a conductive gel for good conductivity will not heat appreciably even though this same radiofrequency current will cause intense heating near the much smaller active electrode. It is recommended for most radiofrequency procedures that the dispersive electrode, therefore, should have an area of greater than 150 square centimeters to be safe from any significant heat elevation when RF lesions delivering 50 watts or less are used.

The mechanism for radiofrequency heating is shown in figure 4.4. The electric field lines emanate from the active electrode tip and are created by the voltage impressed upon it by the radiofrequency generator. This electric field creates an electric force on the charged ions within the electrolytic medium of the tissue. According to the physics laws this force produces a motion, and the motion is oscillatory at the frequency of the RF current.

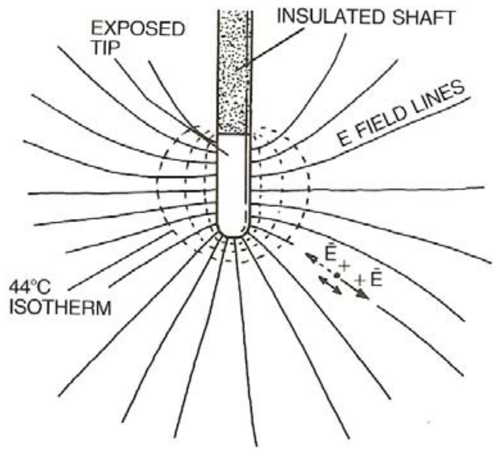


Figure 4.4 mechanisms for Radiofrequency heating

It is this radiofrequency motion which causes the ions to rub against the surrounding fluid medium, causing friction which results in the tissue heating. The temperature at any point is controlled by the frictionally induced power dissipation at that point, mediated by thermal diffusion and thermal convection. The thermal diffusion and convection are typically caused by blood circulation.

The temperature distribution around the electrode tip can be calculated by making certain simplifying assumptions. One of the assumptions is that the medium is homogeneous and that the factors of thermal diffusion and circulation are also uniform. Under these circumstances one can calculate the isotherms (surfaces of constant temperature) surrounding the electrode tip for a given impressed radiofrequency voltage. These isothermal surfaces are critical to determining the lesion size. As it is known that living tissue will be permanently destroyed for sustained temperatures of approximately 45 C, the 45 degree isotherm can be considered to be the outer border of the lesion since tissue within this volume will be thermally destroyed and tissue outside of this volume will experience lower temperatures than are necessary for cellular destruction. Isothermal surfaces are indicated by the -- lines in **figure 4.4**

It is important to understand that the radiofrequency field, and thus power dissipation in the tissue actually heats the tissue as opposed to the electrode itself. The heated tissue in turn raises the temperature of the electrode tip and thus heats the tip. Therefore, it is not the electrode tip which heats the tissue, but rather the tissue which heats the electrode tip. If the electrode is properly designed so as not to sink away too much of the thermal energy, the electrode will give an accurate representation of the tissue temperature at its surface. It is for this reason that thermal monitoring of the radiofrequency tip is a good indication of the hottest portion of the lesion volumes, namely the isotherm that lies closest to the surface of the electrode. With the simplifying assumptions of a homogeneous medium, the lesion size represented by the 45 degree isotherm increases with increasing tip temperature and also increases with increasing tip dimension particularly the radius of the electrode tip.

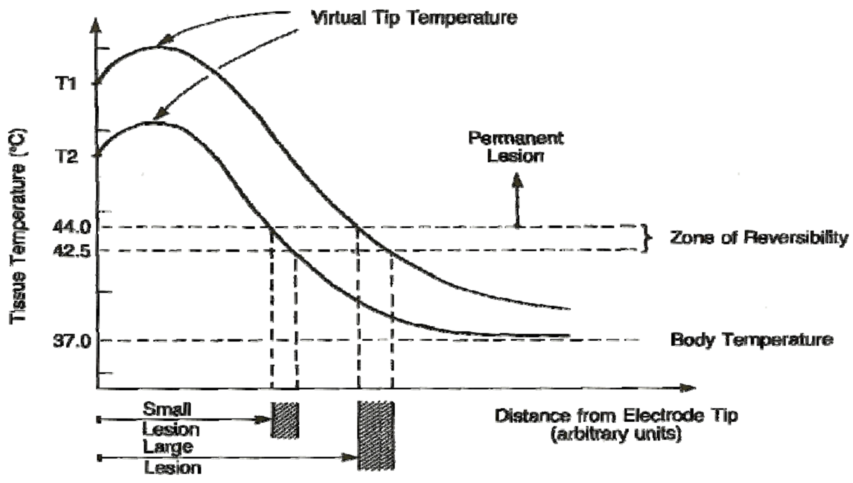


Figure 4.5 Schematic of Tissue Temperature v Distance for Electrode Tip.

Figure 4.5 shows a schematic diagram of the temperature of the tissue as a function of distance from the electrode tip. It should be noted that the temperature is not isotropic for a non-spherical electrode, and thus these curves may differ at different orientations on a non-spherical electrode tip. The temperature at the surface of the electrode, such as T2, measures very nearly the hottest tissue nearby, and the tissue at greater distances falls off until it asymptotically approaches body temperature at large distances from the electrode tip. By raising the radiofrequency voltage, one will increase the temperature to T1 near the electrode tip, and thus the distances to the 45 C isotherm will increase accordingly. With knowledge of these characteristics and the temperature vs.distance curve, one can therefore judge the size of the lesion volumes by choosing the appropriate tip temperature for a given tip geometry. This is the reason temperature measurement has been historically essential to produce consistent and quantified lesion volumes.

Measurement of the tip temperature has another very important benefit. By avoiding tip temperatures near 100 C (the temperature at which water boils), one avoids the undesired effects of charring, sticking or the formation of a hemorrhage or explosive gas which may be also be accompanied by sparking. In the early days of neurosurgical lesions, before reliable tip temperature measurement was possible, neurosurgeons would establish the end point of their lesion making by listening for the “popping” lesion. The popping was caused by the tip temperature exceeding 100 C and the subsequent gas formation at the tip to the electrode. This obviously was not a controlled lesion technique and led to unpredictable and dangerous destructive conditions.

In pain management there are now well-established prescriptions for appropriate electrode size and tip temperature to achieve desired lesion volumes. It has been historically clear that prescriptions which involve power and current did not have lasting value, but rather prescriptions that involve temperature, electrode size and accounting for the heat washout caused by blood flow. The importance of temperature control was not always recognized. For instance, in the early days of percutaneous cervical cordotomy, elaborate prescriptions of current, power and time for making RF lesions were established. The subsequent clinical results were not consistent in the early days of cordotomies, and it was only when temperature was measured at the tip of the cordotomy electrode that consistency and reproducibility was finally achieved.

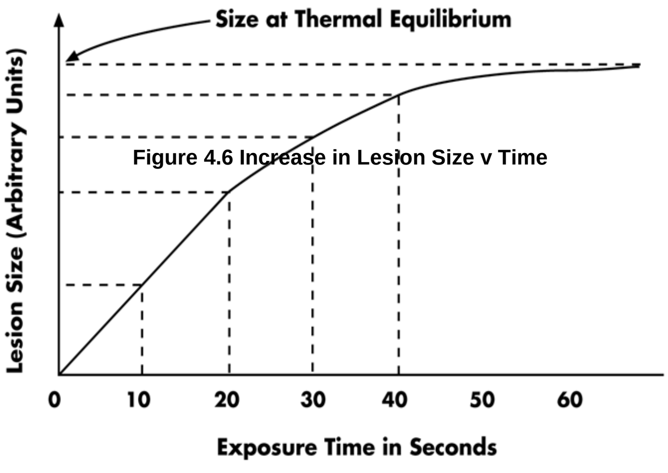


Figure 4.6 Increase in Lesion Size v Time

Another important aspect of controlled radiofrequency lesion making is illustrated in **Figure 4.6**. This shows experimental data of the increase in lesion size for a fixed electrode geometry and a fixed tip temperature. The lesion size in this situation is defined as the width of the prolate ellipsoidal width of the prolate ellipsoidal lesion volume. The graph clearly shows that for constant tip temperature the lesion size grows and asymptotically reaches a maximum value in a time between 30 and 60 seconds. The 45C isothermal surface can then be referred to as the equilibrium lesion size. Leaving the radiofrequency power turned on indefinitely beyond 60 seconds will not increase the equilibrium lesion size. In the past, so-called time-dependent lesions were made in which a certain power was held by the radiofrequency generator for 10-20 seconds. This too led to inconsistent results, and resulted in the acknowledgment of the equilibrium lesion size as being the optimum methodology.

It is noteworthy that impedance monitoring has a great value in assessing the progress of a heat lesion. The impedance seen by the electrode tip depends on tissue interfaces and this property has been used very effectively to distinguish between the interface of electrolytic fluids and tissue. For example this has been used with percutaneous cordotomy electrodes to clearly tell when the electrode has traversed from the cerebral spinal fluid to a position of contact with the spinal cord. Impedance monitoring has also been used to identify when an advancing electrode has progressed from the annulus of the disk into the nucleus pulposus. The change of impedance during the heating process is dramatic. It has been shown that as the tissue or medium heats up, the impedance will drop. This is very much related to the phenomena that the engine oil in an automobile will become less viscous as the temperature of the engine increases. There is a point, however, as the temperature at the lesion tip approaches 100 C, when the impedance will cease to decrease and, in fact, will rise precipitously as the temperature approaches the boiling point. The reason for this is that the protein coagulation has a rapid onset in this temperature range causing a decrease in Ionic mobility. Near the boiling point, gas suddenly forms around the electrode tip, acting as an electrically insulating barrier thus sending the impedance to very high levels. At the onset of boiling, the impedance rises very rapidly. In summary, it is clear that the monitoring of temperature and impedance are both of great significance.

4.2.2 Pulsed radiofrequency

Historically, radiofrequency was neuroablation. This was true for percutaneous cordotomy, the treatment of trigeminal neuralgia, and the destruction of the medial branch nerve for facet pain. Mysteries remained however. It was not understood why RF lesions were so often followed by long periods of discomfort before any beneficial clinical effect appeared. In the 1990s, additional unanswered questions were added. The mode of action of RF lesions of the lumbar sympathetic change (other than for vascular disease) was not understood since there were acceptable success rates, though the results did not correlate with the degree of sympathetic block.

This led to the hypothesis by Sluijter that heat might not be the element causing the clinical effect of an RF lesion. The next obvious steps were to define a method to apply radiofrequency at high intensity without allowing the tip temperature to rise to neurodestructive levels. The method that was chosen by Sluijter was placing the output setting of the RF generator in the same range as was customary for making heat lesions but interrupting the output, thus allowing for sufficient time for the generated heat to be washed away by thermoconductivity and circulation.

This method has been commonly referred to as pulsed radiofrequency (PRF). Pulsed radiofrequency is a relatively new technique that applies short pulses of radiofrequency (20 ms) at a high voltage of 45 to 60 volts to neural tissue. **Figure 4.7** shows the currently accepted paradigm of 20 milliseconds of RF followed by 480 milliseconds of off time. In this way high intensity radiofrequency is delivered but with a short enough on time so as not to cause heating above 42 C.

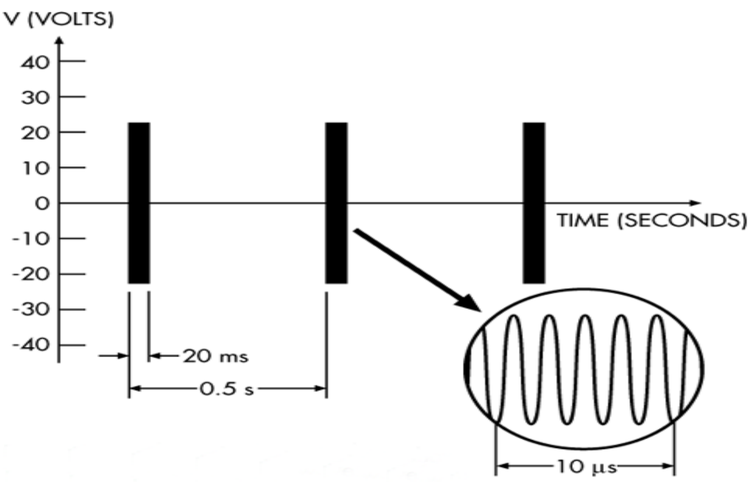


Figure 4.7 Typical Pulsed RF Signal

It is a natural reaction to think of pulsed radiofrequency as being analogous to the neural modulation effects achieved using spinal cord stimulators or TENS units. However, these two modalities are very different. In neural modulation the therapeutic effect is achieved by applying low frequency (< 1000Hz) rectangular pulses.

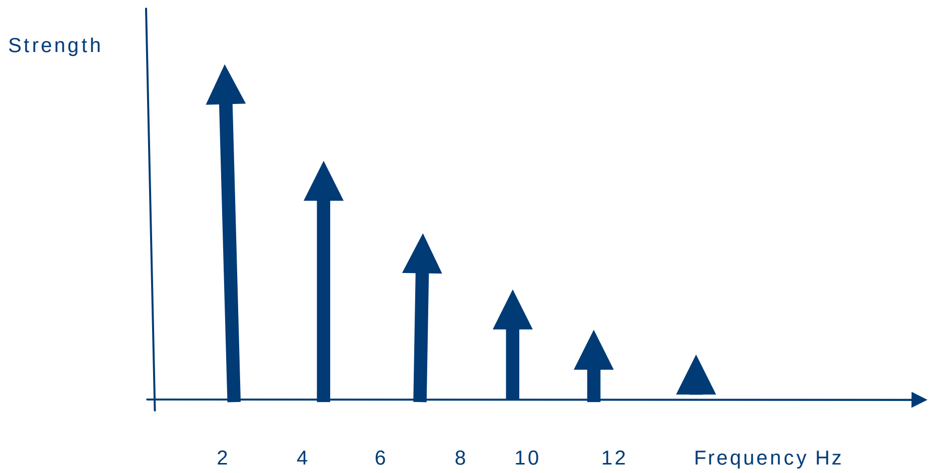


Figure 4.8 Frequency Spectrum of a 2Hz Rectangular Pulse.

Figure 4.8 shows the frequency spectrum of a two Hz rectangular pulse. As can be seen from the figure, the major frequency component is at two Hz and falls off as the frequency increases. At frequencies above 1000 Hz, the amplitude of the frequency component is getting very small. There is a very different situation with pulsed radiofrequency. In this case, the rectangular pulses have radiofrequency inside of them. This changes the frequency spectrum entirely. As can be seen from **figure 4.9**, the major frequency component is now 500 kHz and decreases at higher and lower frequencies. At frequencies below 1000 Hz, the contribution can be shown to be negligible. In conclusion, the frequency spectrums of pulsed radiofrequency are entirely different than the frequency spectrums of low frequency stimulators.

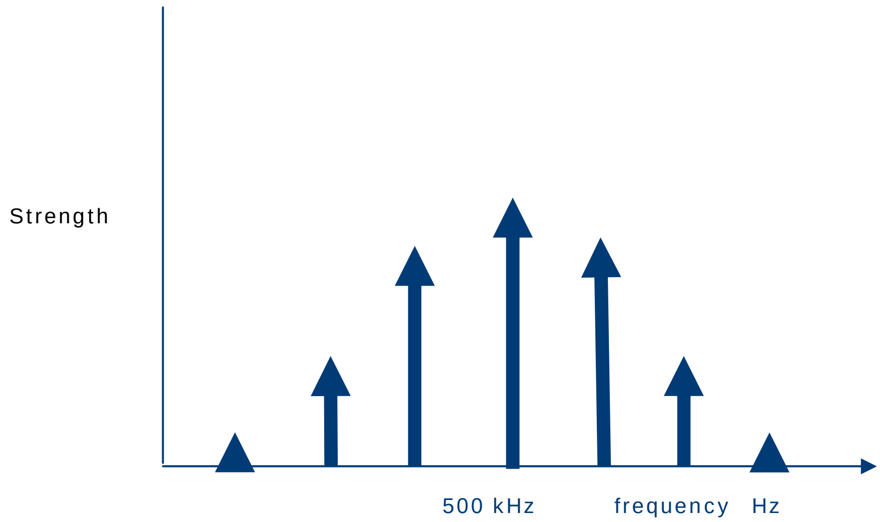


Figure 4.9 Frequency Spectrum of a 500KHZ Signal.

There is very little conclusive research to date on the mode of action of PRF. A few preliminary studies have shown that a modification of CFOS and DNA expression has been observed in cells of rat DRG after exposure to PRF. However, additional basic research needs to be done to come to any good scientific conclusion as to the mechanism of action of PRF.

In this era of evidence based medicine, pulsed radiofrequency has not yet been validated. Several retrospective studies and audits have been conducted and the initial results are positive. Because of a lack of uniform treatment guidelines, the anecdotal results for pulsed have ranged from magnificent to abysmal. It is this author's belief that standardization of many of the PRF parameters will at worst result in uniform treatment for all patients and at best significantly improve the clinical outcomes. In any case, controlled clinical studies are long overdue for this potentially promising modality.

When the study of PRF began, the parameters were arbitrary. For the voltage, a value is taken that was within the range of the voltage during the initial heating phase of an RF heat lesion. The values of 20 milliseconds on time and 480 milliseconds off time were chosen because they were thought to provide good conditions for preventing heating above 42 degrees Centigrade. The initial choice of 120 second duration of the procedure was completely arbitrary, and it was just taken as a starting point. With no scientific basis, these parameters have been arbitrarily modified by clinicians and thus there is no consensus as to what the optimum parameters are.

One of the major variables in pulsed radiofrequency treatment is the voltage level when the pulses are “on”. This arises from the desire to keep the temperature below 42 degrees C. If 42 degrees C. is reached, it is necessary to either manually or automatically reduce the pulsed amplitude or the pulsed duration in order to ensure the temperature does not exceed 42 degrees. Using the pulsed dose method, every pulsed is ensured to be of the same amplitude and duration. This method is explained in detail in the following paragraph.

4.2.3 The Pulse Dose Concept.

Whenever Pulsed RF is used, if the selected temperature limit is reached, the pulse must be modified in some way to prevent the selected temperature limit from being exceeded; this can be done by either.

1. Modifying the pulse **amplitude** of the pulses- i.e. if a 45 volt amplitude was set, and if the temperature limit was set to 42 degrees and was reached, the next pulses will be reduced in voltage to prevent the temperature from increasing above the 42 C temperature limit.

2. Modifying the pulse **width** whenever the temperature limit was reached, thus insuring that each pulse delivered was the full set voltage amplitude.

In **Pulse dose** the two conditions shown above are avoided. A **FULL** pulse is always given, i.e. if the setting is 45 volts amplitude for 20 milliseconds, you will always deliver this pulse amplitude and duration. If the set temperature limit is reached, the generator will wait until the temperature drops below the set temperature limit, and then again will give a **FULL** amplitude and duration pulse.

Because the generator is only delivering full pulses, in this mode initially one sets the "number of pulses" that is desired for the procedure as opposed to procedure time, since procedure time can vary depending on whether the set temperature limit was reached.

The following diagrams depict the different modes-

Figure 4.10 Shows Historical Pulsed RF amplitude control

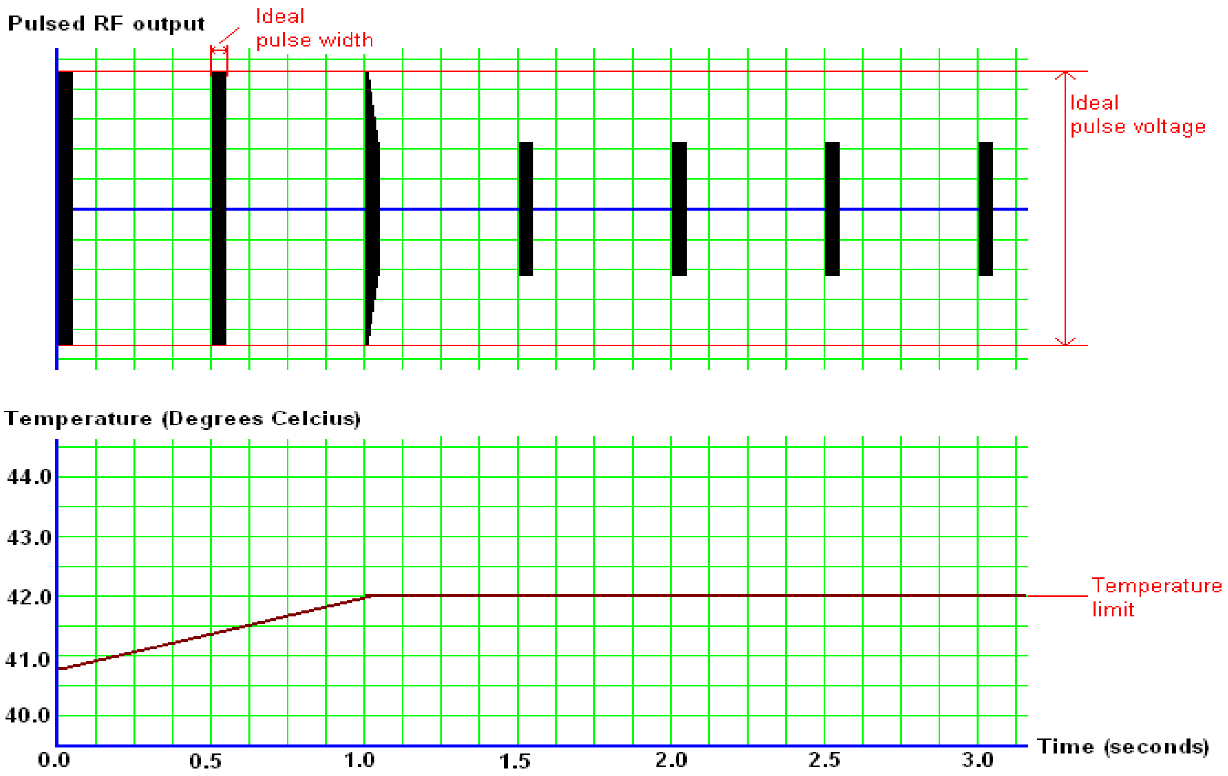
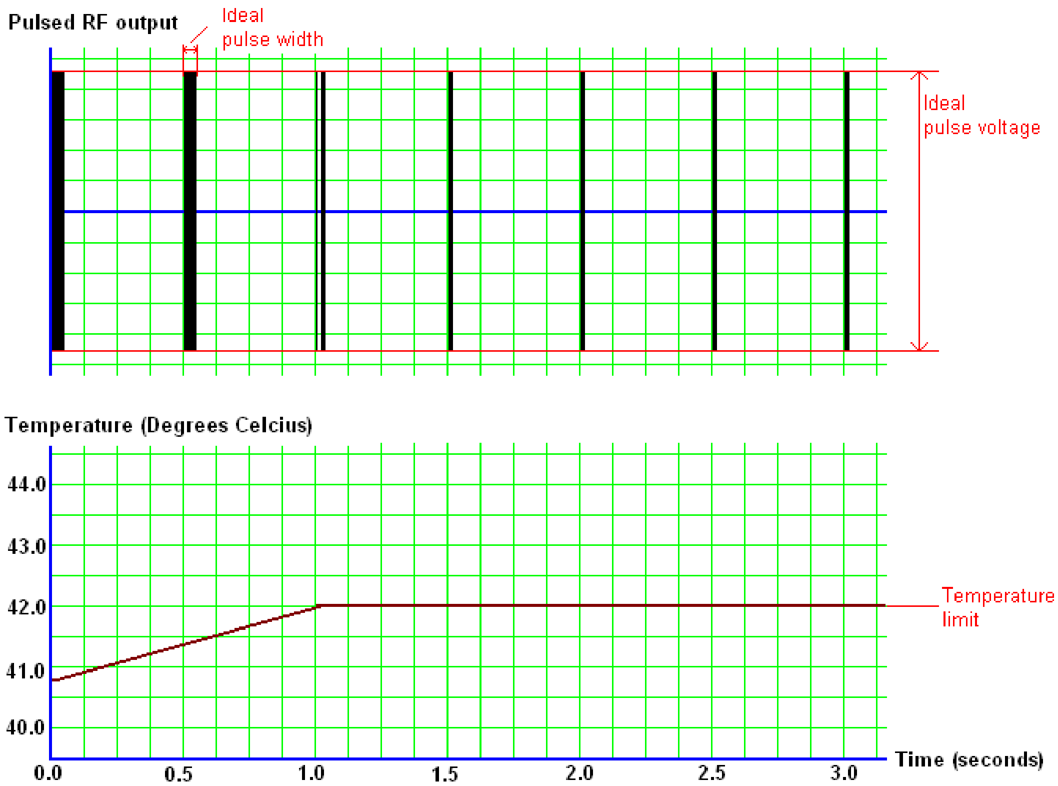


Figure 4.10 Pulse RF Amplitude Control

The beginning pulses are the desired pulses of 45 volts amplitude and 20 ms duration. Note that the moment the set temperature limit is reached the voltage is changed (reduced) in order to keep the temperature below this limit. (Note that this implies that every patient gets unpredictable and variable pulse amplitude which is undesirable).

Figure 4.11 Shows Historical Pulsed RF – pulse width control



When the temperature limit is reached the pulse width is changed as opposed to the pulse amplitude. Note that the pulse width is changed the moment the temperature limit is reached, the width is varied to keep the temperature limit. Though this is better than amplitude control, it still implies that treatments will not be consistent and uniform between patients.

Figure: 4.12 Shows Pulse Dose- a new more consistent approach.

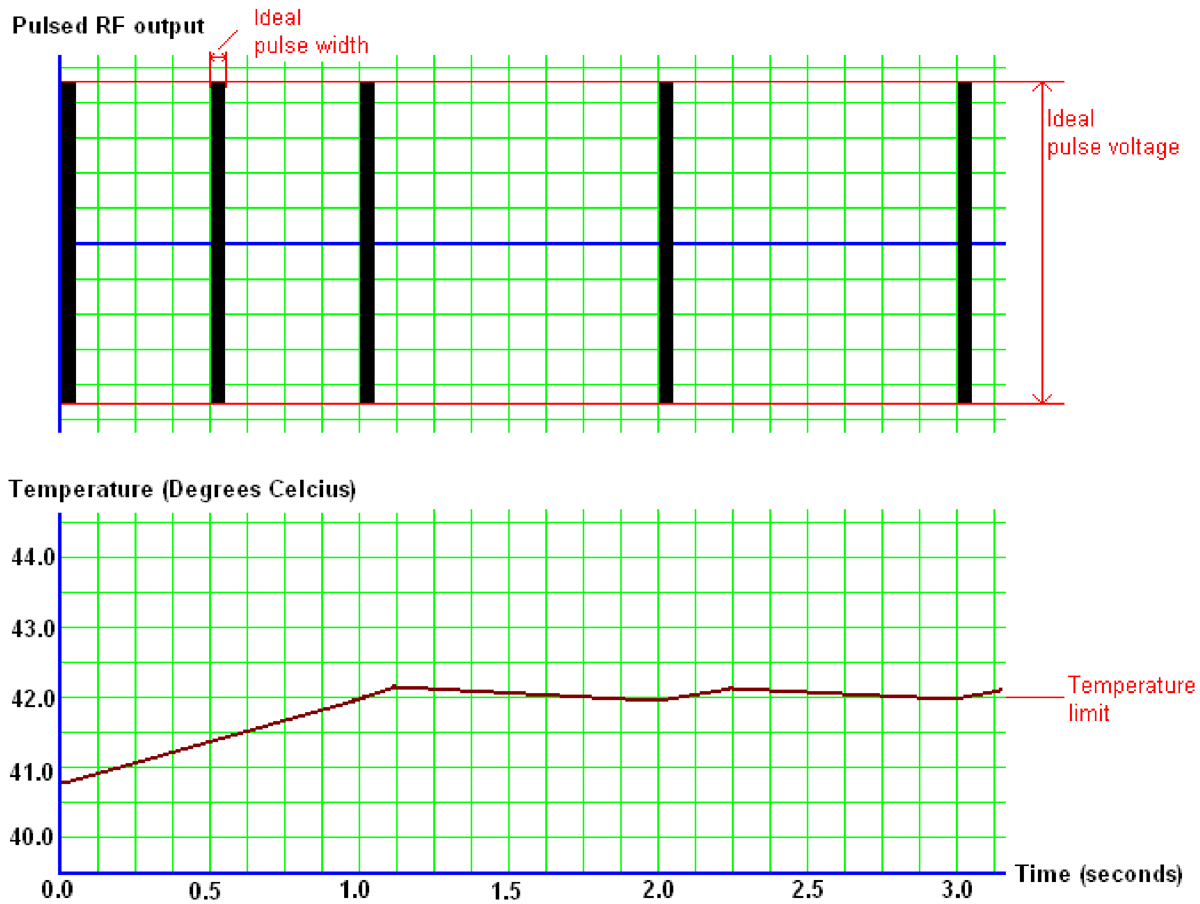


Figure 4.12 Pulse Dose

In the pulse dose mode, only amplitudes that are the full set voltages and widths that are the full set pulse width are delivered. If the temperature limit is reached, the generator stops giving output until the temperature falls below the temperature limit. This guarantees that every treatment delivers the full set amplitude and pulse width. The number of pulses or “doses” are set by the operator as opposed to time, thus ensuring that every treatment is consistent patient to patient.

Here is why pulsed dose is superior to the other methods. Imagine doing medial branch heat lesions and every patient is treated at a different temperature, i.e. one at 80 º C, one at 70 º C, another at 60 º C. Would you be surprised if this resulted in variable patient outcomes? Pulsed dose standardizes pulsed RF, just as always using the same temperature standardizes heat RF.

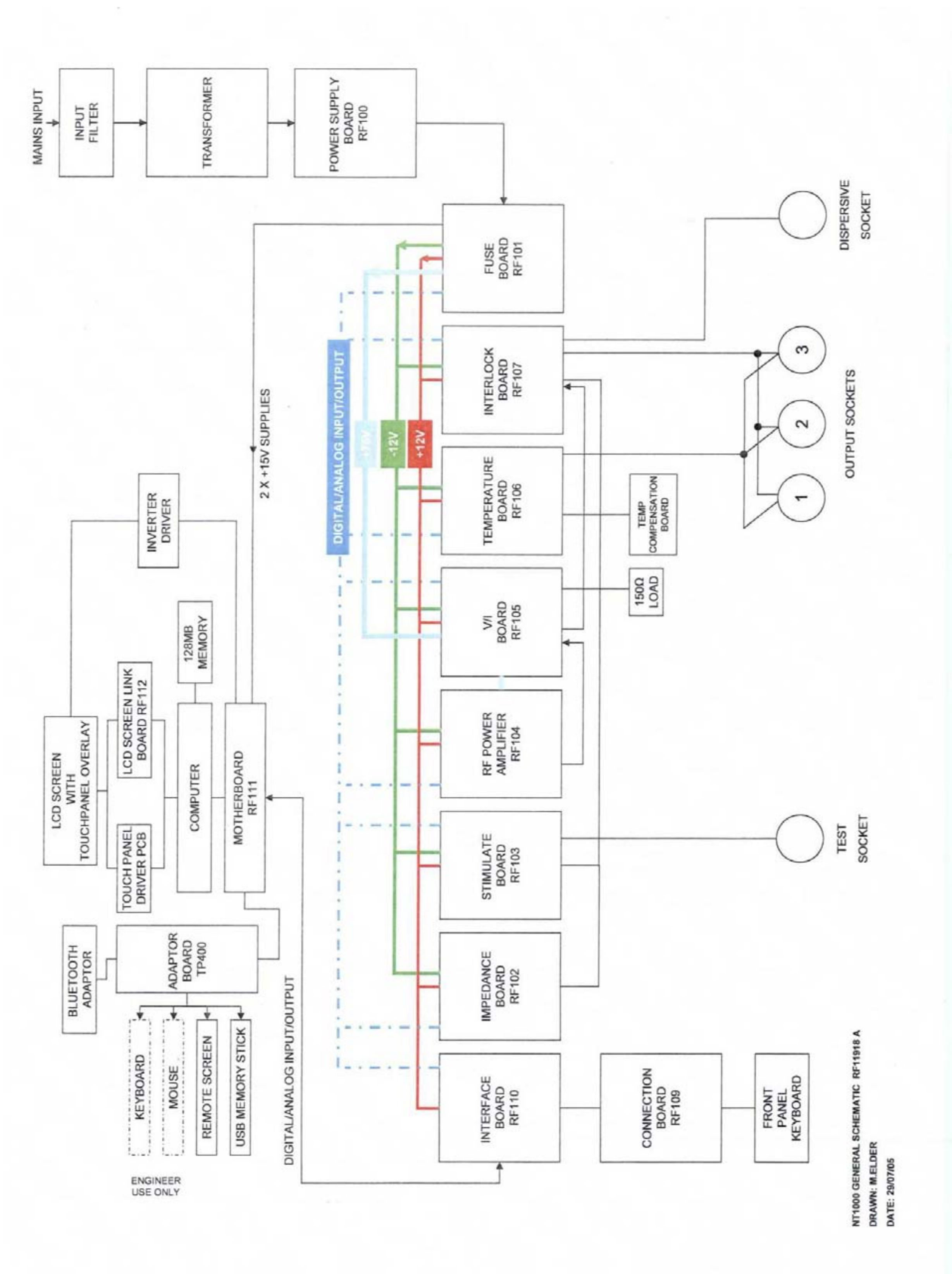


Figure 4.13 General Schematic of the Neurotherm NT1100

4.3 General Description

Figure 4.13 Shows a General Schematic of the Neurotherm NT 1100, and a brief description of the various Printed Circuit Boards used is given below. A more detailed description of each board together with its circuit diagram is given in Section 5.

(a) Mains Input Unit

The Mains Input- - either 115v or 230v comes into the machine via a Corcom Input Unit which includes Mains Filter, Dual Fuses (1Amp for 230v input, 2 Amp for 115v input), two pole On/Off Switch and Voltage Changing Module.

(b) Mains Isolating Transformer

Output from the Mains Input Unit goes to a 150w Isolating Transformer which has the Mains and Low Voltage Windings on two independent isolated bobbins. Thermal Fuses are fitted on the Mains Input Windings and on each secondary Winding. Independent Secondary Windings are:-

67v at 1.25 amp	AC
12v at 2 amp	AC
14v at 2 amp	AC
14v at 1 amp	AC

(c) Power Supply Board RF100

The Power Supply is located on the bottom baseplate of the machine close to the transformer and contains full wave rectifier bridges, voltage regulators and smoothing capacitors to produce a series of DC voltages. These are:-

90v (75v under load) Rectified and smoothed for Generating RF
15v Rectified and Smoothed for the Computer and Display
12v 2amp Regulated DC for Circuit Boards
-12v 1amp Regulated DC for Circuit Boards and Fan

The Power Supply Board is fully socketed for ease of replacement with connectors for Transformer, Fan and Rack.

All voltage with the exception of the Fan go to the Fuseboard in the rack.

(d) Card Rack

The main card rack in the machine contains seven circuit boards and wiring between the various card is on a 2 section backplane.

Fuse Board RF 101

DC voltages from the power supply go to a Fuse Board which provides fusing as follows :-

+ 12 v 2amp for logic (fused 2amp)
- 12 v 1amp for logic (fused 1 amp)
+ 90v for RF (fused 2amp)
+ 15v for Computer and Display Section is divided into two separate 15 v supplies each fused at 2 amps.

Each fused supply has an associated LED which indicates whether the supply is good (LED – ON) or the fuse is blown (LED – OFF).
All fused supplies are monitored by opto isolated couplers and a “Fuse OK” signal is monitored by the computer.

4.4 General Signal Information

Motherboard RF111 (Part)

The computer is connected to a motherboard which provides an interface for a series of Digital and Analogue Input / Output signals. Signals provided are :-

29 Digital Inputs
47 Digital Outputs
8 Analogue Inputs
4 Analogue Outputs

The Computer operates at 5 volts but interface to the various cards is at 12v DC.

The Motherboard is connected by 2 x 50 way ribbon cables to the Interface Board RF 110.

Interface Board RF110

This board which sits at one end of the rack provides the interconnection between the computer motherboard, the front panel keyboard and the rack.

The board has no active components It connects into the rack via a 96 way edge connector and connect to the computer motherboard by 2 x 50 way ribbon cables and to the Connection Board and front panel keyboard by a 34 way ribbon cable.

Connection Board RF109 and Front Panel Keyboard

The Front Panel Keyboard consists of 14 Membrane Keys with tactile feel 4 of which have an integral LED. There is also a single ‘Mains’ LED. The Panel also contains two rotary potentiometers with integral switches (which indicate when the potentiometers are in the ‘off’ position).

The Connection Board is located on the rear of the Front Panel Keyboard. The connection to the Membrane Keyboard is via a 21 way flat film connector and the connection to the two potentiometers with integral switches is via a 10 way latched connector. A 34 way ribbon connector connects the Connection Board to the Interface Board.

A small circuit and sounder are also mounted on the Connection Board to give the “tick” as time counts down.

Impedance Board RF 102

The Impedance Board measures impedance at the patient using a small 53 KHz signal. Its input is connected to the Interlock Board and can be switched to measure the impedance at any of the 3 probe connectors.

The Board contains a 500 Ohm Test Resistor which is switched into circuit during the self test sequence of the computer to check that the Impedance Circuit is working correctly. The Board also contains a ‘tone’ circuit whose output frequency is proportional to the impedance measured and is available if required for cordotomy procedures or during standard impedance measurements. The volume of the tone can be set up on the ‘Options’ screen of the machine.

Impedance is measured in all lesion procedures and in stimulation mode when no stimulation signal is present. The output of the board is connected to an analogue input on the Computer Motherboard and displayed as ohms on the display screen.

Stimulate Board RF 103

The Stimulation Board provides the biphasic stimulation signals used in the Stimulation ‘Motor’ or ‘Sensory’ modes of the machine.

The board produces the following “frequencies” and “widths” of stimulation pulse.

Frequencies

Sensory 10,20, 50, 75,100, 150, 180, 200 Hz
Motor 2Hz or 5Hz

Pulse Widths

0.1 mS, 0.2 mS, 0.5 mS, 1 mS

These frequencies and pulse widths are selected by user via the appropriate “screens” and selected on the board via an appropriate BCD code from the computer via its Digital Outputs.

In a similar way the maximum pulse height and whether the pulse is a voltage or current pulse is selected via computer Digital Outputs.

The outputs available are 0-0.5v, 0-3v, 0-5v
and 0-1mA, 0-6mA, 0-10mA

The board also contains a tone circuit which is connected to the test socket on the front of the machine and is used via the test block to check stimulation pulses appear at a probe.

The stimulation circuit can be connected to any of the 3 probe input sockets on the front of the machine as selected by the user.

A hardware interlock is fitted to prevent stimulate pulses being emitted when the stimulation mode is selected and the voltage/current control is not initially set to zero. This circuit is in addition to the software interlock.

The flashing LED on the appropriate stimulate mode “select” button operates when output is present (this is controlled by software).

The output from the board is connected to an analogue input on the Computer Motherboard and displayed on the display screen.

Temperature Board RF106

The temperature Board measures the temperature at any selected output and controls the power sent to a probe by switching it off when a selected temperature is reached. The input to the board is from the three probe sockets on the front panel of the machine.

The board contains a single temperature measuring circuit and which probe is connected to it is controlled by the computer.

In procedures, where multiple probes are connected to the machine the single temperature circuit is switched between probes.

The temperature circuit is designed for Type K Thermocouples and the small signal from the selected probe is passed via a multi stage low pass filter to a Monolithic Thermocouple Amplifier with Cold Junction Compensation. This Thermocouple Amplifier is also connected to a Temperature Compensation Board mounted on the rear of the probe sockets which effectively moves the Cold Junction Compensation point from the Temperature Board to the Probe Socket and hence avoids any errors due to temperature rise within the Neurotherm.

The output from the Thermocouple Amplifier is approximately 0-1v for 0-100 °C , the voltage is then multiplied x 2 to give a 0-2v signal to an analogue input of the computer to display the appropriate temperature.

The computer (via one of its analogue outputs) sends out a 0-2v signal to represent the temperature the user has selected to control to. This signal is compared with the measured temperature signal and when the measured signal approaches the control temperature the Board sends an excess temperature signal to the RF Power Amplifier to shut down the RF. This control of the Power Amplifier is made via hardware and the computer does not form part of the control loop.

The measured temperature is also compared with a 95°C set temperature and if the measured temperature gets to 95° C the Power Amplifier output is shut down and the RF is also isolated from the patient via a relay. This safety circuit is also a hardware only lockout.

The Temperature Board also contains the circuitry to generate the frequencies and pulse widths for Pulsed RF. The following frequencies and pulse widths are provided

Frequency 1, 2, 5, 10 Hz
Pulse Width 5, 10, 20, 50 mS

These frequencies and pulse widths are selected by the user via the appropriate “screens” and selected on the board via an appropriate BCD code from the computer via its Digital Outputs.

These pulse frequencies are also used as primary switching frequencies for the interlacing of impedance measurement during RF Lesioning, and are used for this purpose on the V/I Board.

RF Power Amplifier RF104

The RF Power Amplifier is located on the base of the machine and uses the air flow from the fan to directly cool its integral heat sink. The Amplifier produces a sine wave output which is a constant voltage over a very wide patient impedance range. The Amplifier is set to give 30 watts at 200 ohm load.

The output voltage of the Amplifier is approximately 0-75 Vrms for a DC input of 0-5 volts. In Manual Mode this DC voltage comes from the RF Power Control on the Front Panel, but when the Amplifier is in Auto Mode the voltage is provided by one of the Analogue Outputs of the computer.

The amplifier also has a Low Power Mode which is switched on when a Cordotomy Treatment is being used.

Output from the Amplifier is enabled both by hardware and software and both signals have to be enabled for output to be present. The Hardware Enable is used for Impedance Interlacing, Pulsed RF, Temperature Control, 95°C Excess Temperature and Hardware Interlock.

The Software Enable is given when the machine is in the correct operating state, no errors have been monitored by the computer and the Computer Watchdog Timer is running correctly.

The Amplifier Board is designed to be tolerant to a shorted output and will cut out if the board detects over-temperature. If the Board detects a failure it sends an error signal to the Computer which will be displayed.

V/I Board RF105

The V/I Board has several different functions, these are:-

a) Provide the 75v for the RF Power Amplifier
b) Measure the RF Current and RF Voltage being delivered by the RF Amplifier.
c) Switching RF Power to a Test Load
d) Provide timing circuit for interlacing the Impedance and RF Signals

The 75V DC Voltage from the Power Supply Board is fused on the Fuse Board and then goes to the V/I Board. When a condition that RF is required is determined by the computer, an “RF ON Enable” signal is sent from the computer and switches the 75V DC through to the RF Power Amplifier. (RF Power at this point is not switched to the patient a whole series of conditions have to be met for this to occur).

RF Signal sinewave at 480KHz comes onto the Board from the RF Power Amplifier and its Voltage and Current are detected by two toriod coils, the output of each is full wave rectified and produces a DC Output Voltage which is proportional to the RF Voltage and Current from the Power Amplifier. These voltages go to two Analogue Inputs on the Computer Motherboard and are used to display RF Voltage and RF Current.

Under normal circumstances the output RF is fed to an external 150ohm 100 watt Test Load fixed in the base of the machine and only passes to the Interlock Board when a "Disconnect Test Load" signal is received from the computer.

In order to measure the Impedance of the patient when RF is present it is necessary to turn off the RF for about 25mS twice a second. The circuitry to carry out this signal interlacing is contained on the V/I Board. The key stages of measurement are:-

a) Disconnect RF from patient
b) Connect Impedance Measuring Circuit
c) Wait for signal to stabilise and then sample and hold the reading
d) Disconnect Impedance Circuit
e) Reconnect RF
f) Sample RF
   Then 500 ms later
g) Hold RF Signal
h) Disconnect RF from patient etc.

This interlacing procedure is triggered by pulses from the Temperature Board, so that when the machine is in pulsed or dosed RF Modes, the temperature measurement is carried out during the "off period" of the RF.

Interlock Board RF107

The Interlock Board provides the main final interlock to only allow RF to go to the patient if all key conditions are met. It is also the point where switching of RF between outputs occurs.

RF arrives at the board from the V/I Board and then passes to the patient via a safety relay and then a series of relays which select which output should be activated.

In order for the safety relay to operate the following conditions have to be met

a) A lesion must have started and not be timed out
b) The Temperature Board must not have detected a temperature in excess of 95° C
c) The Computer Watchdog Timer must be running
d) Pulse or Lesion Mode must have been selected
e) If Auto Start has been selected, RF Control is turned off (fully anticlockwise)
f) Auto Stop has not been pressed.

If all the conditions for the safety relay are met the RF signal is switched to 3 relays which control which outputs of the machine receives an RF signal. This is under the control of the computer, as when multiple outputs are used the RF is switched to each output in turn.

When operating with Dual Probes and a lesion is made between two electrodes, one of the outputs of the machine is switched to act as the dispersive.

When a procedure is completed, an alarm tone is sounded. The volume of this alarm can be set up on the “Options” Screen of the machine, and the computer generates the appropriate Analogue Output Signal to activate the required volume on the board.

Computer Board and Ancillary Boards

The Computer Board is a PC104 Single Board Computer with a 5 watt requirement, so forced air cooling of the computer is not required. The board contains interfaces which include USB, TFT Display, Keyboard, Mouse, Serial Port for Touchscreen and Flash Memory. Its link to the machine is via its 64 way PC104 Interface Connector which connects directly into the Computer Motherboard. Some interfaces, for example, the USB Memory Stick, Remote Screen and Printer Bluetooth Adaptor connect from the computer card to the Adaptor Board TP400 via a short 50 way ribbon cable.

The Adaptor Board which is mounted on the Motherboard (but not connected to it) provides external connections at the rear of the machine. Two other connections for keyboard and mouse for engineers use only are also provided.

The Computer Board has a small sub-board into which the 128 MB Flash Memory Card is plugged, this memory contains the working system software for the machine and a segment of its memory is used to store the readings from procedures for later downloading to the memory stick.

The computer also connects directly to the TFT Display and Touchscreen. For the TFT Display the connection goes via a small link board which reorders the pins numbers and connectors so that ribbon cables can be used. The Touchscreen goes via a small Driver Board which enables the touchscreen to connect to the RS232 interface of the computer. The TFT Display has back illumination which is provided by a small inverter board mounted on the rear of the display; this inverter gets a 12vDC signal from the Computer Motherboard.

The rationale of using a number of small interface boards for the display and touchscreen is that if at some stage in the future the computer, touchscreen or display were changed, then the only boards requiring modification would be the small interface board or Adaptor Board.

4.5 Connector Panel Layout

Dispersive Socket
This 4mm socket is for the lead of the Dispersive Patient Plate which should be at least 200 sq cm (21 square inches).

Test Socket
This 2mm socket is used to connect the Test Block for use in testing the thermocouple probes in the Stimulate Mode.

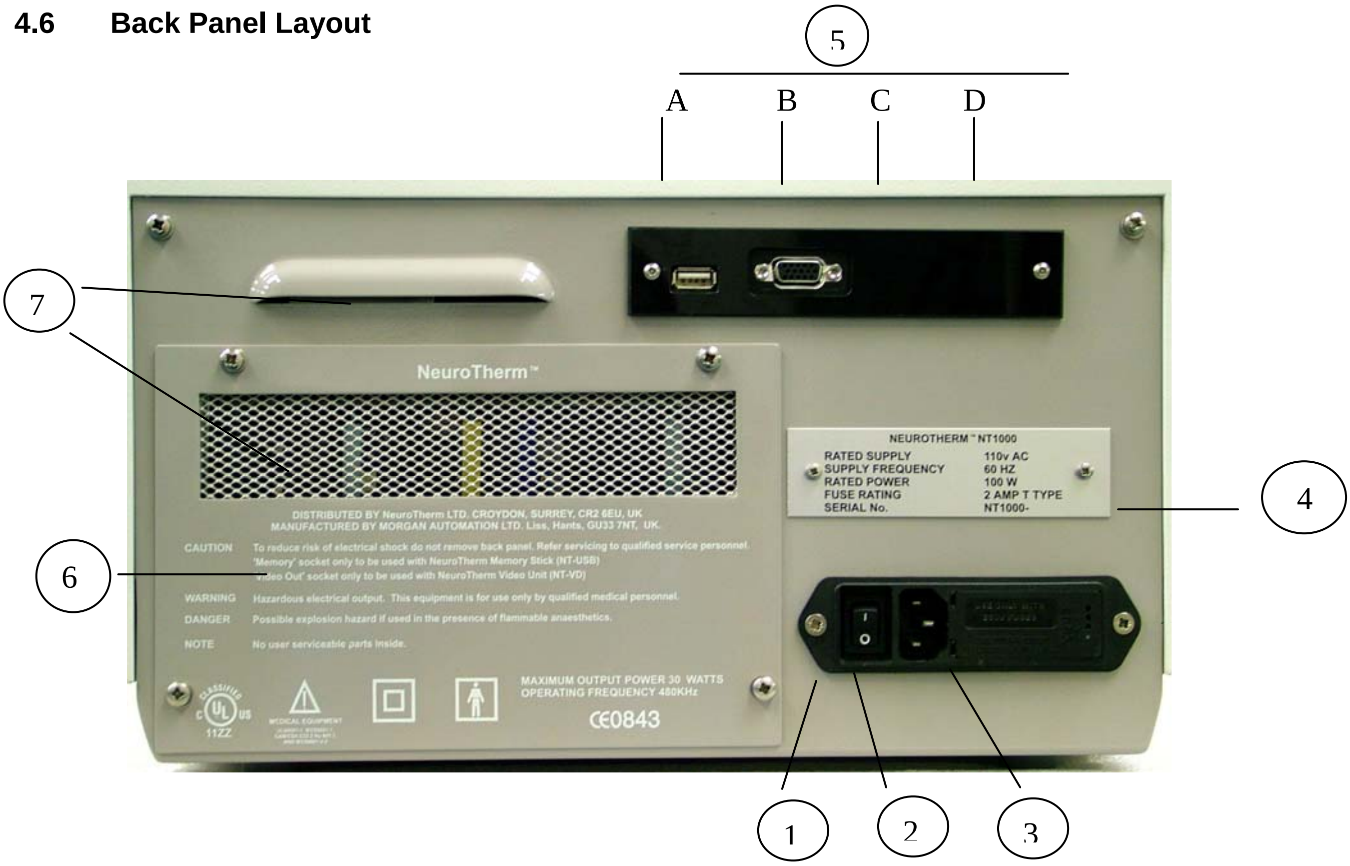
Probe Socket No 1
This 4 pin socket is used to connect single electrodes for standard RF Lesion and Pulsed RF Lesion Procedures.

Probe Socket No 2
This 4 pin socket is used to connect electrodes used for ‘special’ procedures .

Probe Socket No 3
This 4 pin socket is used to connect electrodes used for ‘special’ procedures.

[Special procedures include two and three electrode procedures, dual electrode procedures, bipolar electrode procedures and cordotomy procedures]

4.6 Back Panel Layout



1. Mains On/Off Switch
   This is a rocker type switch, combined with an I.E.C. connector socket with twin 'in-line' anti-surge fuses in a single unit to IEC 950

2. Mains IEC Connector
   The three pin plug of the mains must be pushed into this socket. This cannot be done incorrectly i.e. with the live and neutral reversed because of the orientation of the unused earth pin.

3. Fuses and Voltage Changes
   The Neurotherm is protected by two in-line fuses, one on the live line and one on the neutral line. These fuses are located to the right hand side of the IEC socket. The fuses are 20mm Anti-Surge to BS 4265. 1 amp for 230v supply, 2 amps for 115v supply. To access the fuse holder lift protective lid from the right hand edge and hinge back, the fuse carrier can then be removed. The mains input unit also contains a small printed circuit card which allows the mains input voltage to be changed [Note this is for **factory setting only** and should not be altered]

4. Serial Plate
   This plate gives information on Rated Supply, Rated Power, Fuse Ratings and the Machine Serial Number.

5. Rear Connector
   Depending on the options chosen, there are a series of connectors on the rear of the generator, some which are available to the operator and some which are covered over with a protective cover.

Connector A- Memory socket available on all machines for use **only** with Neurotherm Memory Stick (NT-USB). DO NOT CONNECT ANY OTHER DEVICE TO THIS SOCKET AS IT WILL COMPROMISE THE SAFETY OF THE PATIENT

Connector B- ‘Video Out’ socket- available on some machines for use only with Neurotherm Video Unit (NT-VD) - this unit provides opto-isolated connection to a remote display. DO NOT CONNECT ANY OTHER DEVICE TO THIS SOCKET AS IT WILL COMPROMISE THE SAFETY OF THE PATIENT

Connector C- Remote keyboard- this connector is covered over and is a keyboard connection for service engineers only.

Connector D- Remote Mouse- this connector is covered over and is a mouse connection for service engineers only.

6. Contact Address
If the Neurotherm requires a routine service or in the unlikely event of the machine malfunctioning, the contact address of Neurotherm Ltd is shown on the back plate. The full address, telephone and contact details are shown in Section 11.

7. Ventilation Apertures
These apertures are to ensure the correct air circulation within the generator and should not be blocked or obstructed.

5.0 DETAILED DESCRIPTION OF MODULES

5.1 Power Entry Module, Isolation Transformer and Power Supply Board

Referring to Figure 5.1 Mains Power is connected into the rear of the equipment and goes via a Medical Filter to a double pole On/Off Switch and then via two fuses to a voltage selector which is connected to the main Isolating Transformer TR1.

The Voltage Selector Unit is a small printed circuit card which allows the mains input voltage to be changed. {Note. It is for factory setting only and should not be altered.}

The Isolation Transformer is of a double bobbin type and has four secondary windings namely:

Winding 1	67v	1.25A
Winding 2	12v	2A
Winding 3	14v	2A
Winding 4	14v	1A

The transformer is fitted with thermal fuses on all primary and secondary windings.

The transformer secondary windings are connected onto the Power Supply Board via an 8way Connector CON I.

The Power Supply Board provides the following supplies:

(a) 90v (75v under load) Rectified and Smoothed for generating the RF Power.

(b) 15v Rectified and Smoothed for powering the computer and display via supplies on the Computer Motherboard.

(c) 12v 2 amp regulated DC for the circuit boards

(d) -12v amp regulated DC for the circuit boards and fan.

A 10 way connector (CON 2) is provided for connection of all DC voltages to the Card Rack and 3 way connector (CON 3) is provided for connection of the main cooling fan.

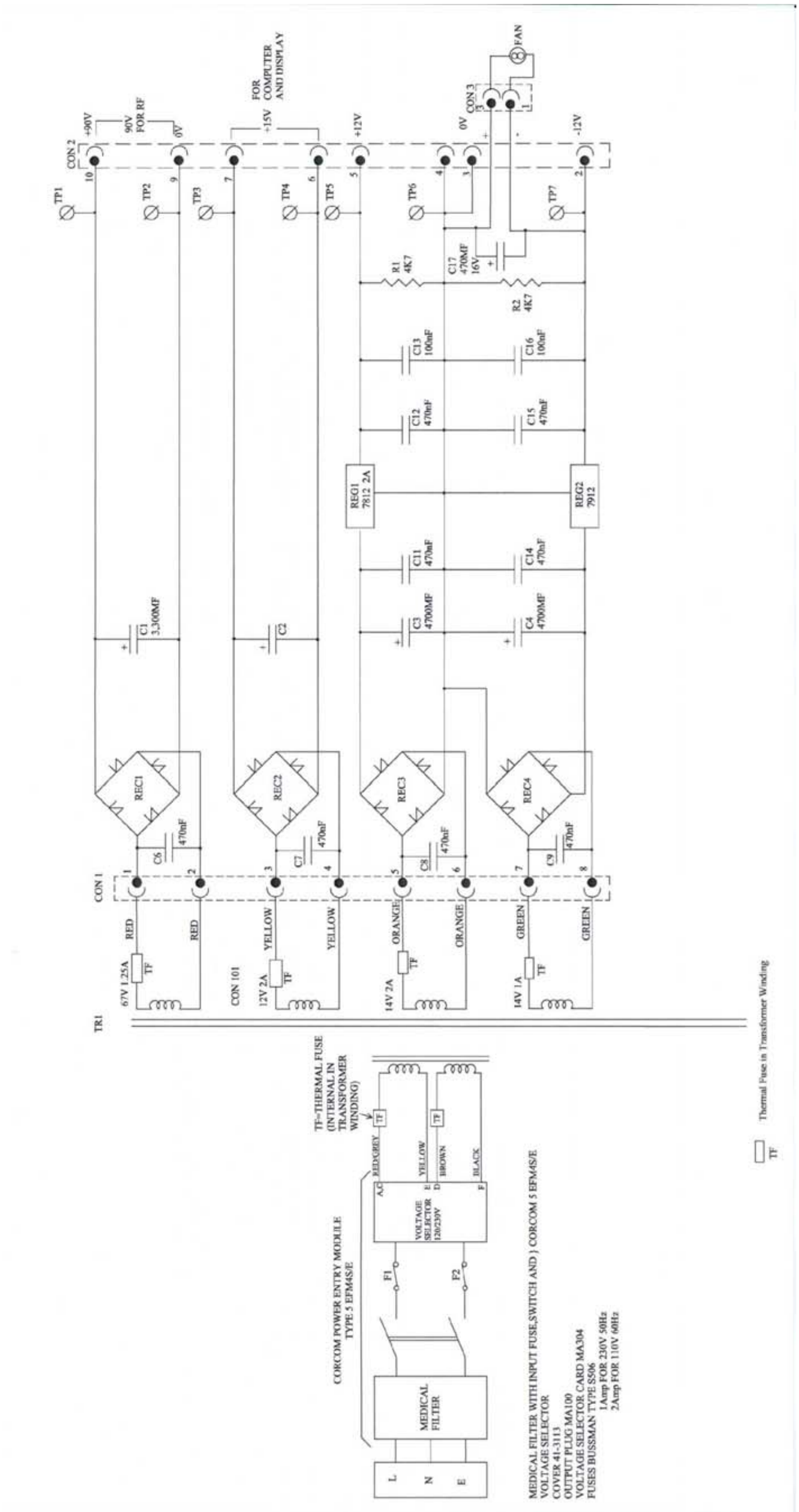

CON 1
CON 2
CON 3
CON 101
TR1
FAN
+90V
90V FOR RF
0V
+15V
FOR COMPUTER AND DISPLAY
+12V
-12V
TP1
TP2
TP3
TP4
TP5
TP6
TP7
REC1
REC2
REC3
REC4
REG1 7812 2A
REG2 7912
C1 3,300MF
C2
C3 4700MF
C4 4700MF
C6 470nF
C7 470nF
C8 470nF
C9 470nF
C11 470nF
C12 470nF
C13 100nF
C14 470nF
C15 470nF
C16 100nF
C17 470MF 16V
R1 4K7
R2 4K7
67V 1.25A
12V 2A
14V 2A
14V 1A
RED
YELLOW
ORANGE
GREEN
TF
TF=THERMAL FUSE (INTERNAL IN TRANSFORMER WINDING)
RED/GREY
BROWN
BLACK
VOLTAGE SELECTOR 120/230V
F1
F2
MEDICAL FILTER
L
N
E
CORCOM POWER ENTRY MODULE TYPE 5 EFM4S/E
MEDICAL FILTER WITH INPUT FUSE,SWITCH AND) CORCOM 5 EFM4S/E
VOLTAGE SELECTOR
COVER 41-3113
OUTPUT PLUG MA100
VOLTAGE SELECTOR CARD MA304
FUSES BUSSMAN TYPE S506
1Amp FOR 230V 50Hz
2Amp FOR 110V 60Hz
Thermal Fuse in Transformer Winding

Figure 5.1 Power Supply Unit – Circuit Diagram

5.2 Fuse Board

Referring to Figure 5.2

DC voltages from the Power Supply Board go to the Fuse Board which provides fusing for the various supplies together with LED indication of the status of the each supply (LED ON – Supply Healthy) and Test Points for monitoring and fault finding.

The fusing provided is:

F101	+12V	for logic fused 2 amps
F102	-12V	for logic fused 1 amp
F104	+90V	for RF Power fused 2 amps
F105	+15v	for Computer supply (5v) fused 2 amps
F106	+15v	for Display Illumination fused 2 amps

Test points provided are:

TP 1	+12v	Logic
TP2	0v	
TP3	-12v	
TP5	+90v	RF Power
TP6	0v	
TP7	+15v	Supplies to Computer Motherboard
TP8	0v	
TP9	+15v	

The LED indication is:

LED 101	+12v	Logic
LED 102	-12v	Logic
LED 104	+90v	RF Power
LED 105	+15v	Computer 5v
LED 106	+15v	Display Illumination

All supplies are connected on their secondary side (after the appropriate fuse) to a Quad Opto Isolated Coupler which produces a digital input to the computer to indicate that all supplies are present. The signal “Fuses OK” goes to Digital Input C3 and is high when all supplies are present.

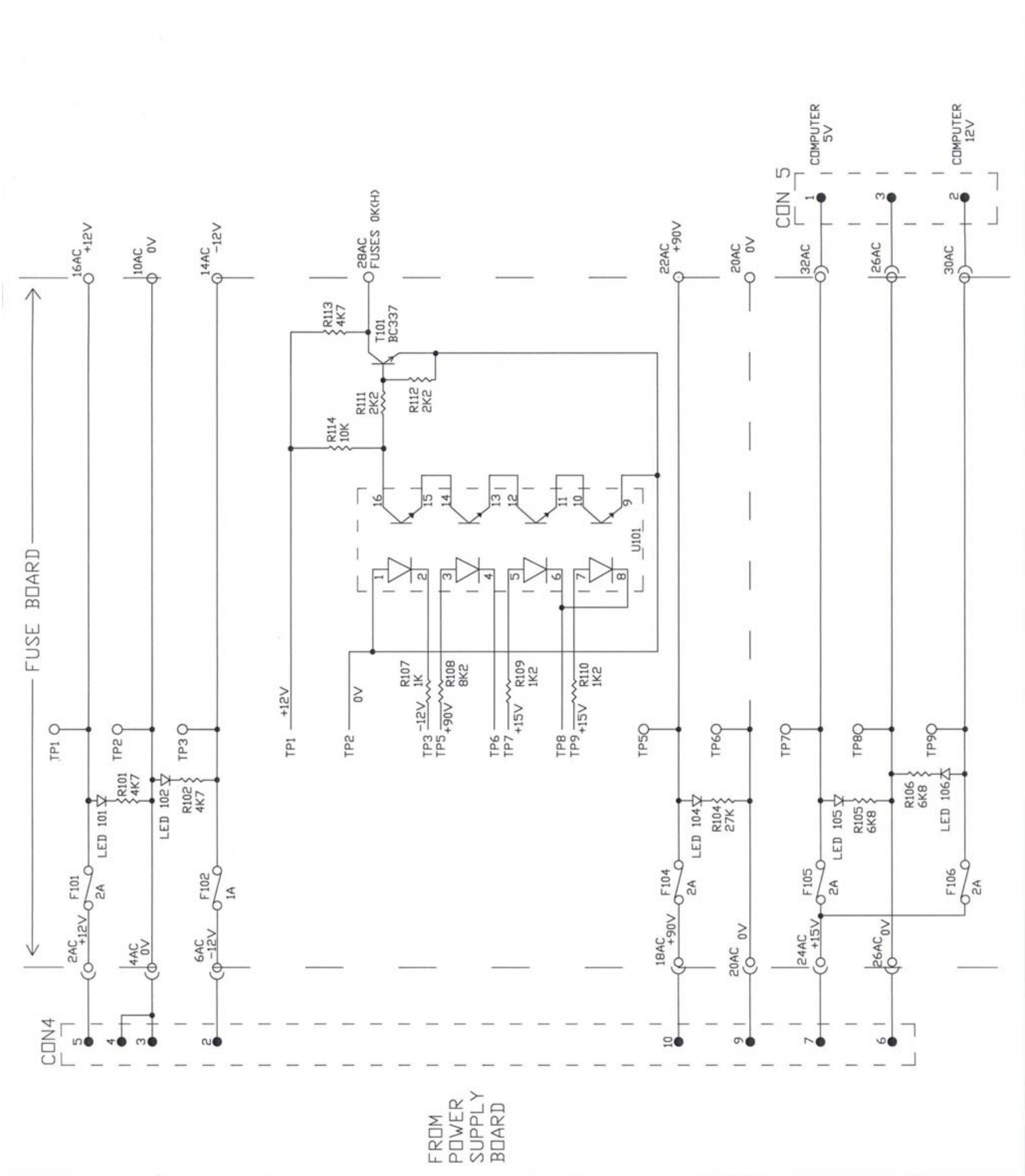


Figure 5.2 Fuse Board – Circuit Diagram

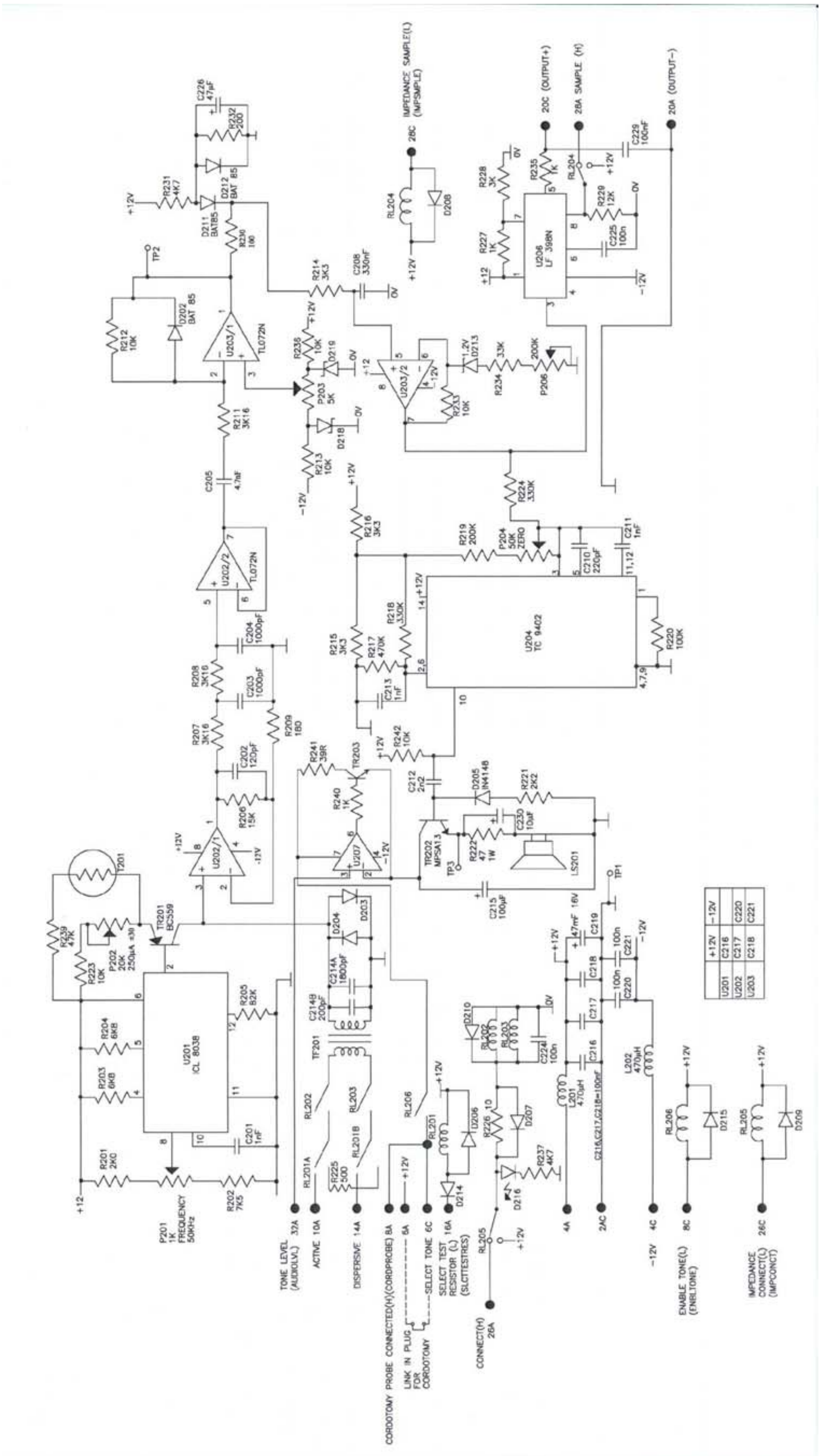

U201 ICL 8038
U204 TC 9402
U206 LF 398N
LS201

Figure 5.3 Impedance Board – Circuit Diagram

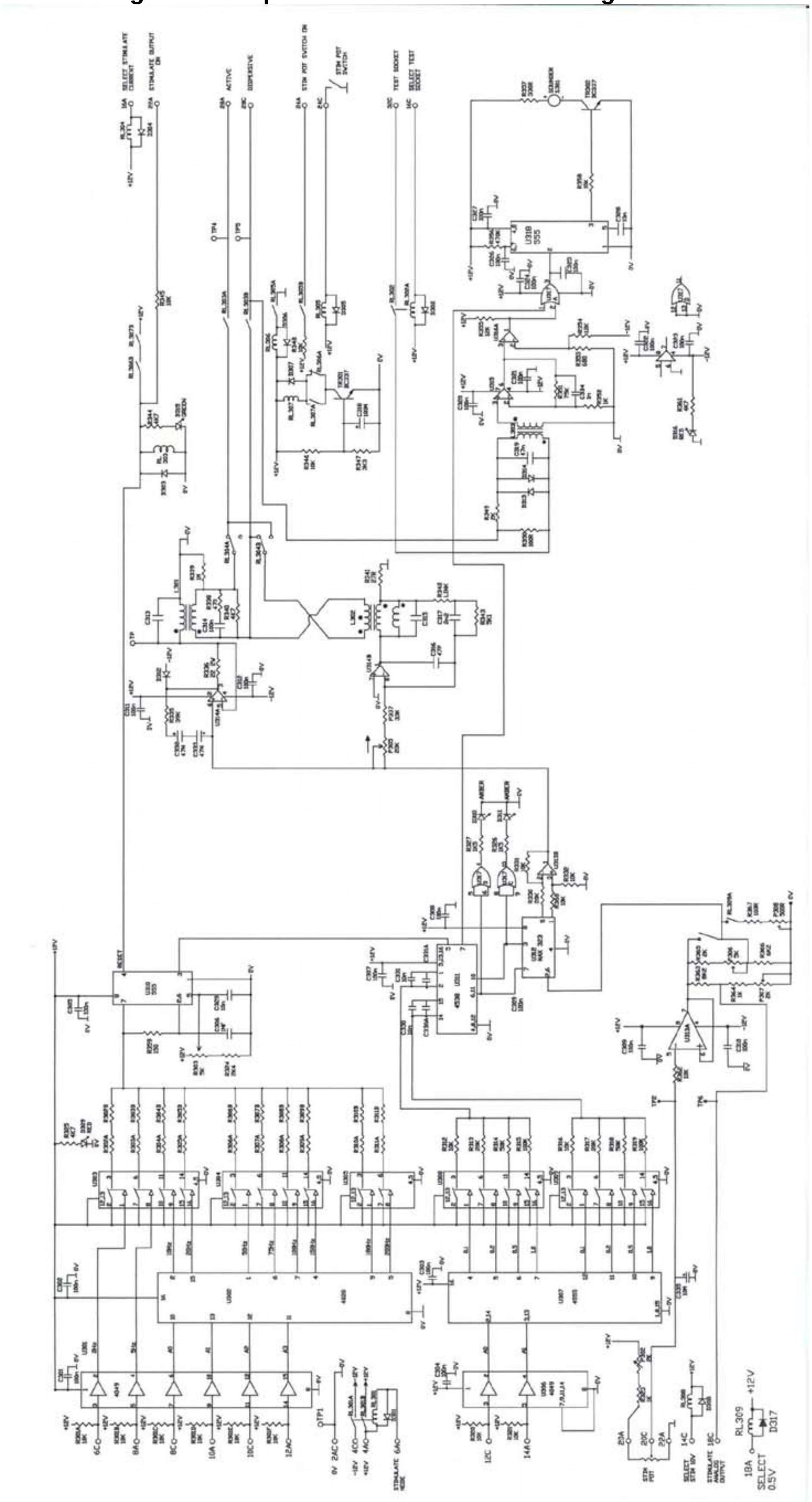


Figure 5.4 Stimulate Board – Circuit Diagram

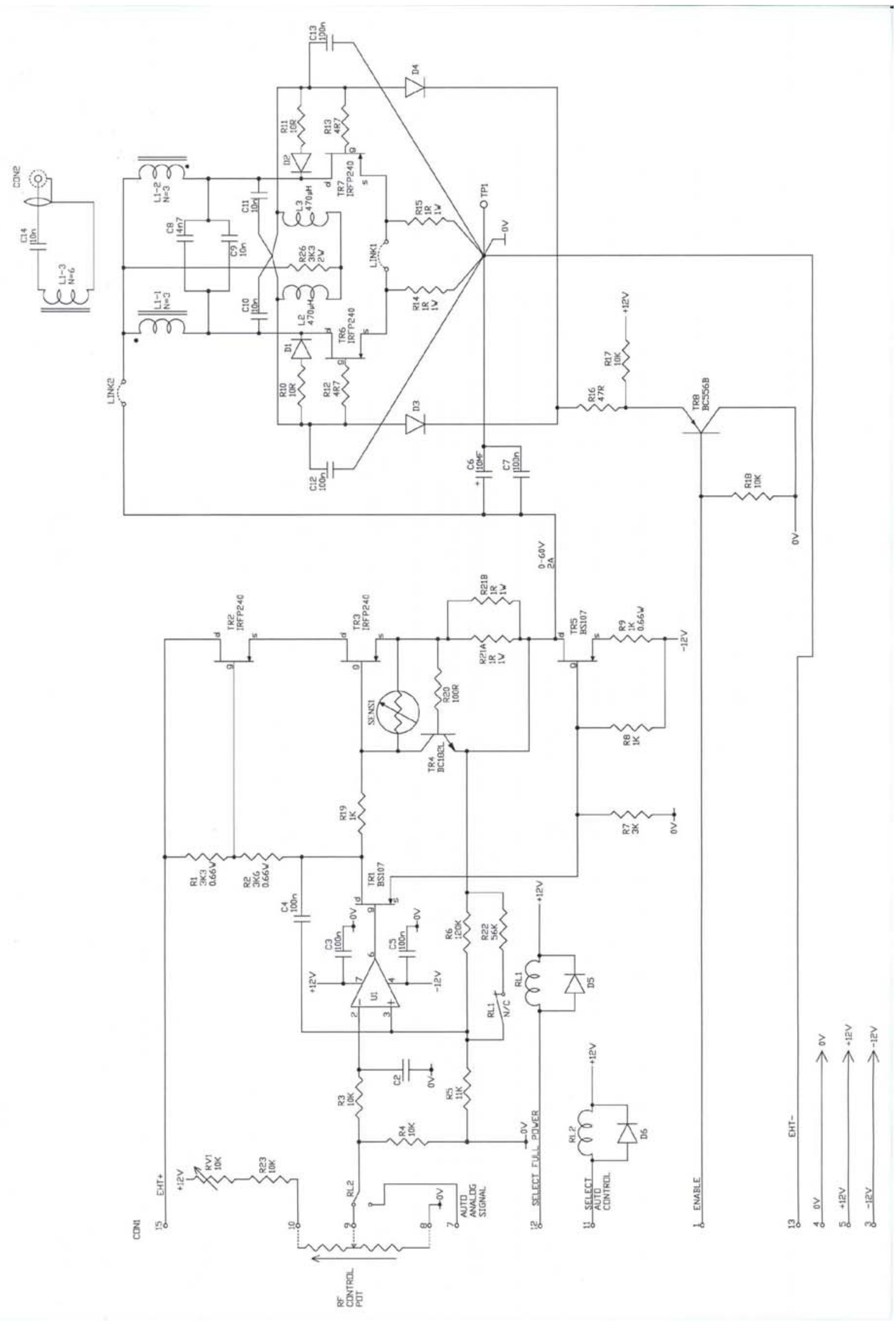


Figure 5.5 RF Amplifier Board – Circuit Diagram

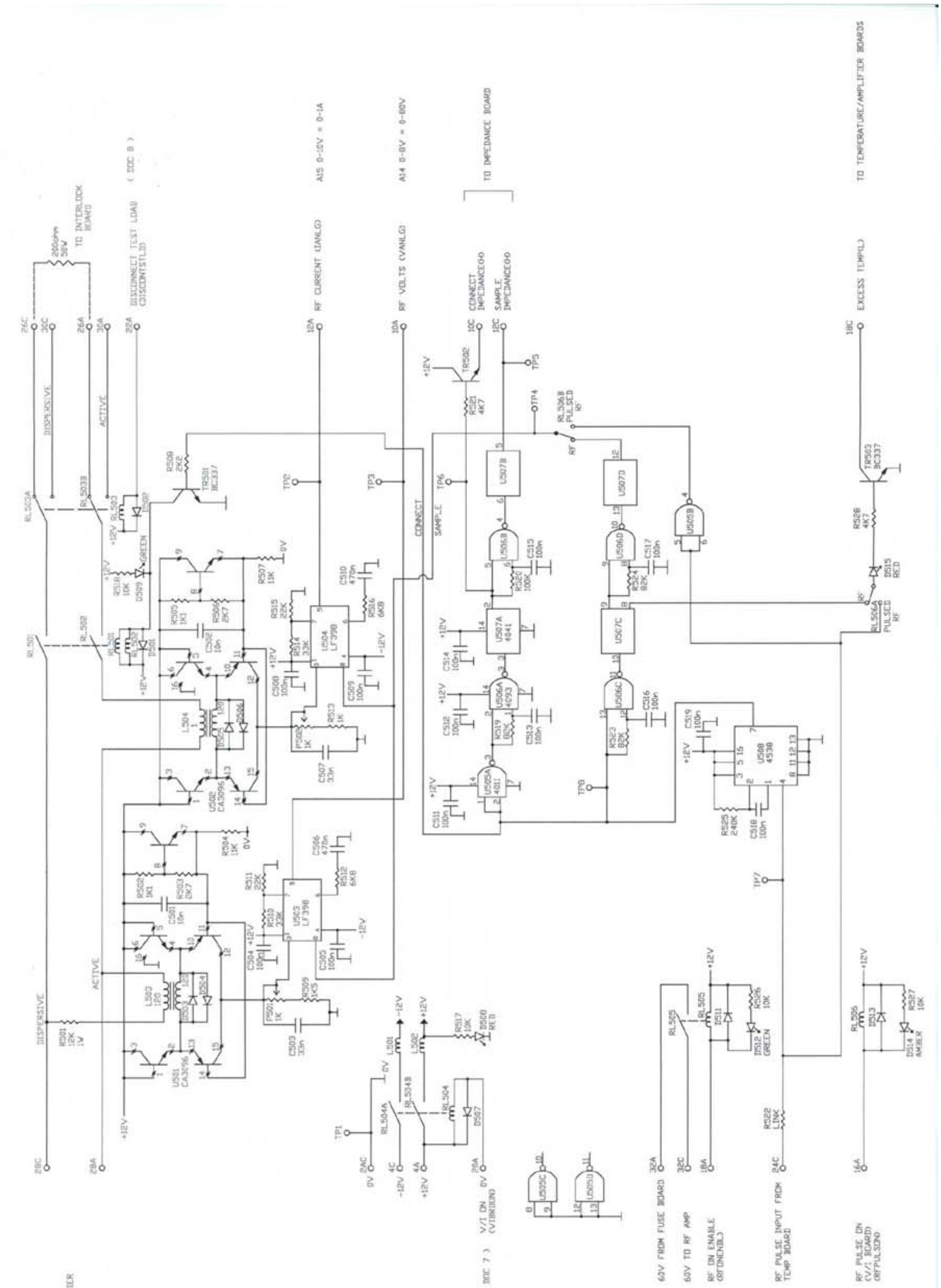


Figure 5.6 V/I Board – Circuit Diagram

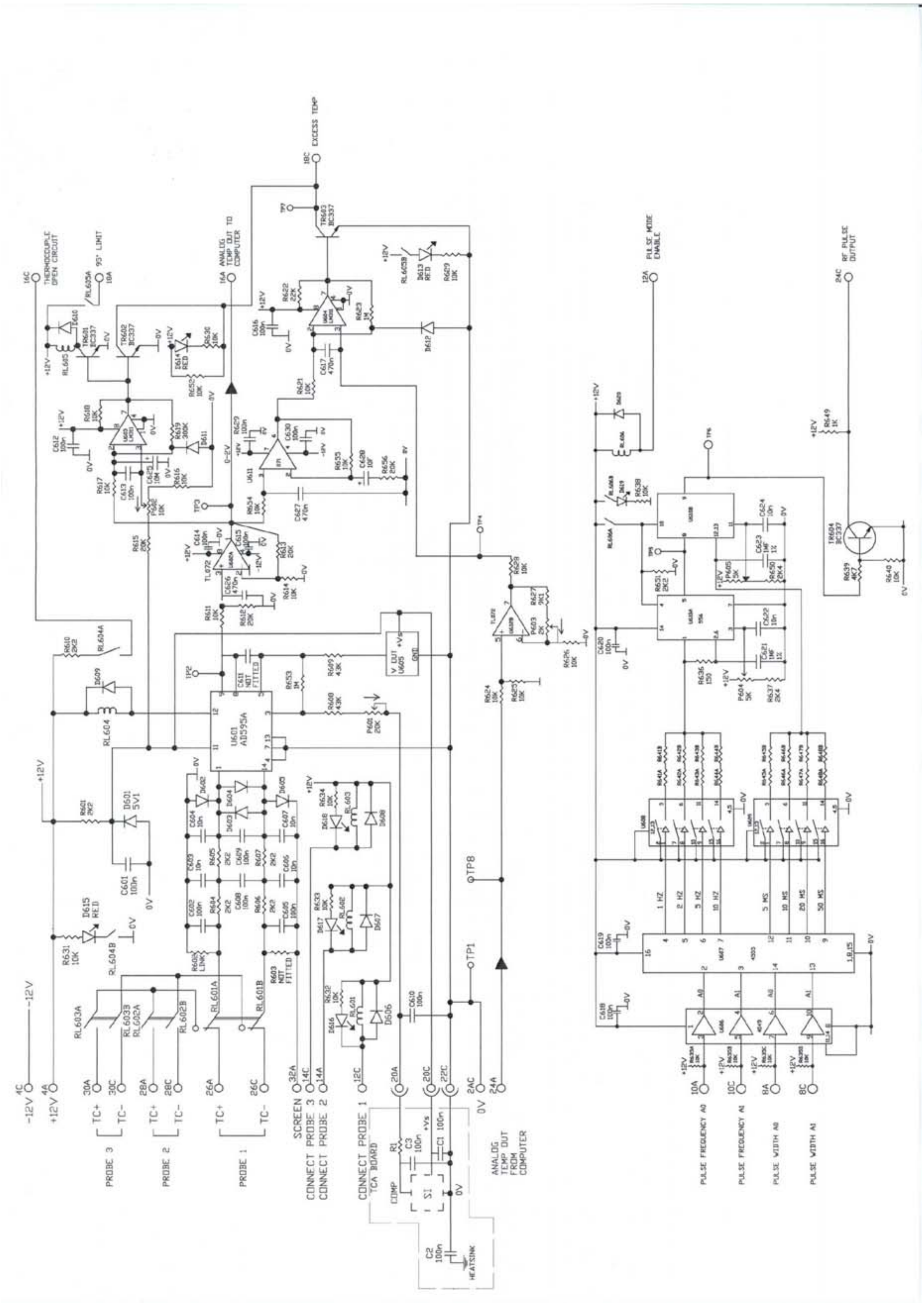


Figure 5.7 Temperature Board – Circuit Diagram

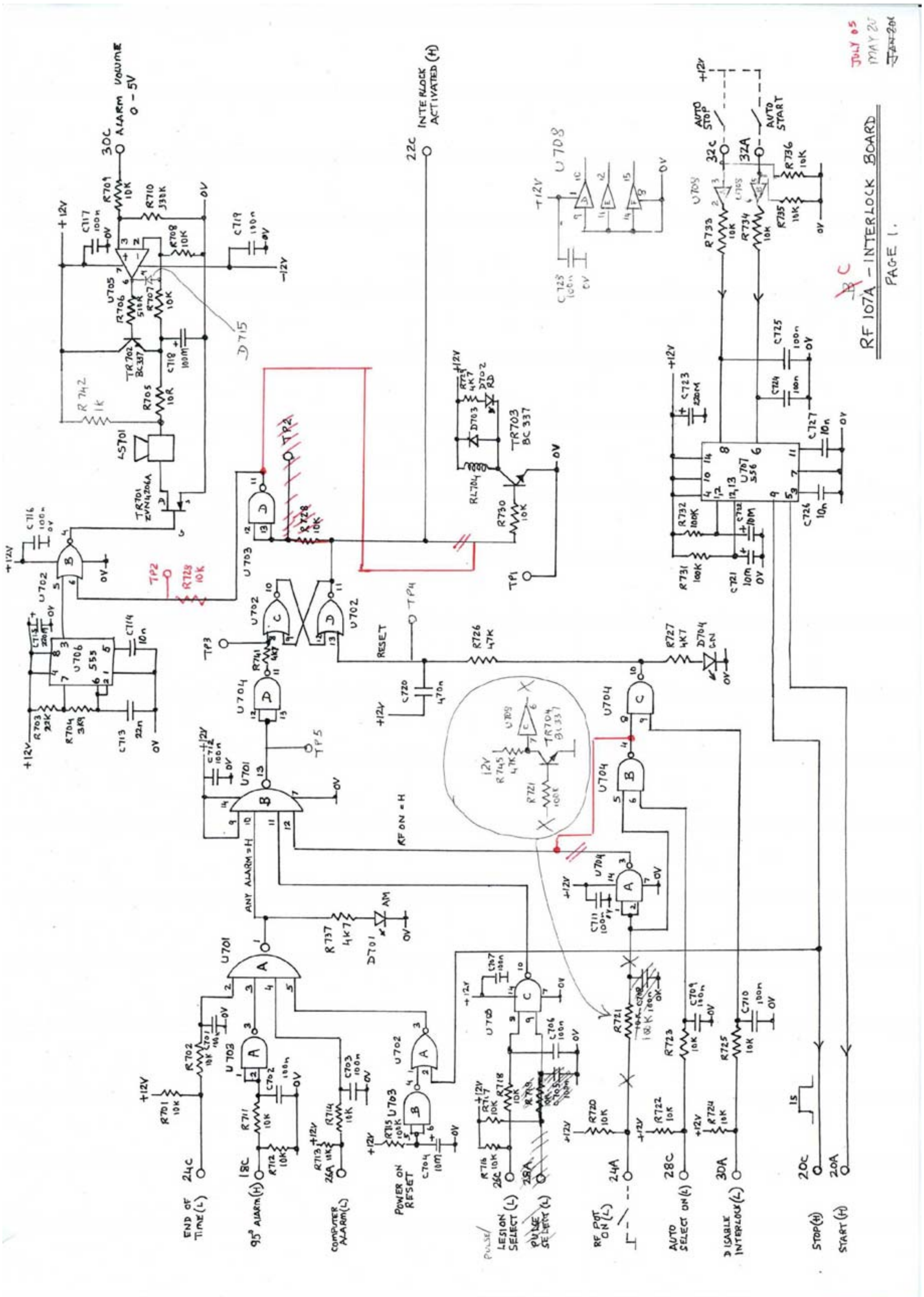


Figure 5.8 Interlock Board – Circuit Diagram

6.0 CIRCUIT DIAGRAMS AND COMPONENT LISTS

This section contains details of circuit boards, and general wiring:-

a) Component Lists

b) Circuits

c) Board Layouts

Details are included for the following Boards:-

a)	Power Supply Board	RF100C
b)	Fuse Board	RF101D
c)	Impedance Board	RF102D
d)	Stimulate Board	RF103D
e)	RF Generator Board	RF104C
f)	RF Voltage and Current Board	RF105D
g)	Temperature Board	RF106D
h)	Interlock Board	RF107D
i)	Interface Board	RF110C
j)	Front Panel and Connection	RF109B
k)	Computer Motherboard	RF111B

6.1 Power Supply Board - RF100C

Components

R1	4K7±5%	1/4 watt	Carbon Film
R2	4K7±5%	1/4 watt	Carbon Film
C1	3300MF	160v	Electrolytic
C2	4700MF	63v	Electrolytic
C3	4700MF	25v	Electrolytic
C4	4700MF	25v	Electrolytic
C6	470nF	100v	Polyester
C7	470nF	100v	Polyester
C8	470nF	100v	Polyester
C9	470nF	100v	Polyester
C11	470nF	63v	Polyester
C12	470nf	63v	Polyester
C13	100nF	63v	Polyester
C14	470nF	63v	Polyester
C15	470nF	63v	Polyester
C16	100nF	63v	Polyester
C17	470MF	16v	Electrolytic

REC1	6 amp	Rectifier Bridge	KBPC 602
REC2	6 amp	Rectifier Bridge	KBPC 602
REC3	6 amp	Rectifier Bridge	KBPC 602
REC4	6 amp	Rectifier Bridge	KBPC 602

REG	78S12	2 amp	Regulator
REG	7912	1 amp	Regulator

CON1	8 way	Connector	Molex 39-26-3080
CON2	10 way	Connector	Molex 39-26-3100
CON3	3 way	Connector	Molex 39-26-3030

TP1-TP7 PCB Test Points

The two regulators are each mounted on heatsinks Heatsink type SW38-4

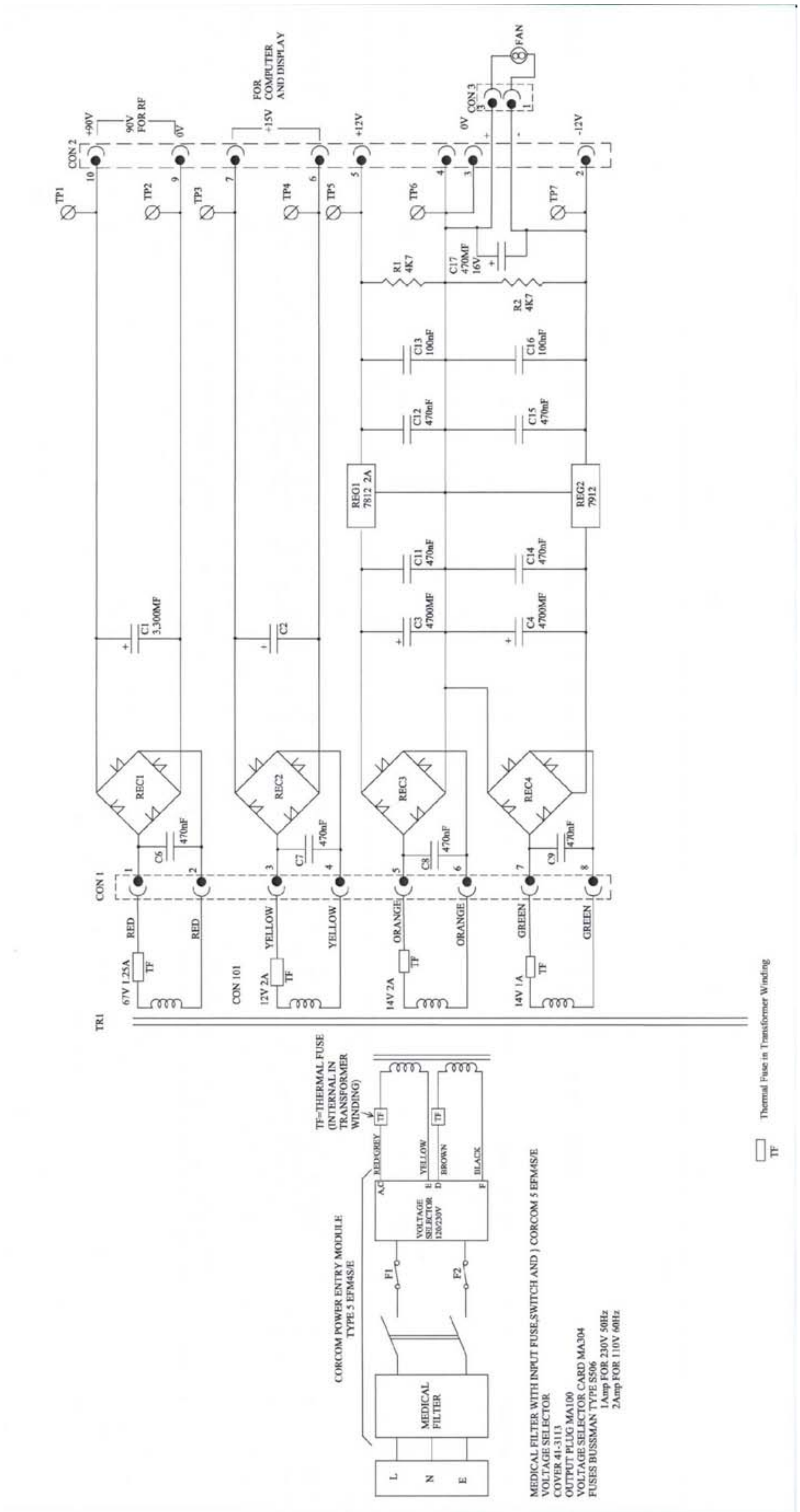


Figure 6.1 Power Supply Board – RF100 C – Circuit Diagram

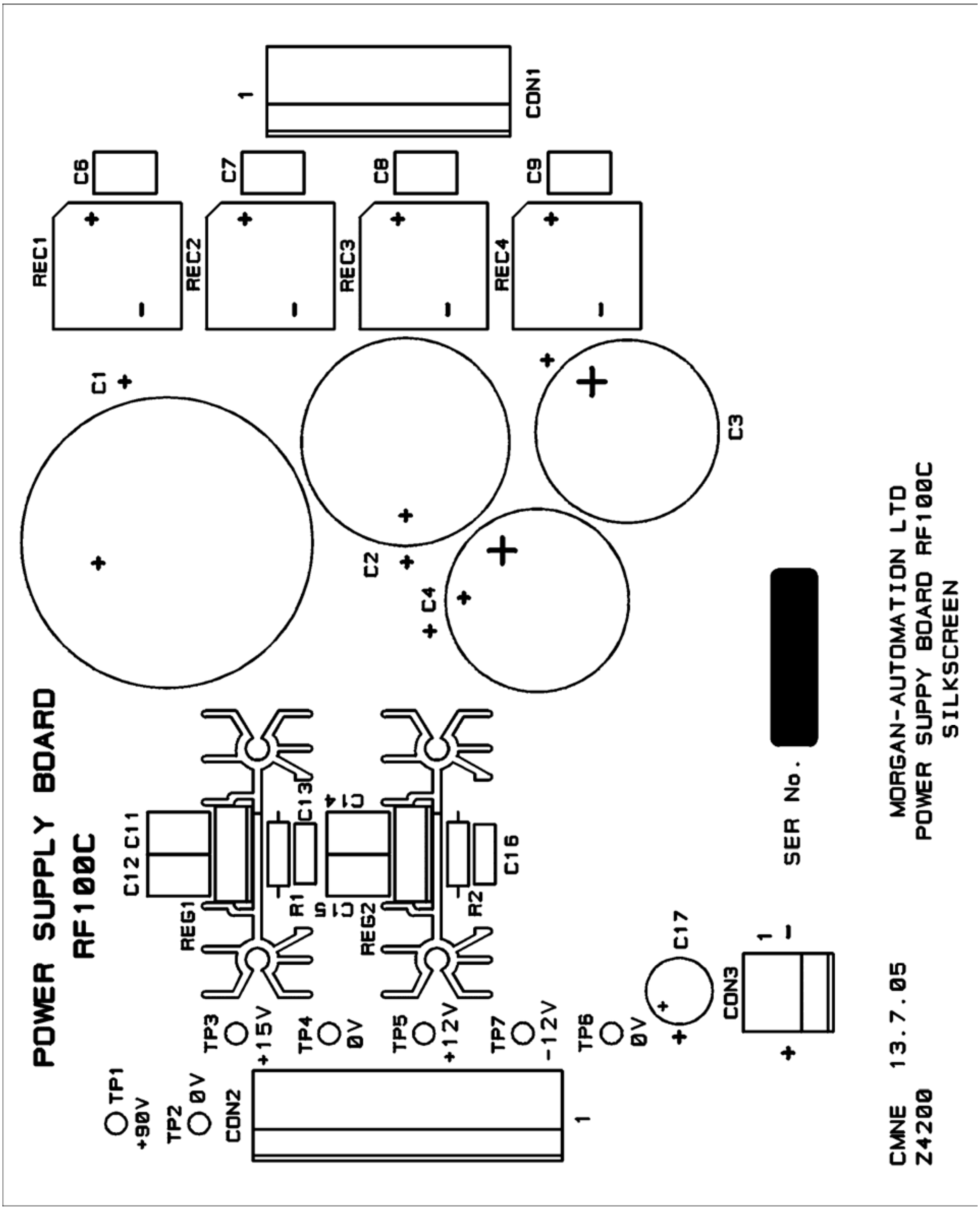


Figure 6.2 Power Supply Board –RF100 C – Component Layout

6.2 Fuse Board – RF101D

R101	4K7±5%	0.25 watt	Carbon Film
R102	4K7±5%	0.25 watt	Carbon Film
R104	27K±5%	0.25 watt	Carbon Film
R105	6K8±5%	0.25 watt	Carbon Film
R106	6K8±5%	0.25 watt	Carbon Film
R107	IK±5%	0.25 watt	Carbon Film
R108	8K2±5%	0.25 watt	Carbon Film
R109	1K2±5%	0.25 watt	Carbon Film
R110	1K2±5%	0.25 watt	Carbon Film
R111	2K2±5%	0.25 watt	Carbon Film
R112	2K2±5%	0.25 watt	Carbon Film
R113	4K7±5%	0.25 watt	Carbon Film
R114	10k±5%	0.25 watt	Carbon Film

T101 BC337 NPN Transistor

U101 4 way Transistor Output Opto Isolator Type KP1040E

LED 101
LED 102
LED 104
LED 105
LED 106
} Low power 5mm Board Indicators-Green

F 101
F 102
F 104
F 105
F 106
} Open Fuse holders with Covers

Test Points TP1 –TP9 PCB Test Terminals

Black Handle

Edge Connector DIN 41612 Type D32 Way

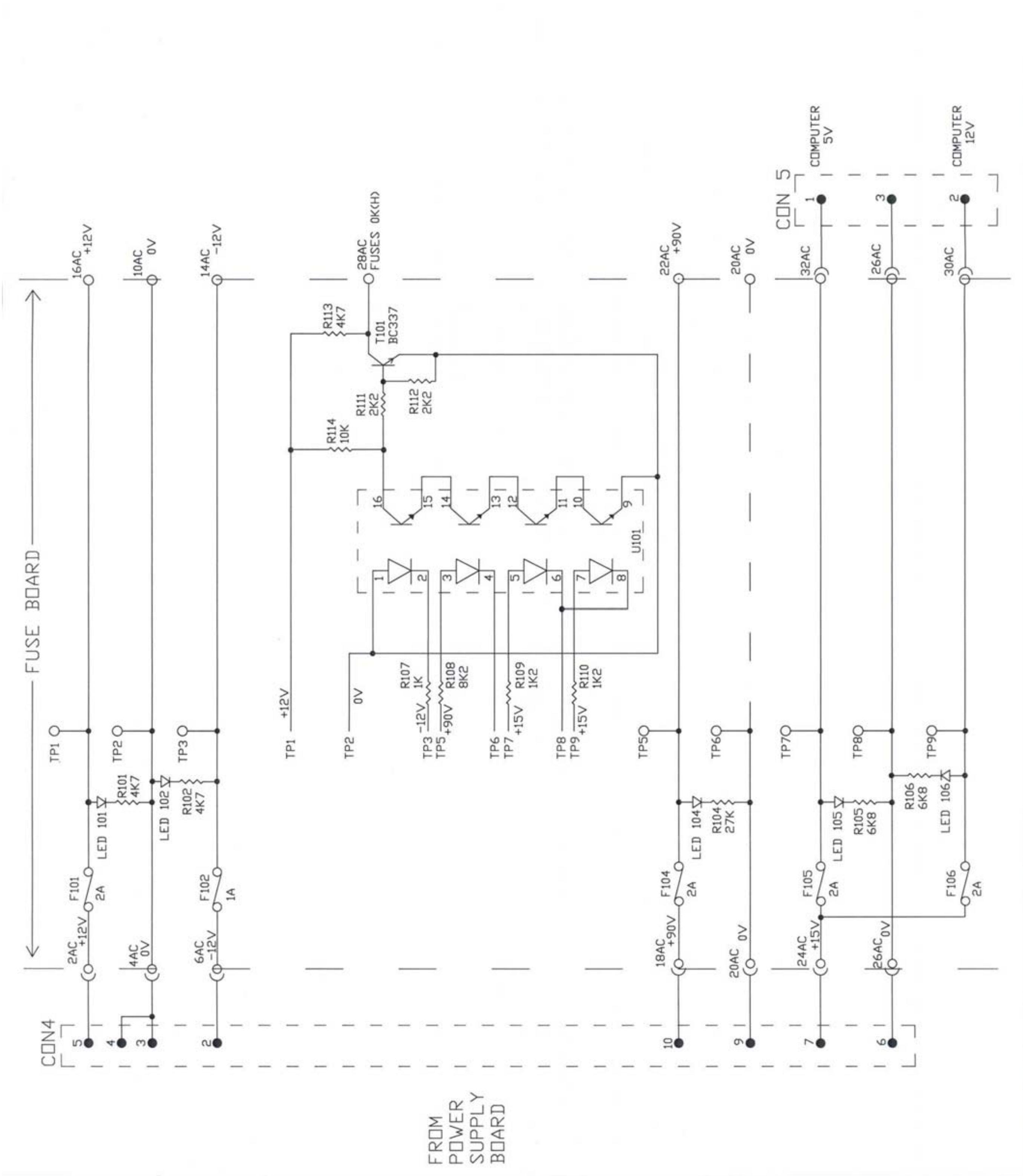


Figure 6.3 Fuse Board – RF101 D – Circuit Diagram

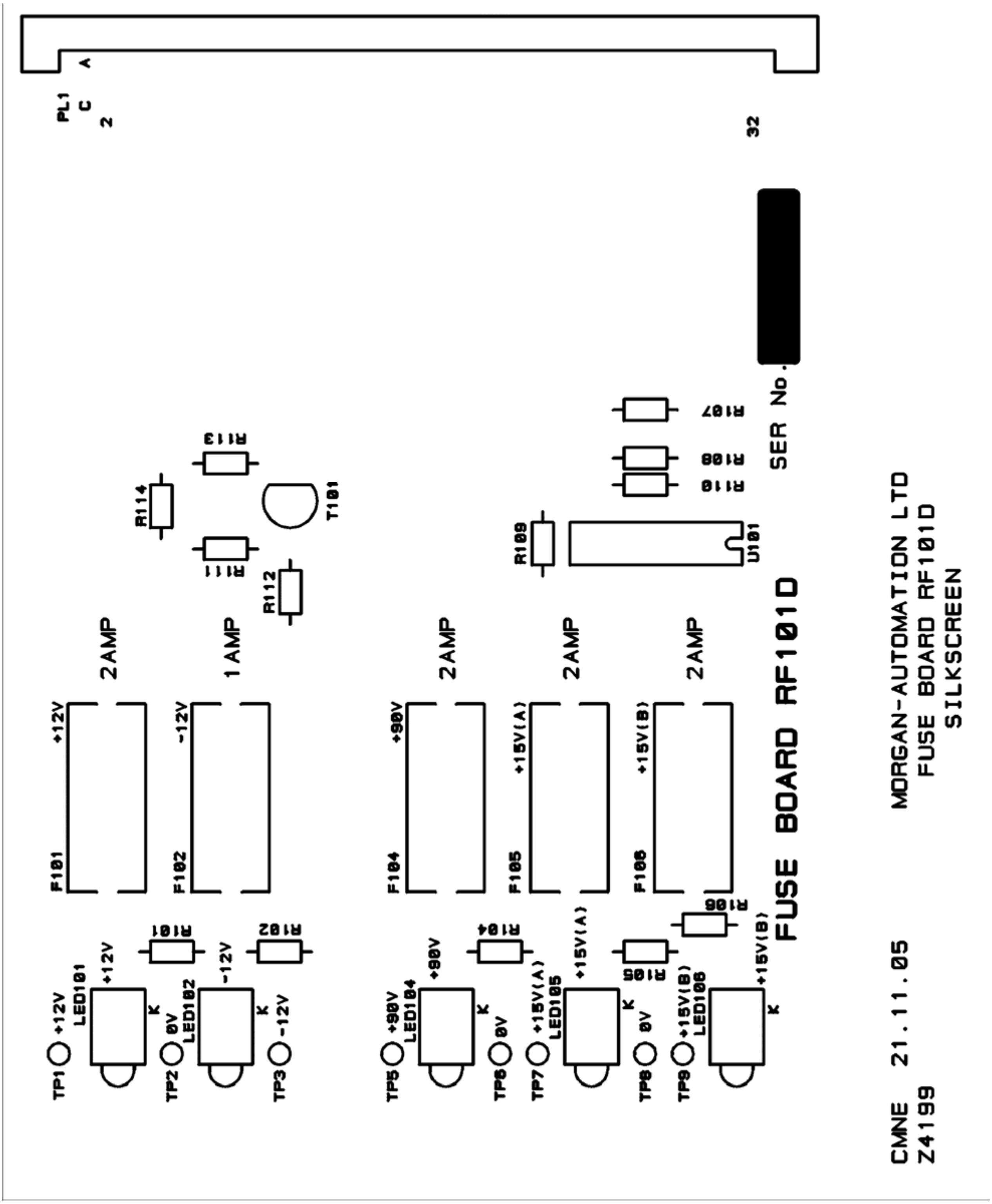


Figure 6.4 Fuse Board – RF 101 D – Component Layout

6.3 Impedance Board –RF 102D

Components

R201	2K	±5%	0.25 W	Carbon Film
R202	7K5	±5%	0.25 W	Carbon Film
R203	6K8	±5%	0.25 W	Carbon Film
R204	6K8	±5%	0.25 W	Carbon Film
R205	82K	±5%	0.25 W	Carbon Film
R206	15K	±5%	0.25 W	Carbon Film
R207	3K16	±0.5%	0.25 W	Precision Metal Film
R208	3K16	±0.5%	0.25 W	Precision Metal Film
R209	180R	±5%	0.25 W	Carbon Film
R211	3K16	±0.5%	0.25 W	Precision Metal Film
R212	10K	±5%	0.25 W	Carbon Film
R213	10K	±5%	0.25 W	Carbon Film
R214	3K3	±5%	0.25 W	Carbon Film
R215	3K3	±5%	0.25 W	Carbon Film
R216	3K3	±5%	0.25 W	Carbon Film
R217	470K	±5%	0.25 W	Carbon Film
R218	330K	±5%	0.25 W	Carbon Film
R219	200K	±5%	0.25 W	Carbon Film
R220	100K	±5%	0.25 W	Carbon Film
R221	2K2	±5%	0.25 W	Carbon Film
R222	47R	±5%	1 Watt	Carbon Film
R223	10K	±5%	0.25 W	Carbon Film
R224	330K	±5%	0.25 W	Carbon Film
R225	499R	±0.1%	0.25 W	Precision Metal Film
R226	10R	±5%	0.25 W	Carbon Film
R227	1K	±5%	0.25 W	Carbon Film
R228	3K	±5%	0.25 W	Carbon Film
R229	12K	±5%	0.25 W	Carbon Film
R230	100R	±5%	0.25 W	Carbon Film
R231	4K7	±5%	0.25 W	Carbon Film
R232	200R	±5%	0.25 W	Carbon Film
R233	10K	±5%	0.25 W	Carbon Film
R234	33K	±5%	0.25 W	Carbon Film
R235	1K	±5%	0.25 W	Carbon Film
R236	10K	±5%	0.25 W	Carbon Film
R237	4K7	±5%	0.25 W	Carbon Film
R239	LINK			
R240	1K	±5%	0.25 W	Carbon Film
R241	39R	±5%	0.25 W	Carbon Film
R242	10K	±5%	0.25 W	Carbon Film
P201	1K		Potentiometer 18 turn	
P202	20K		Potentiometer 18 turn	
P203	5K		Potentiometer 18 turn	

Impedance Board – RF 102D contd

P204	50K		Potentiometer 18 turn
P206	200K		Potentiometer 18 turn
C201	1000pF ±1%		Silver Mica
C202	120pF ±1%		Silver Mica
C203	1000pF ±1%		Silver Mica
C204	1000pF ±1%		Silver Mica
C205	4.7nF	100V	Polyester
C208	330nF	63V	Polyester
C210	220pF		miniature plate ceramic
C211	1nF	100V	Ceramic
C212	2.2nF	100V	Ceramic
C213	1nF	100V	Ceramic
C214B	1800pF ±1%		Silver Mica
C215	100MF	16V	Electrolytic
C216	100nF	63V	Polyester
C217	100nf	63V	Polyester
C218	100nF	63V	Polyester
C219	47MF	16V	Electrolytic
C220	100nF	63V	Polyester
C221	100nF	63V	Polyester
C224	100nF	63V	Polyester
C225	100nF	63V	Polyester
C226	47MF	16V	Electrolytic
C229	100nF	63V	Polyester
C230	10MF	16V	Electrolytic
D202	BAT85X		
D203	IN4148		
D204	IN4148		
D205	IN4148		
D206	IN4148		
D207	IN4148		
D208	IN4148		
D209	IN4148		
D210	IN4148		
D211	BAT85		
D212	BAT85		
D213	ZXR125ER		1.2V Reference Diode
D214	IN4002		
D215	IN4148		
D216	LED Amber		
D218	ZXR 125ER		1.2V Reference Diode
D219	ZXR125ER		1.2V Reference Diode
TR201	BC559		PNP Transistor
TR202	MPSA13		Darlington
TR203	MPSA13		Darlington

Impedance Board – RF102D contd

U201	ICL 8038 CCPD	Frequency Generator
U202	TL072N	Dual Amplifier
U203	TL072N	Dual Amplifier
U204	TC9402CPD	Voltage to Frequency Converter
U206	LF398N	Sample/Hold
U207	LM741CN	Operation Amplifier
L201	470µH	
L202	470µH	
TF201	PT4	1:1 Pulse Transformer
T 201	Thermistor 100K at 25°C NTC Type	
LS201	Loudspeaker 8ohm 40mm dia 200mW	
RL201	12V	Low Power 2 pole relay
RL202	12V	Reed Relay
RL203	12V	Reed Relay
RL204	12V	Low Power 2 pole relay
RL205	12V	Low Power 2 pole relay
RL206	12V	Low Power 2 pole relay
TP1-TP3	Test Points	

64 Way Connector DIN416 Type D 32 way ac

Handle - White

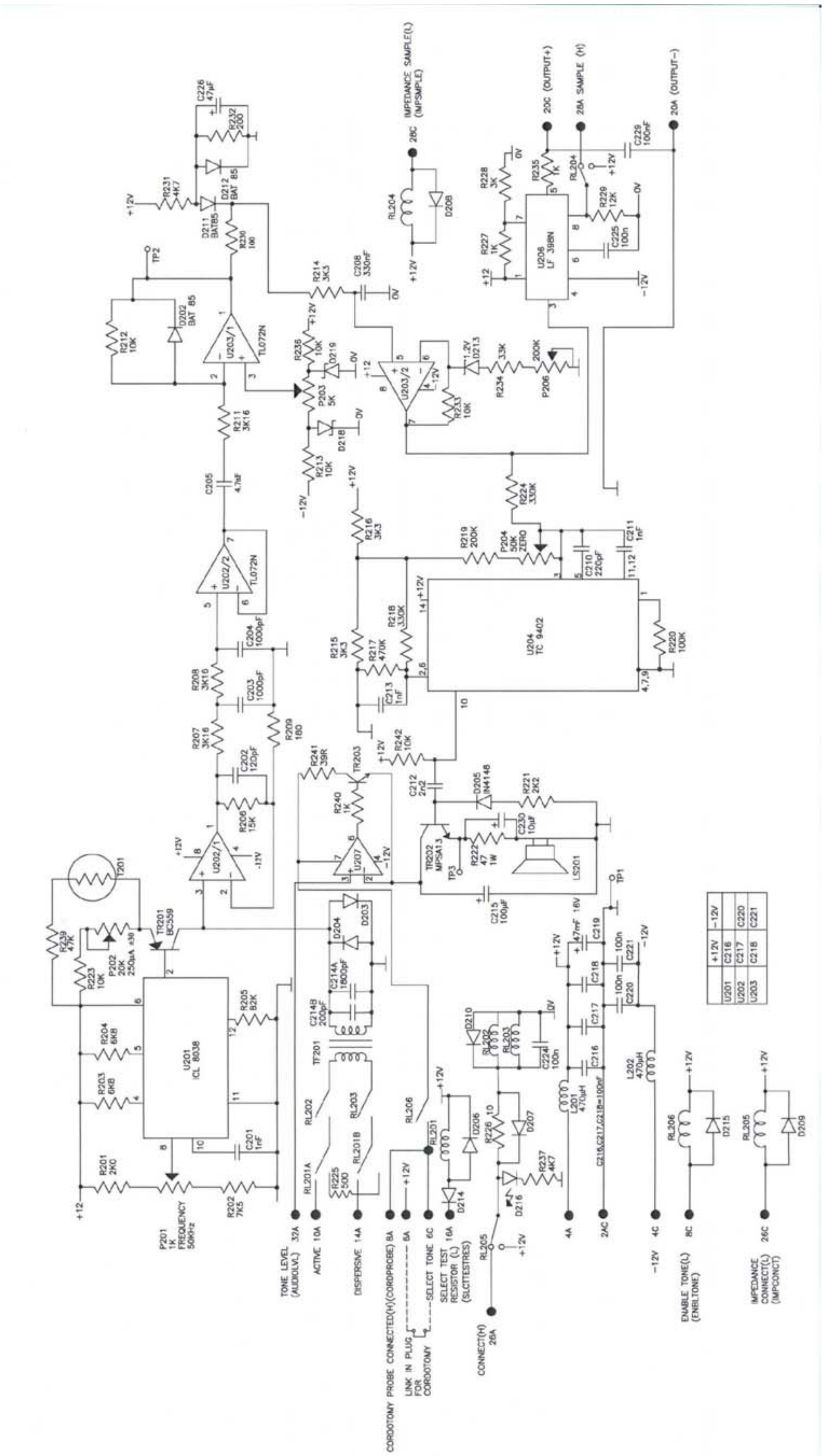


Figure 6.5 Impedance Board – RF102 D – Circuit Diagram

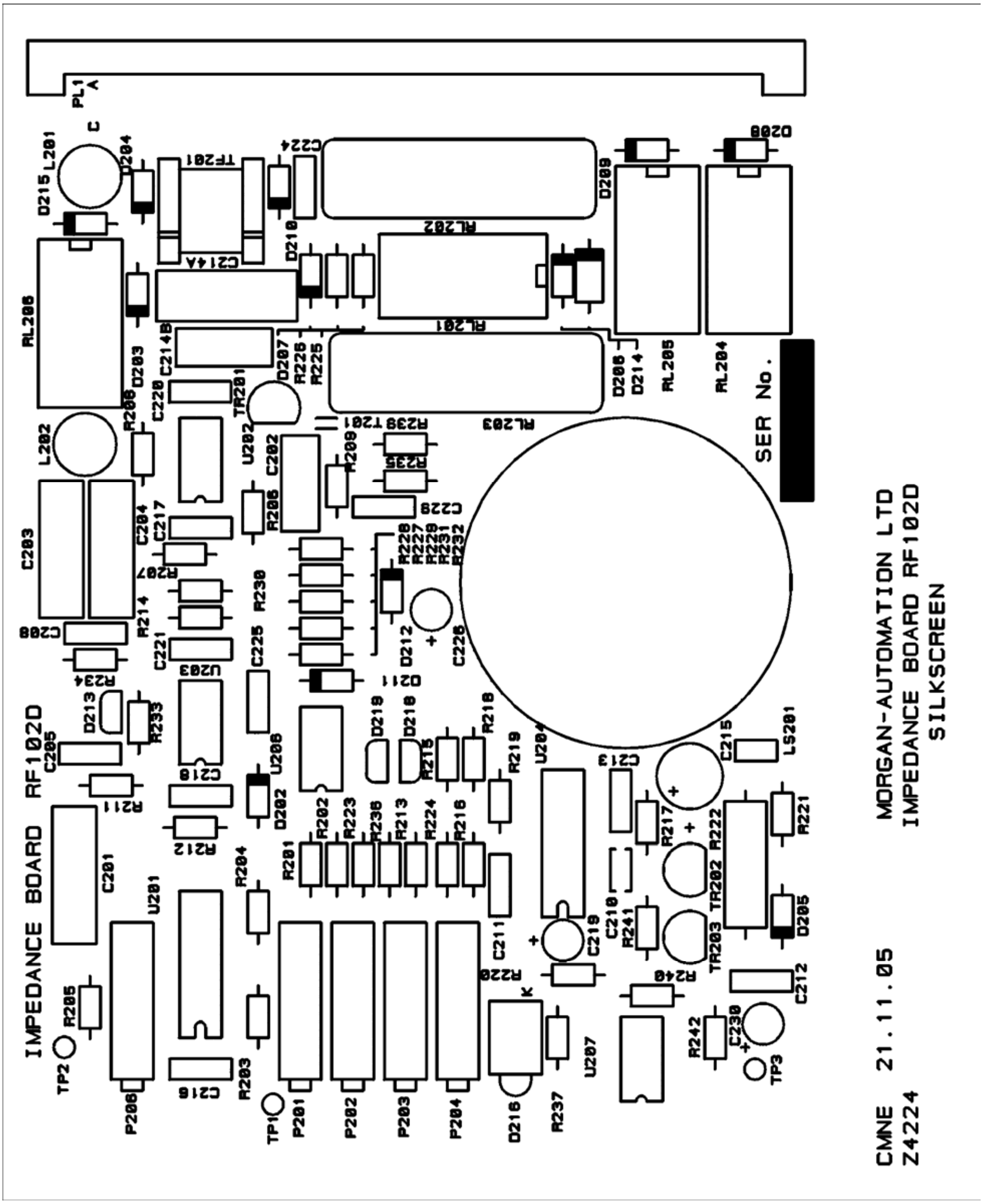


Figure 6.6 Impedance Board – RF102 D – Component Layout

6.4 Stimulate Board RF103D + Sub Board

R301A-F	10K		7	Bussed Resistors SIL
R302A	698K	±1%	0.6 watt	Metal Film
R302B	16K2	±1%	0.6 watt	Metal Film
R303A	280K	±1%	0.25 watt	Metal Film
R303 B	K6	±1%	0.25 watt	Metal Film
R304A	140K	±1%	0.6 watt	Metal Film
R304B	2K7	±1%	0.25 watt	Metal Film
R305A	68K	±1%	0.25 watt	Metal Film
R305B	3K24	±1%	0.6 watt	Metal Film
R306A	28K	±1%	0.6 watt	Metal Film
R306B	442R	±1%	0.6 watt	Metal Film
R307A	16K2	±1%	0.6 watt	Metal Film
R307B	2K7	±1%	0.25 watt	Metal Film
R308A	14K	±1%	0.6 watt	Metal Film
R308B	133R	±1%	0.6 watt	Metal Film
R309A	9K1	±1%	0.25 watt	Metal Film
R309B	274R	±1%	0.6 watt	Metal Film
R310A	7K5	±1%	0.25 watt	Metal Film
R310B	287R	±1%	0.6 watt	Metal Film
R311A	6K8	±1%	0.25 watt	Metal Film
R311B	191R	±1%	0.6 watt	Metal Film
R312	9K1	±1%	0.25 watt	Metal Film
R313	18K	±1%	0.25 watt	Metal Film
R314	45K3	±1%	0.6 watt	Metal Film
R315	91K	±1%	0.25 watt	Metal Film
R316	9K1	±1%	0.25 watt	Metal Film
R317	18K	±1%	0.25 watt	Metal Film
R318	45K3	±1%	0.6 watt	Metal Film
R319	91K	±1%	0.25 watt	Metal Film
R320	10K	±5%	0.25 watt	Carbon Film
R321	10K	±5%	0.25 watt	Carbon Film
R323	1K	±1%	0.25 watt	Metal Film
R324	2K4	±1%	0.25 watt	Metal Film
R325	4K7	±5%	0.25 watt	Carbon Film
R326	1K5	±5%	0.25 watt	Carbon Film
R327	1K5	±5%	0.25 watt	Carbon Film
R330	18K	±1%	0.25 watt	Metal Film
R331	10K	±1%	0.25 watt	Metal Film
R332	10K	±1%	0.25 watt	Metal Film
R335	39K	±1%	0.25 watt	Metal Film
R336	22R	±5%	2.5 watt	vitreous
R337	33K	±1%	0.25 watt	Metal Film
R338	470R	±5%	0.25 watt	Carbon Film
R339	1M	±5%	0.25 watt	Carbon Film
R340	4K7	±5%	0.25 watt	Carbon Film
R341	27R	±5%	0.25 watt	Carbon Film
R342	LINK			

Stimulate Board RF103D + Sub Board contd

R343	5K1 ±5%	0.25 watt	Carbon Film
R344	4K7 ±5^%	0.25 watt	Carbon Film
R345	10K ±5%	0.25 watt	Carbon Film
R346	10K ±5%	0.25 watt	Carbon Film
R347	3K3 ±5%	0.25 watt	Carbon Film
R348	10K ±5%	0.25 watt	Carbon Film
R349	2K ±5%	0.25 watt	Carbon Film
R350	100R ±5%	0.25 watt	Carbon Film
R351	75K ±5%	0.25 watt	Carbon Film
R352	1K ±5%	0.25 watt	Carbon Film
R353	680R ±5%	0.25 watt	Carbon Film
R354	12K ±5%	0.25 watt	Carbon Film
R355	12K ±5%	0.25 watt	Carbon Film
R356	470K ±5%	0.25 watt	Carbon Film
R357	330R ±5%	0.25 watt	Carbon Film
R358	10K ±5%	0.25 watt	Carbon Film
R359	150R ±5%	0.25 watt	Carbon Film
R361	4K7 ±5%	0.25 watt	Carbon Film
R362	10K ±1%	0.25 watt	Metal Film
R363	8K2 ±1%	0.25 watt	Metal Film
R364	1K ±1%	0.25 watt	Metal Film
R365	2K ±1%	0.25 watt	Metal Film
R366	6K2 ±1%	0.25 watt	Metal Film
R367	100R ±1%	0.25 watt	Metal Film
R368	9K1 ±1%	0.25 watt	Metal Film

P302	2K	18 Turn Potentiometer
P303	5K	18 Turn Potentiometer
P305	20K	18 Turn Potentiometer
P306	5K	18 Turn Potentiometer
P307	2K	18 Turn Potentiometer
P308	500R	18 Turn Potentiometer

C301	100nF	63v	Polyester
C302	100nF	63v	Polyester
C303	100nF	63v	Polyester
C304	100nF	63v	Polyester
C305	100nF	63v	Polyester
C306	1MF±5%	63v	Metallised Polyester
C307	100nF	63v	Polyester
C308	100nF	63v	Polyester
C309	100nF	63v	Polyester
C310	100nF	63v	Polyester
C311	100nF	63v	Polyester
C312	100nF	63v	Polyester
C313	Select on Test		
C314	100nF	63v	Polyester
C315	NOT FITTED		
C316	47pF	100v	Ceramic
C317	2.2nF	100v	Polyester

Stimulate Board RF103D + Sub Board contd

C318	100MF	63v	Electrolytic
C319	47nF	63v	Polyester
C320	100nF	63v	Polyester
C321	100nF	63v	Polyester
C322	100nF	63v	Polyester
C323	100nF	63v	Polyester
C324	100nF	63v	Polyester
C325	100nF	63v	Polyester
C326	100nF	63v	Polyester
C327	100nF	63v	Polyester
C328	10nF	100v	Polyester
C329	10nF	100v	Polyester
C330	10Nf ±1%	100v	Precision Polypropylene
C330A			Select on Test
C331	10n±1%	100v	Precision Polypropylene
C331A	Select on test		
C332	47MF	16v	Electrolytic
C333	47MF	16v	Electrolytic
C334	1n	100v	Polyester
C335	10µF	50v	Electrolytic

D301	IN4148	
D302	IN4148	
D303	IN4148	
D304	IN4148	
D305	IN4148	
D306	IN4148	
D307	IN4148	
D308	IN4148	
D309	Red LED	
D310	Amber LED	
D311	Amber LED	
D312	BAT 85	Schottky Barrier Diode
D313	IN4148	
D314	IN4148	
D315	Green LED	
D316	Red LED	
D317	IN4148	

TR301	BC337	NPN Transistor
TR302	BC337	NPN Transistor

S301	Sounder

U301	4049B	Hex Inverting Buffers
U302	4028B	1 of 10 Decoders
U303	MAX313CPE	Quad SPST CMOS Analogue Switches
U304	MAX313CPE	Quad SPST CMOS Analogue Switches
U305	MAX313CPE	Quad SPST CMOS Analogue Switches

Stimulate Board RF103D + Sub Board contd

U306	4049B	Hex Inverting Buffers
U307	4555B	1 of 4 Decoder/Demultiplexer
U308	MAX313CPE	Quad SPST CMOS Analogue Switches
U309	MAX313CPE	Quad SPST CMOS Analogue Switches
U310	NE555N	Timer
U311	HCF4538BEY	Dual Precision Monostable Multivibrator
U312	MAX323	Dual Analogue Switch
U313	TL082	Dual Operational Amplifier
U314	TCA0372	Power Op Amp
U315	TL071	Operational Amplifier
U316	LM393N	Comparator
U317	4071	Quad 2 Input OR Gates
U318	NE555N	Timer
L301	1:1	Transformer
L302	1 + 1 : 1 + 1	Transformer
L303	1 : 1	Transformer
RL301	Double Pole Relay	12v
RL302	Single Pole Relay	12v
RL303	Double Pole Relay	12v
RL304	Double Pole Relay	12v
RL305	Double Pole Relay	12v
RL306	Double Pole Relay	12v
RL307	Double Pole Relay	12v
RL308	Double Pole Relay	12v
RL309	Double Pole Relay	12v
TP 1-6	Test Points	
Connector	DIN 41612	Type D 32 way ac
Handle Green		

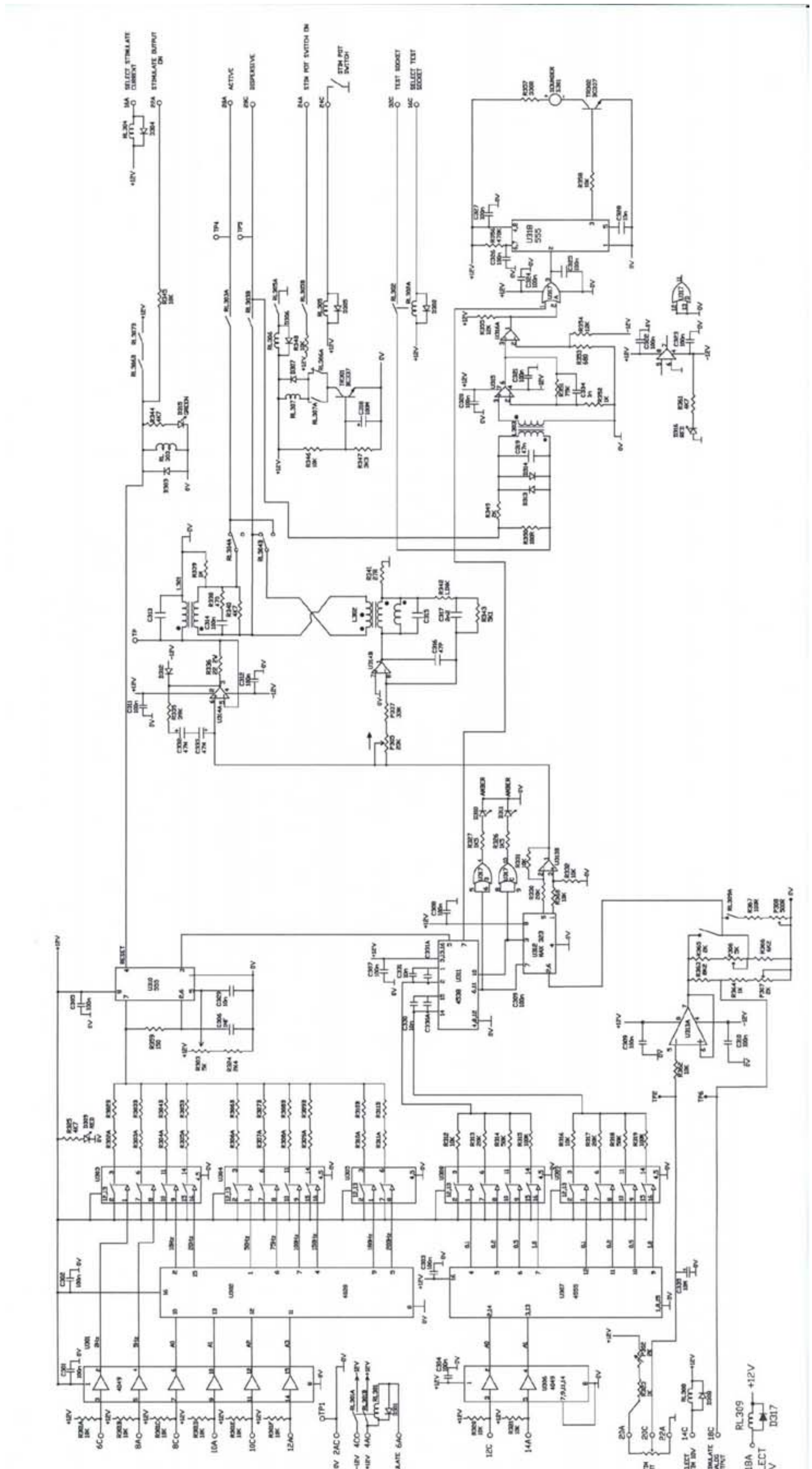


Figure 6.7 Stimulate Board – RF 103 D – Circuit Diagram

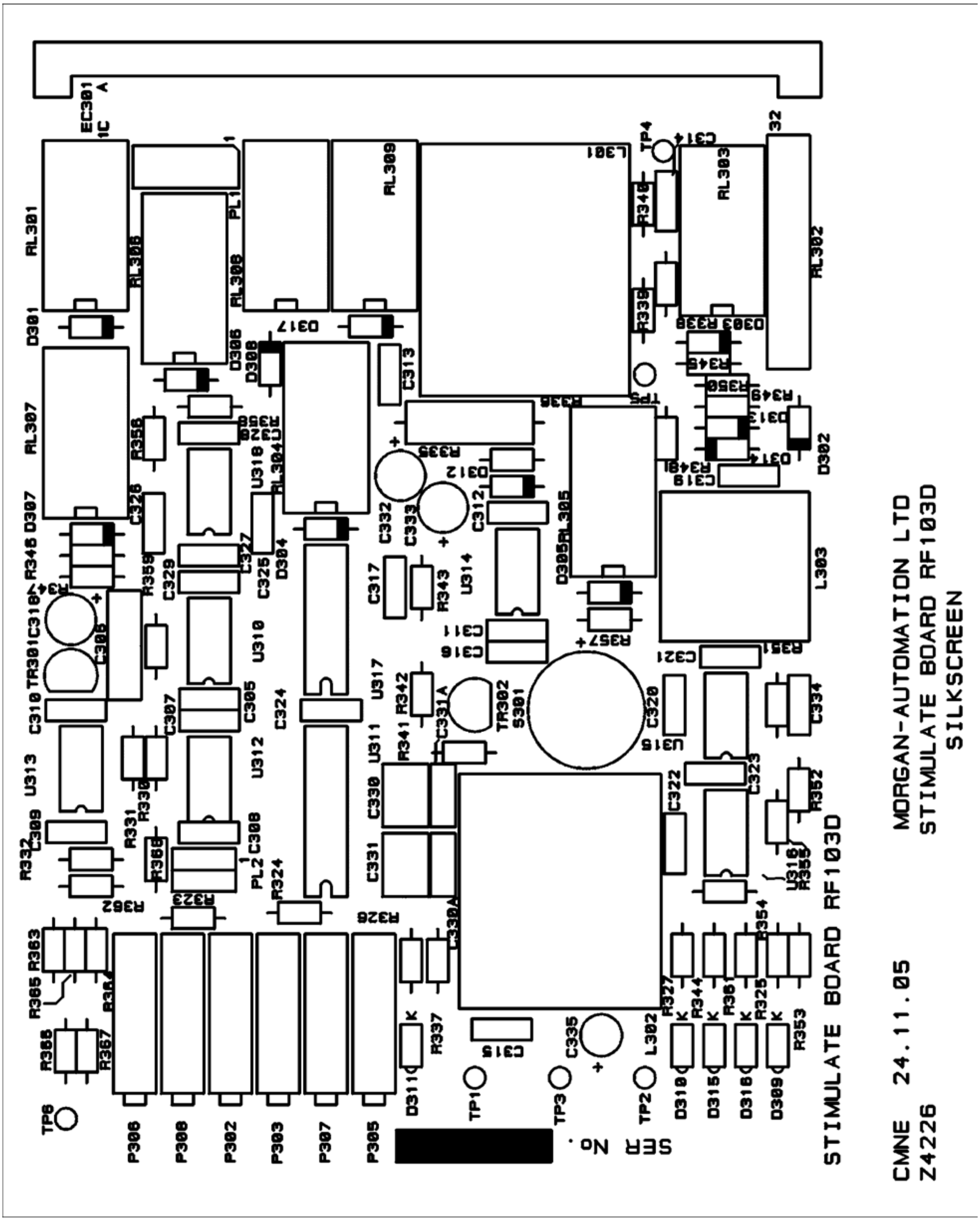


Figure 6.8 Stimulates Board – RF103 D – Component Layout

6.5 RF Amplifier Board RF 104 C

COMPONENTS

RI	3K3	± 5%	0.66w	Carbon Film
R2	3K6	± 5%	0.66w	Carbon Film
R3	10K	± 5%	0.25w	Carbon Film
R4	1M	± 5%	0.25w	Carbon Film
R5	12K	± 1%	0.25w	Metal Film
R6	120K	± 1%	0.25w	Metal Film
R7	1K5	± 5%	0.25w	Carbon Film
R8	820R	±5%	0.25w	Carbon Film
R9	IK	±5%	0.66w	Carbon Film
R10	100R	±5%	0.25w	Carbon Film
R11	100R	±5%	0.25w	Carbon Film
R12	4R7	± 5%	0.25w	Carbon Film
R13	4R7	± 5%	0.25w	Carbon Film
R14	1R	± 5%	1 watt	Power Oxide Resistor
R15	1R	± 5%	1 watt	Power Oxide Resistor
R19	10K	± 5%	0.66w	Carbon Film
R20	100R	± 5%	0.25w	Carbon Film
R21	0R39	± 5%	2.5 w	Power Oxide Resistor
R22	120K	± 1%	0.25w	Metal Film
R23	10K	± 5%	0.25w	Carbon Film
R24	3K3	± 5%	1watt	Power Oxide Resister
R25	12K	± 1%	0.25w	Metal Film
R26	15K	± 5%	0.25w	Carbon Film
R27	10K	± 5%	0.25w	Carbon Film
R29	10K	± 5%	0.25w	Carbon Film
R30	1K8	±5%	0.25w	Carbon Film
R31	560K	±5%	0.25w	Carbon Film
R32	330K	±5%	0.25w	Carbon Film
RVI	10K		18 tum potentimeter	

RF Amplifier Board RF 104 C contd

C2	100nF	100v	Polyester
C3	100nF	100v	Polyester
C4	100nF	100v	Polyester
C5	100nF	100v	Polyester
C6	220nF	100v	Polyester
C8	4n7	375v AC	Polypropylene
C9	820pF	250v	Silver Mica
C10	10nF	375v AC	Polypropylene
C11	10nF	375v AC	Polypropylene
C12	100nF	250v AC	Polypropylene
C13	100nF	250v AC	Polypropylene
C14	22nF	375v AC	Polypropylene
C15	10nF	100v	Polyester
C16	10nF	100v	Polyester
C17	100nF	100v	Polyester

L1	4+4: 9	On Former
L2	47µH	
L3	47 µH	

D1	BAV 21	Fast High Voltage Diode
D2	BAV 21	Fast High Voltage Diode
D3	IN4148	
D4	IN4148	
D5	IN4148	
D6	IN4148	
D7	IN4148	
D8	IN4148	
D9	BZX 79 C10	10v Zener

RF Amplifier Board RF 104 C contd

TR1	2N 5550	NPNTransistor
TR2	IRFP 240	Power MOSFET
TR3	IRFP 240	Power MOSFET
TR4	BC182L	NPN Transistor
TR5	2N5550	NPN Transistor
TR6	IRFP240	Power MOSFET
TR7	IRFP 240	Power MOSFET
U1	LM741 CN	Operational Amplifier
U2	4N32	Darlington Opto Isolator
U3	TC4427CPA	Dual Mosfet Driver
SENS 1	T75	Thermal Switch 75º
RL1	2pole	12 Volt Relay
RL2	2pole	12 Volt Relay
CON1	15way	Molex friction Lock Header
CON2	SMB	Straight Male PCB Header
TP 1	Test Point	

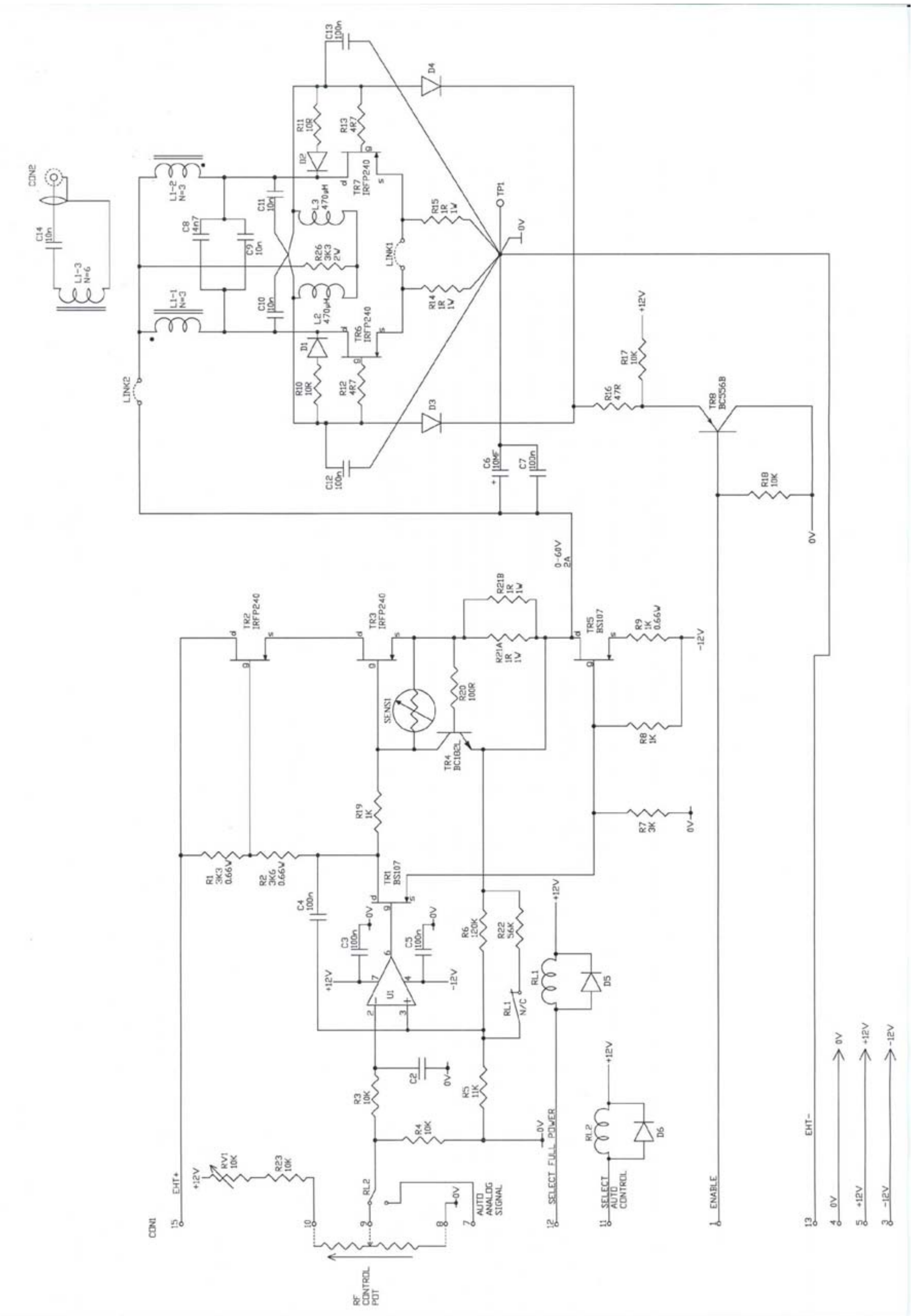


Figure 6.9 RF Amplifier Board – RF104 C – Circuit Diagram

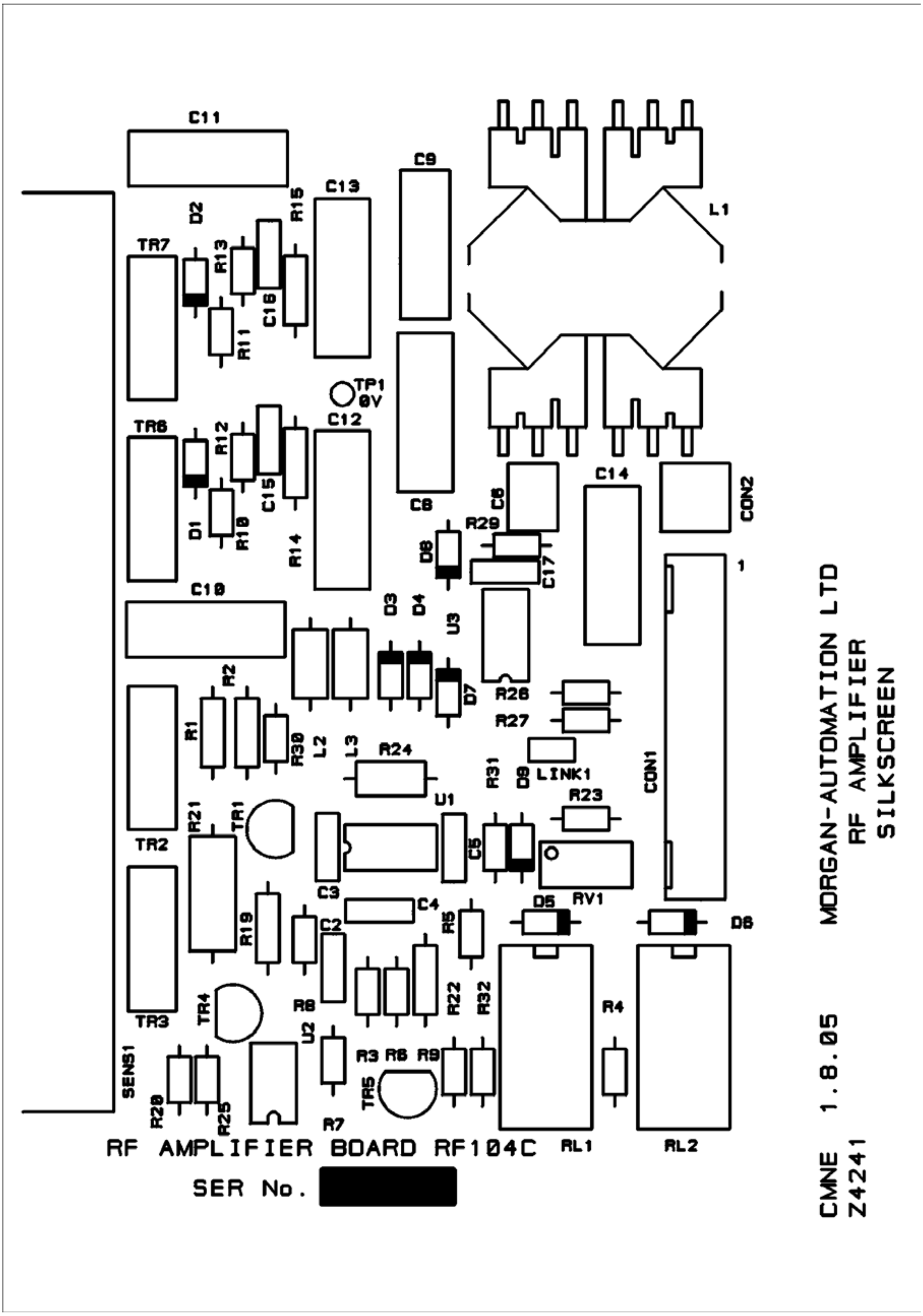


Figure 6.10 RF Amplifier Board – RF104C – Component Layout

6.6 RF Voltage and Current Metering Board RF 105C

Components

R501	12K	±5%	1watt	Carbon Film
R502	1K1	±5%	0.25 watt	Carbon Film
R503	2K7	±5%	0.25 watt	Carbon Film
R504	11K	±5%	0.25 watt	Carbon Film
R505	IK1	±5%	0.25 watt	Carbon Film
R506	2K7	±5%	0.25 watt	Carbon Film
R507	11K	±5%	0.25 watt	Carbon Film
R508	2K2	±5%	0.25 watt	Carbon Film
R509	IK5	±5%	0.25 watt	Carbon Film
R510	33K	±5%	0.25 watt	Carbon Film
R511	22K	±5%	0.25 watt	Carbon Film
R512	6K8	±5%	0.25 watt	Carbon Film
R513	1K	±5%	0.25 watt	Carbon Film
R514	33K	±5%	0.25 watt	Carbon Film
R515	22K	±5%	0.25 watt	Carbon Film
R516	6K8	±5%	0.25 watt	Carbon Film
R517	10K	±5%	0.25 watt	Carbon Film
R518	10K	±5%	0.25 watt	Carbon Film
R519	82K	±5%	0.25 watt	Carbon Film
R520	100K	±5%	0.25 watt	Carbon Film
R521	4K7	±5%	0.25 watt	Carbon Film
R522	LINK			
R523	82K	±5%	0.25 watt	Carbon Film
R524	82K	±5%	0.25 watt	Carbon Film
R525	240K	±5%	0.25 watt	Carbon Film
R526	10K	±5%	0.25 watt	Carbon Film
R527	10K	±5%	0.25 watt	Carbon Film
R528	4K7	±5%	0.25 watt	Carbon Film

RF Voltage and Current Metering Board RF 105C contd

P501	1K	18tum	Potentiometer
P502	1K	18tum	Potentiometer
C501	10nF	100v	Polyester
C502	10nF	100v	Polyester
C503	33nF	100v	Polyester
C504	100nF	63v	Polyester
C505	100nF	63v	Polyester
C506	470nF	63v	Polyester
C507	33nF	100v	Polyester
C508	100nF	63v	Polyester
C509	100nF	63v	Polyester
C510	470nF	63v	Polyester
C511	100nF	63v	Polyester
C512	100nF	63v	Polyester
C513	100nF	63v	Polyester
C514	100nF	63v	Polyester
C515	100nF	63v	Polyester
C516	100nF	63v	Polyester
C517	100nF	63v	Polyester
C518	100nF	63v	Polyester
C519	100nF	63v	Polyester
L501	Inductor 470 µH		
L502	Inductor 470 µH		
L503	120 : 120 Toroid		
L504	1 : 120 Toroid		
D501	IN4148		
D502	IN4148		

RF Voltage and Current Metering Board RF 105C contd

D503	IN4148	
D504	IN4148	
D505	IN4148	
D506	IN4148	
D507	IN4148	
D508	Red LED	
D509	Green LED	
D511	IN 4148	
D512	Green LED	
D513	IN4148	
D514	Amber LED	
D515	Red LED	
TR501	BC337	NPN Transistor
TR502	MPSA 13	Darlington
TR503	BC337	NPN Transistor
U501	CA 3096E	NPN/ PNP Transistor Arrays
U502	CA 3096E	NPN / PNP Transistor Arrays
U503	LF 398	Sample and Hold
U504	LF398	Sample and Hold
U505	4011	Quad 2 – Input NAND Gate
U506	4093	Quad 2 – Input NAND Schmitt Trigger
U507	4041	Quad TRUE / COMPLEMENT Buffer
U508	4538	Dual Precision Monostable Multivibrator

RL 501	Single Pole Reed Relay	12v
RL 502	Single Pole Reed Relay	12v
RL 503	Double Pole Reed Relay	12v
RL 504	Double Pole Reed Relay	12v
RL 505	Single Pole Relay	12v
RL 506	Double Pole Relay	12v

TP1 – 8 Test Points

Connector	DIN 41612	Type D	32way ac

Handle Black

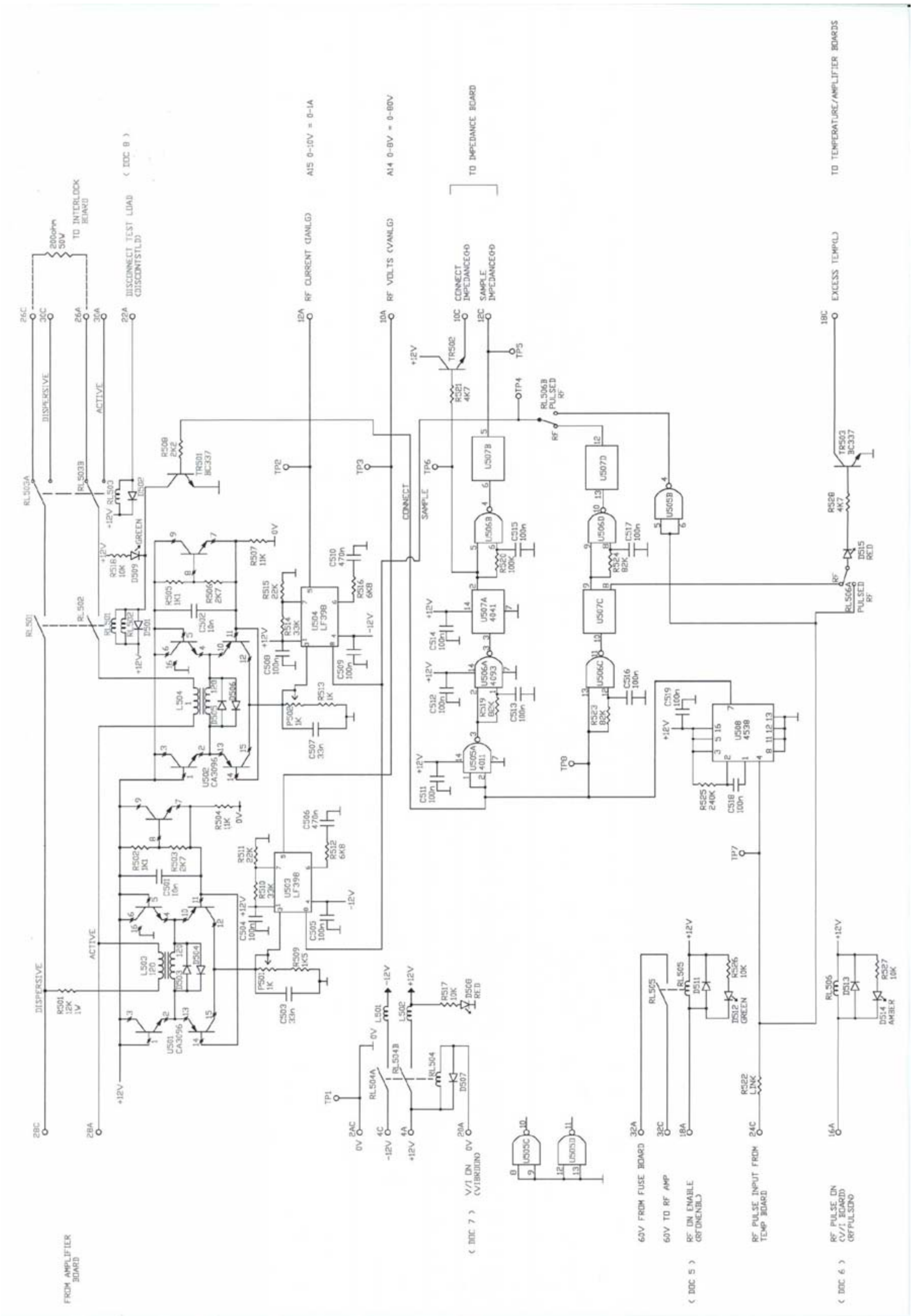


Figure 6.11. V/I Board RF 105C – Circuit Diagram

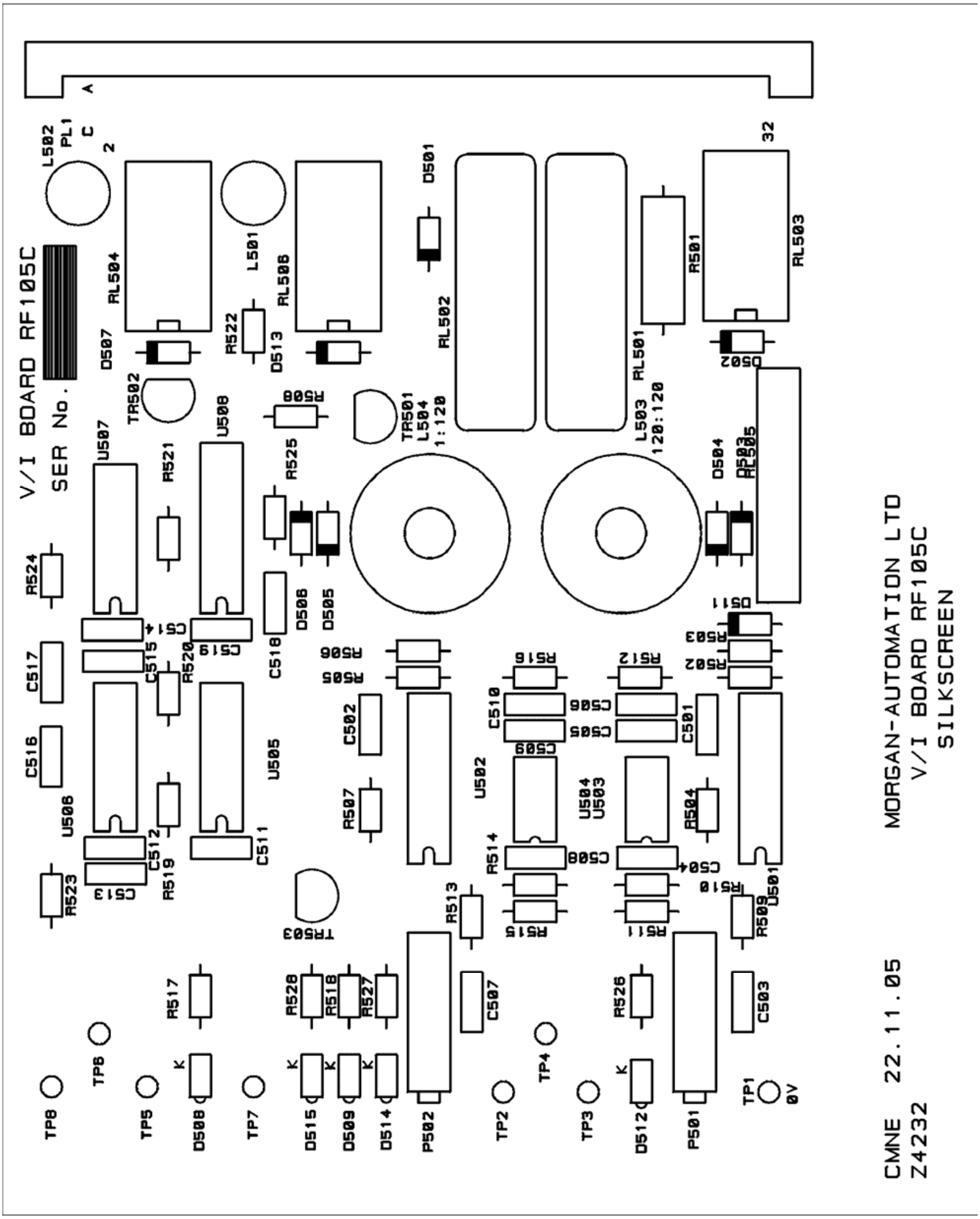


Figure 6.12 V/I Board - RF 105C - Component Layout

6.7 Temperature Board RF106 D

Components

R601	2K2	±5%	0.25 w Carbon Film
R602	LINK		
R603	Not Fitted		
R604	2K2	±5%	0.25 w Carbon Film
R605	2K2	±5%	0.25 w Carbon Film
R606	2K2	±5%	0.25 w Carbon Film
R607	2K2	±5%	0.25 w Carbon Film
R608	43K	±1%	0.25 w Metal Film
R609	43K	±1%	0.25 w Metal Film
R610	2K2	±1%	0.25 w Metal Film
R611	10K	±1%	0.25 w Metal Film
R612	20K	±1%	0.25 w Metal Film
R613	20K	±1%	0.25 w Metal Film
R614	10K	±1%	0.25 w Metal Film
R615	20K	±1%	0.25 w Metal Film
R616	10K	±1%	0.25 w Metal Film
R617	10K	±1%	0.25 w Metal Film
R618	10K	±1%	0.25 w Metal Film
R619	300K	±1%	0.25 w Metal Film
R621	130K	±1%	0.25 w Metal Film
R622	22K	±1%	0.25 w Metal Film
R623	1M	±1%	0.25 w Metal Film
R624	10K	±1%	0.25 w Metal Film
R625	10K	±1%	0.25 w Metal Film
R626	10K	±1%	0.25 w Metal Film
R627	9K1	±1%	0.25 w Metal Film
R628	10K	±1%	0.25 w Metal Film
R629	10K	±5%	0.25 w Carbon Film
R630	10K	±5%	0.25 w Carbon Film
R631	10K	±5%	0.25 w Carbon Film
R632	10K	±5%	0.25 w Carbon Film
R633	10K	±5%	0.25 w Carbon Film
R634	10K	±5%	0.25 w Carbon Film
R635	10K	4 commoned resistors	
R636	150R	±5%	0.25 w Carbon Film
R637	2K4	±1%	0.25 w Metal Film
R638	10K	±5%	0.25 w Carbon Film
R639	4K7	±5%	0.25 w Carbon Film
R640	10K	±5%	0.25 w Carbon Film
R641A	1M3	±1%	0.25 w Metal Film
R641B	127K	±1%	0.25 w Metal Film
R642A	698K	±1%	0.25 w Metal Film
R642B	16K2	±1%	0.25 w Metal Film
R643A	280K	±1%	0.25 w Metal Film
R644B	5K6	±1%	0.25 w Metal Film
R644A	140K	±1%	0.25 w Metal Film
R644B	2K7	±1%	0.25 w Metal Film
R645A	6K8	±1%	0.25 w Metal Film
R645B	191R	±1%	0.25 w Metal Film
R646A	14k	±1%	0.25 w Metal Film

Temperature Board RF106 D contd

R646B	133R	±1%	0.25 w Metal Film
R647A	28K	±1%	0.25 w Metal Film
R647B	442R	±1%	0.25 w Metal Film
R648A	68K	±1%	0.25 w Metal Film
R648B	3K24	±1%	0.25 w Metal Film
R649	1K	±1%	0.25 w Metal Film
R650	2K4	±1%	0.25 w Metal Film
R651	2K2	±5%	0.25 w Carbon Film
R652	10K	±5%	0.25 w Carbon Film
R653	10M	±1%	0.25 w Metal Film
R654	10K	±1%	0.25 w Metal Film
R655	10K	±1%	0.25 w Metal Film
R657	10K	±5%	0.25 w Carbon Film

P601	50K	18 tum potentiometer
P602	10K	18 tum potentiometer
P603	2K	18 tum potentiometer
P604	5K	18 tum potentiometer
P605	5K	18 tum potentiometer

C601	100nF	63v	Polyester
C602	100nF	63v	Polyester
C603	10nF	100v	Polyester
C604	10nF	100v	Polyester
C605	100nF	63v	Polyester
C606	10nF	100v	Polyester
C607	10nF	100v	Polyester
C608	100nF	63v	Polyester
C609	100nF	63v	Polyester
C610	100nF	63v	Polyester
C611	NOT FITTED		Polyester
C612	100nF	63v	Polyester
C613	100nF	63v	Polyester
C614	100nF	63v	Polyester
C615	100nF	63v	Polyester
C616	100nF	63v	Polyester
C617	470nF	63v	Polyester
C618	100nF	63v	Polyester
C619	100nF	63v	Polyester
C620	100nF	63v	Polyester
C621	1MF±5%	63v	Metallised Polyester
C622	10nF	100v	Polyester
C623	IMF ±5%	63v	Metallised Polyester
C624	10nF	100v	Polyester
C625	10MF	35v	Electrolytic
C626	470nF	63v	Polyester

Temperature Board RF106 D contd

C627	470nF	63v	Polyester
C628	100MF	16v	Electrolytic
C629	100nF	63v	Polyester
C630	100n	63v	Polyester

D601	BZX79C	5VI	Zemer Diode
D602	IN4148		
D603	IN4148		
D604	IN4148		
D605	IN4148		
D606	IN4148		
D607	IN4148		
D608	IN4148		
D609	IN4148		
D610	IN4148		
D611	BAT 85		
D612	BAT 85		
D613	Red LED		
D614	Red LED		
D615	Red LED		
D616	Amber LED		
D617	Amber LED		
D618	Amber LED		
D619	Green LED		
D620	IN4148		
D621	BAW 62		

TR 601	BC337	NPN Transistor
TR 602	BC337	NPN Transistor
TR 603	BC337	NPN Transistor
TR 604	BC337	NPN Transistor

U601	AD595A	Thermocouple Amplifier
U602	TL072	Dual Operational Amplifier
U603	LM311	Comparator
U604	LM311	Comparator
U605	LM35DZ	Precision Centigrade Temperature Sensor
U606	4049	Hex Inverting Buffers
U607	4555	Dual 1 of 4 Decoder / Demultiplexer
U608	MAX 313 CPE	Quad SPST Cmos Analog Switches
U609	MAX 313 CPE	Quad SPST Cmos Analog Swiches
U610	556	Dual Timer
U611	TL071	Operational Amplifier

Temperature Board RF106 D contd

RL601	2 pole Relay	12v
RL602	2 pole Relay	12v
RL 603	2 pole Relay	12v
RL 604	2 pole Relay	12v
RL 605	2 pole Relay	12v
RL 606	2 pole Relay	12v
TP1-8	Test Points	
CON 601	DIN41612	Type D 32 way ac

Handle Blue

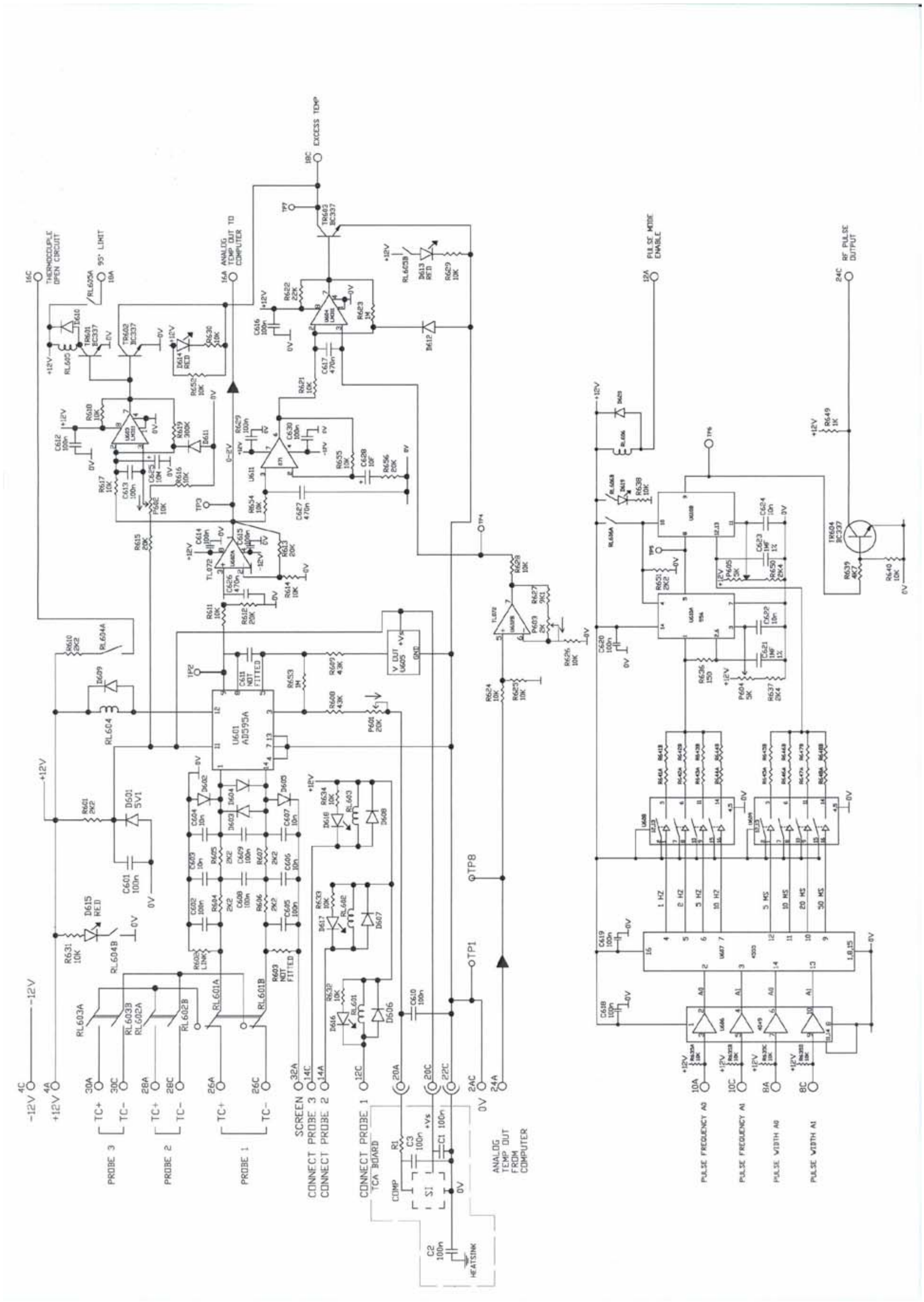


Figure 6.13 Temperature Board RF106D – Circuit Diagram

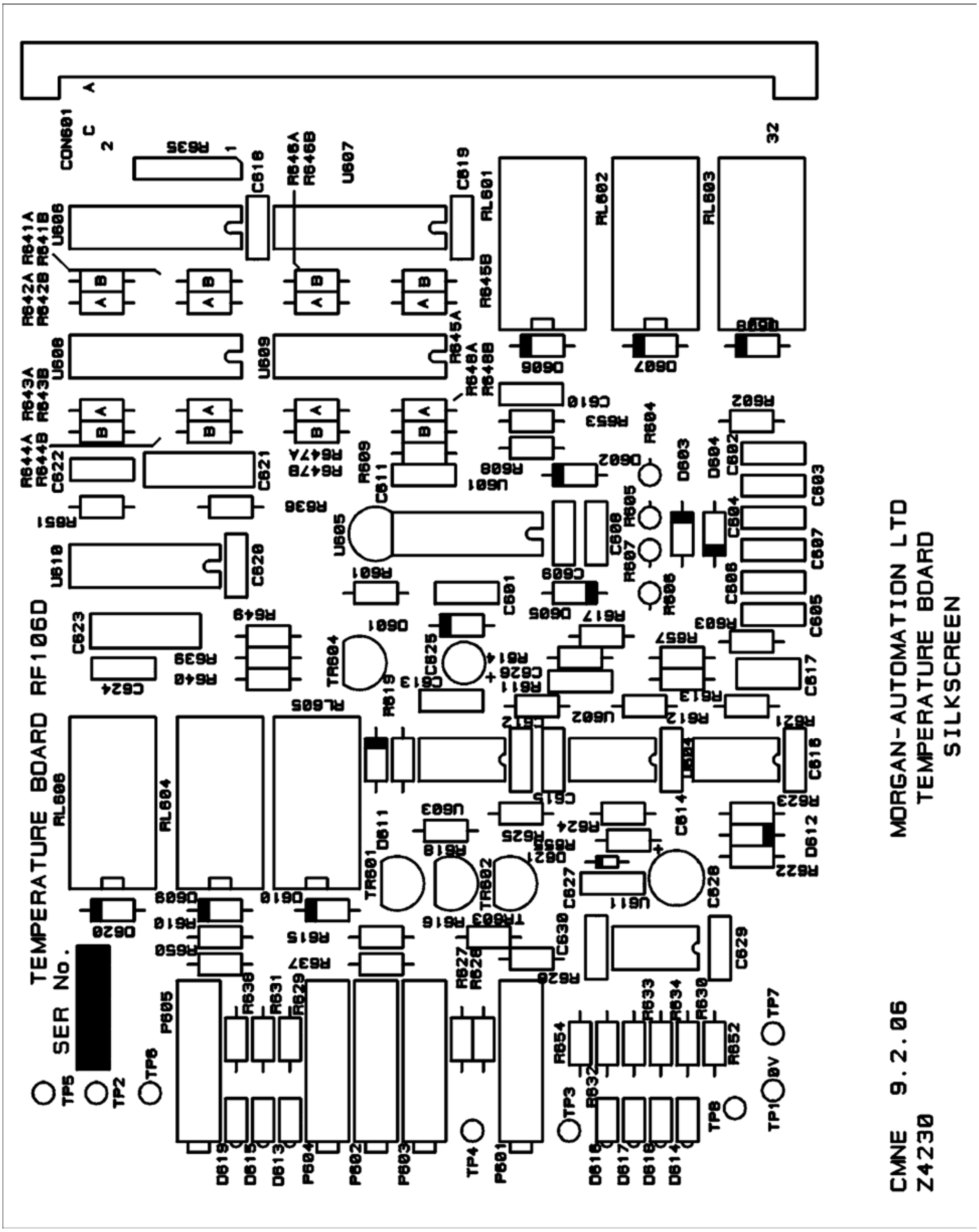


Figure 6.14 Temperature Board RF 106D - Component Layout

6.8 Interlock Board RF107D

Components

R701	10K	±5%	0.25 watt Carbon Film
R702	10K	±5%	0.25 watt Carbon Film
R703	22K	±5%	0.25 watt Carbon Film
R704	3K9	±5%	0.25 watt Carbon Film
R705	10R	±5%	0.5 watt Carbon Film
R706	510R	±5%	0.25 watt Carbon Film
R707	10K	±5%	0.25 watt Carbon Film
R708	10K	±5%	0.25 watt Carbon Film
R709	10K	±5%	0.25 watt Carbon Film
R710	330K	±5%	0.25 watt Carbon Film
R711	10K	±5%	0.25 watt Carbon Film
R712	10K	±5%	0.25 watt Carbon Film
R713	10K	±5%	0.25 watt Carbon Film
R714	10K	±5%	0.25 watt Carbon Film
R715	100K	±5%	0.25 watt Carbon Film
R716	10K	±5%	0.25 watt Carbon Film
R717	10K	±5%	0.25 watt Carbon Film
R718	10K	±5%	0.25 watt Carbon Film
R720	10K	±5%	0.25 watt Carbon Film
R721	100K	±5%	0.25 watt Carbon Film
R722	10K	±5%	0.25 watt Carbon Film
R723	10K	±5%	0.25 watt Carbon Film
R724	10K	±5%	0.25 watt Carbon Film
R725	10K	±5%	0.25 watt Carbon Film
R726	47K	±5%	0.25 watt Carbon Film
R727	4K7	±5%	0.25 watt Carbon Film
R728	10K	±5%	0.25 watt Carbon Film
R729	4K7	±5%	0.25 watt Carbon Film
R730	10K	±5%	0.25 watt Carbon Film
R731	100K	±5%	0.25 watt Carbon Film
R732	100K	±5%	0.25 watt Carbon Film
R733	10K	±5%	0.25 watt Carbon Film
R734	10K	±5%	0.25 watt Carbon Film
R735	10K	±5%	0.25 watt Carbon Film
R736	10K	±5%	0.25 watt Carbon Film
R737	4K7	±5%	0.25 watt Carbon Film
R738	4K7	±5%	0.25 watt Carbon Film
R739	4K7	±5%	0.25 watt Carbon Film
R740	4K7	±5%	0.25 watt Carbon Film
R741	4K7	±5%	0.25 watt Carbon Film
R742	1K	±5%	0.25 watt Carbon Film
R743	4K7	±5%	0.25 watt Carbon Film
R744	4K7	±5%	0.25 watt Carbon Film
R745	4K7	±5%	0.25 watt Carbon Film
R746	4K7	±5%	0.25 watt Carbon Film

Interlock Board RF107D contd

R701	100nF	63v	Polyester
R702	100nF	63v	Polyester
R703	100nF	63v	Polyester
R704	10MF	35v	Electrolytic
R706	100nF	63v	Polyester
R707	100nF	63v	Polyester
R709	100nF	63v	Polyester
R710	100nF	63v	Polyester
R711	100nF	63v	Polyester
R712	100nF	63v	Polyester
R713	22nF	100v	Polyester
R714	10nF	100v	Polyester
R715	220MF	16v	Electrolytic
C716	100nF	63v	Polyester
C717	100nF	63v	Polyester
C718	100MF	16v	Electrolytic
C719	100nF	63v	Polyester
C720	470nF	63v	Polyester
C721	10MF	35v	Electrolytic
C722	10MF	35v	Electrolytic
C723	220MF	16v	Electrolytic
C724	100nF	63v	Polyester
C725	100nF	63v	Polyester
C726	10nF	100v	Polyester
C727	10nF	100v	Polyester
C728	100nF	63v	Polyester

D701	LED – Amber
D702	LED – Red
D703	IN4148
D704	LED – Green
D705	LED – Red
D706	LED –Red
D707	LED – Red
D708	IN4148
D709	IN4148
D710	IN4148
D711	IN4148
D712	IN4148
D713	LED – Red
D714	LED – Red
D715	IN4148
D716	LED – Red
D717	IN4148

Interlock Board RF107D contd

TR701	ZVN4206A	Small Signal MOS	
TR702	BC337	NPN Transistor	
TR703	BC337	NPN Transistor	
TR704	BC337	NPN Transistor	
U701	4012	Dual 4 input NAND Gate	
U702	4001	Quad 2 input NOR Gate	
U703	4011	Quad 2 input NAND Gate	
U704	4011	Quad 2 input NAND Gate	
U705	TL071	Amplifier	
U706	NE 555 N	Timer	
U707	NE 556N	Dual Timer	
U708	4049	Hex Inverting Buffers	
RL701	Double Pole Relay	12v	
RL702	Double Pole Relay	12v	
RL703	Double Pole Relay	12v	
RL704	Double Pole Relay	12v	
RL705	Double Pole Relay	12v	
RL706	Double Pole Relay	12v	
RL707	Double Pole Relay	12v	
TP1-5	Test Points		
Connector	DIN41612	Type D	32way a c

Handle - Yellow

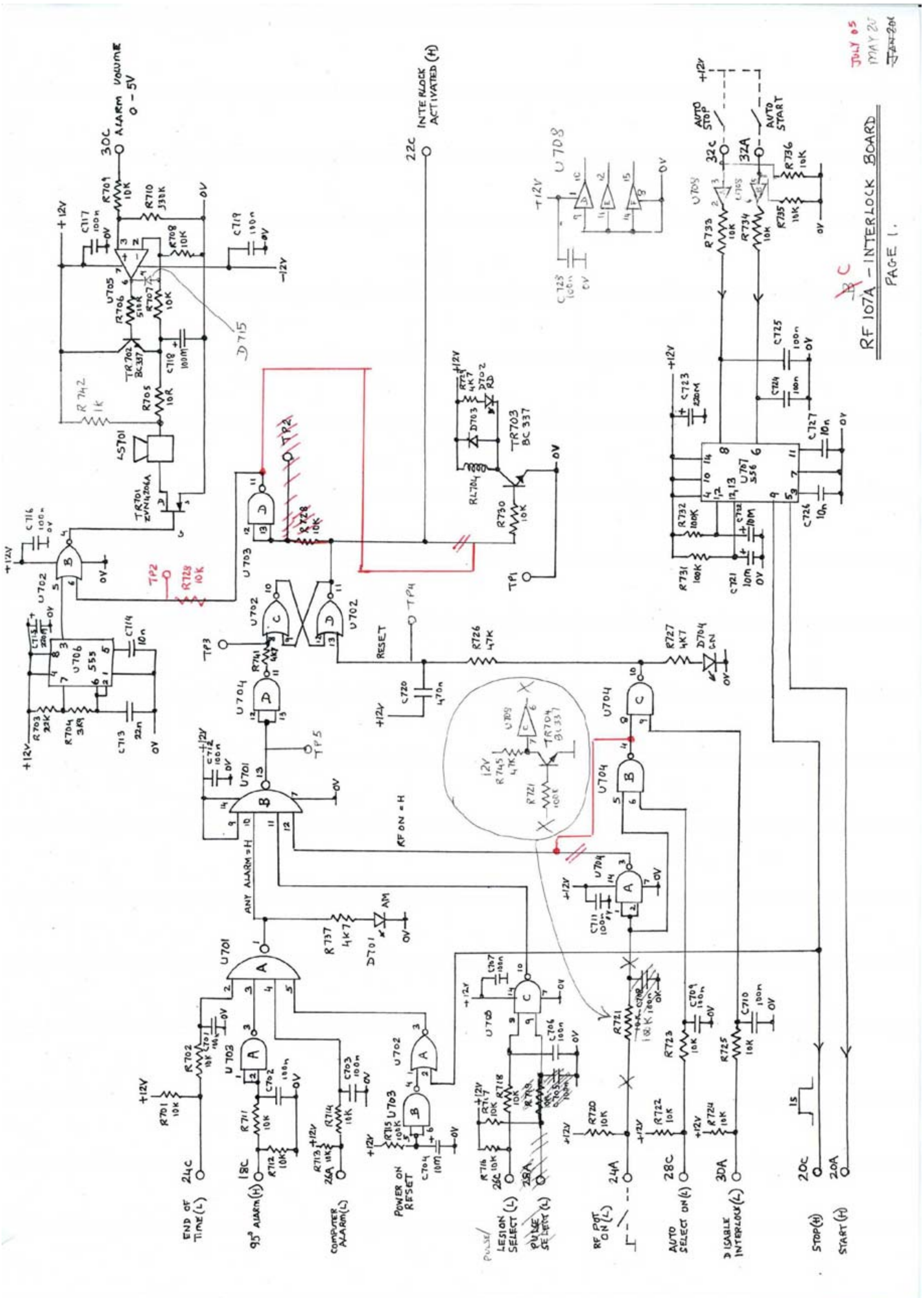


Figure 6.15 Interlock Board – RF 107 D – Circuit Diagram

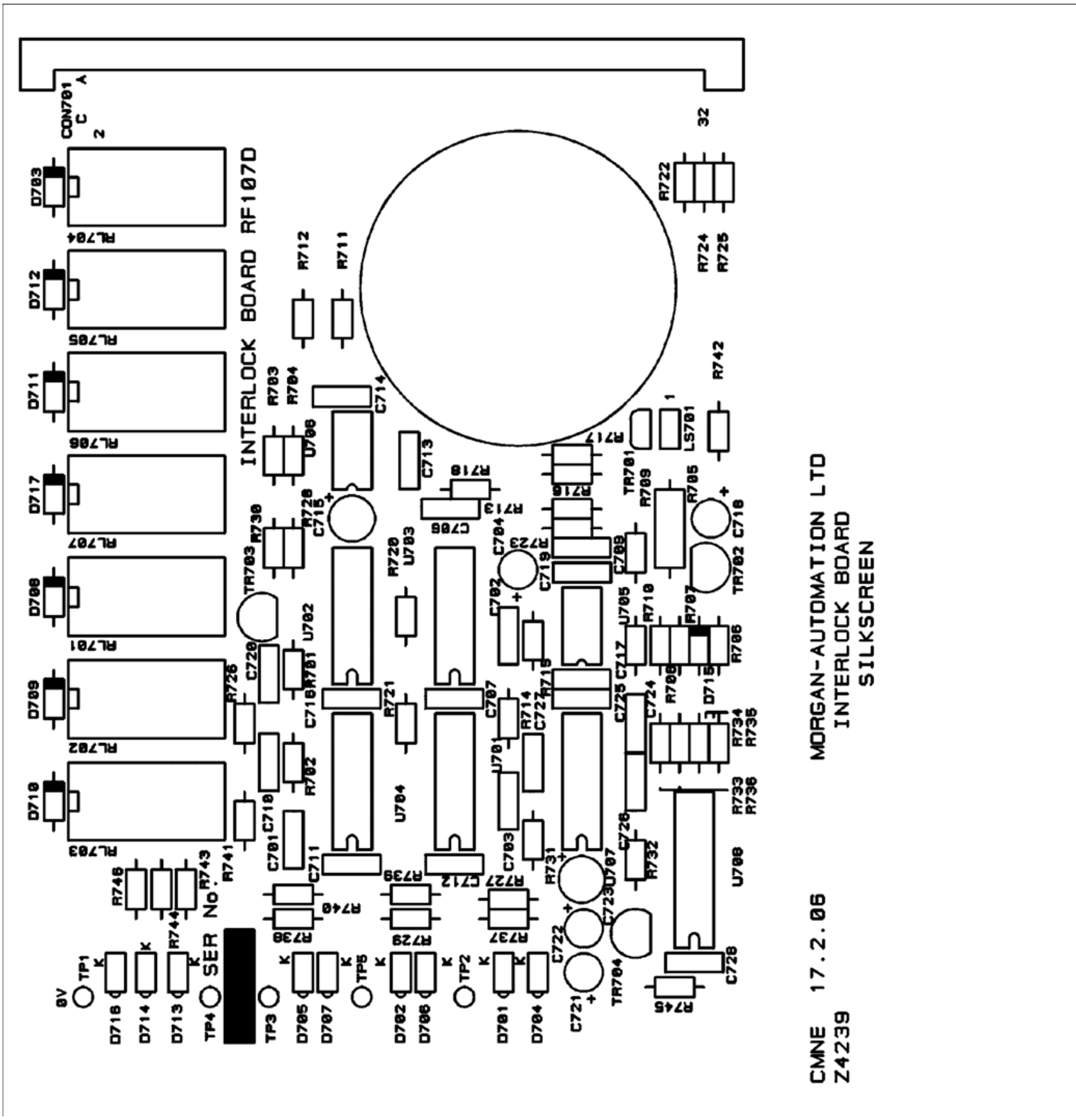


Figure 6.16 Interlock Board - RF107D - Component Layout

6.9 Connection Board RF109B

Components

R901	3K3	±5%	0.25watt	Carbon Film
R902	3K3	±5%	0.25watt	Carbon Film
R903	3K3	±5%	0.25watt	Carbon Film
R904	3K3	±5%	0.25watt	Carbon Film
R905	3K3	±5%	0.25watt	Carbon Film
R906	10K	±5%	0.25watt	Carbon Film
R907	1K	±5%	0.25watt	Carbon Film
R908	330R	±5%	0.25watt	Carbon Film
TR901	BC327		PNP Transistor	
S901	Sounder			
CON901	11 way Single Row Header			
CON901	10 way Single Row Header			
CON901	10 way Header			
CON901	34 way Boxed Header			

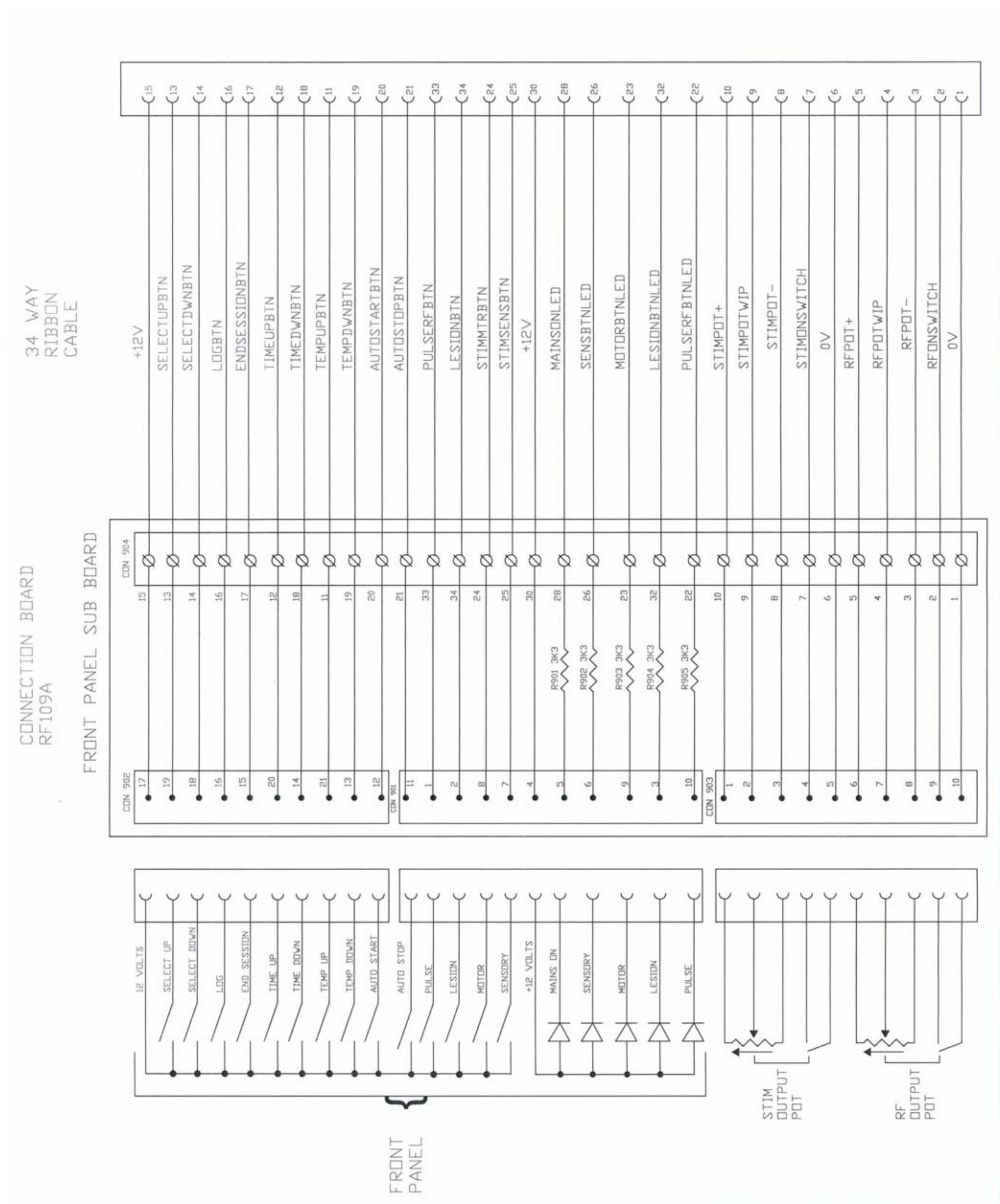


Figure 6.17 Connection Board – RF109B – Circuit Diagram

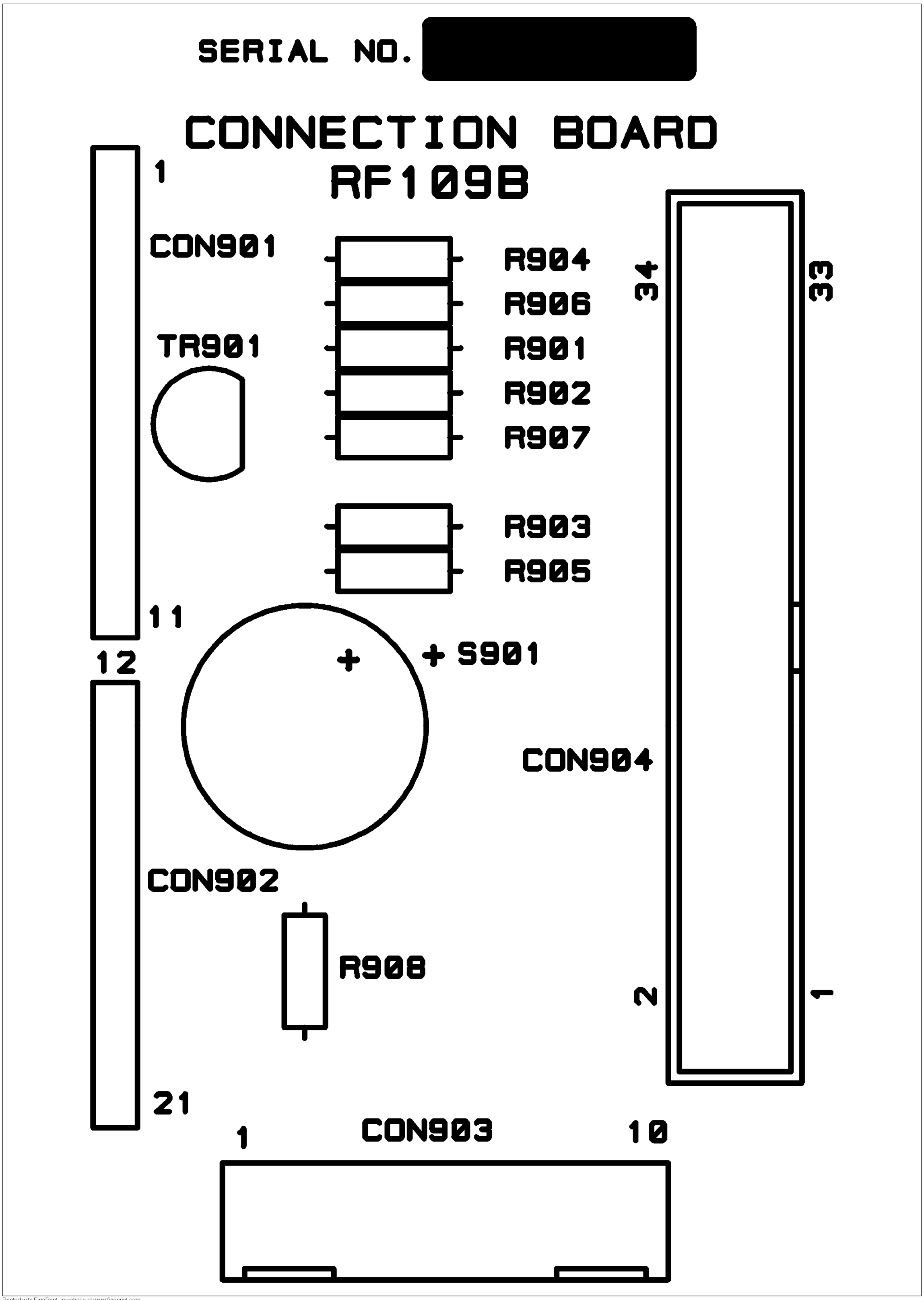


Figure 6.18 Connection Board – RF109B – Component Layout

6.10 Interface Board RF110D

Components

J1	34 way Male PCB Boxed Header with short latches
J2	50 way Male PCB Boxed Header with short latches
J3	50 way Male PCB Boxed Header with short latches

TP1-4 Test Points

Edge Connector 96 way DIN41612

Handle White

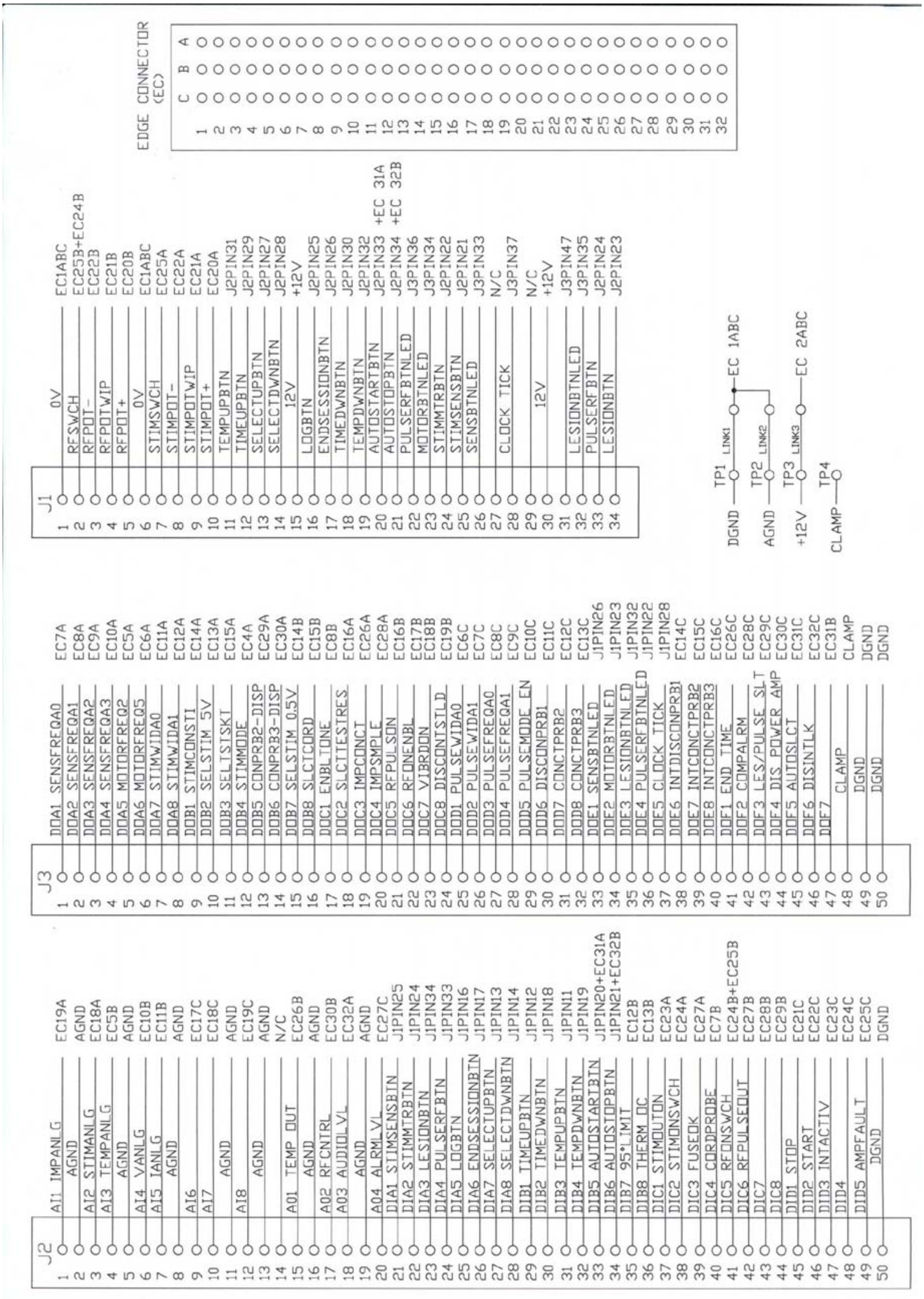


Figure 6.19 Interface Board – RF110D – Circuit Diagram

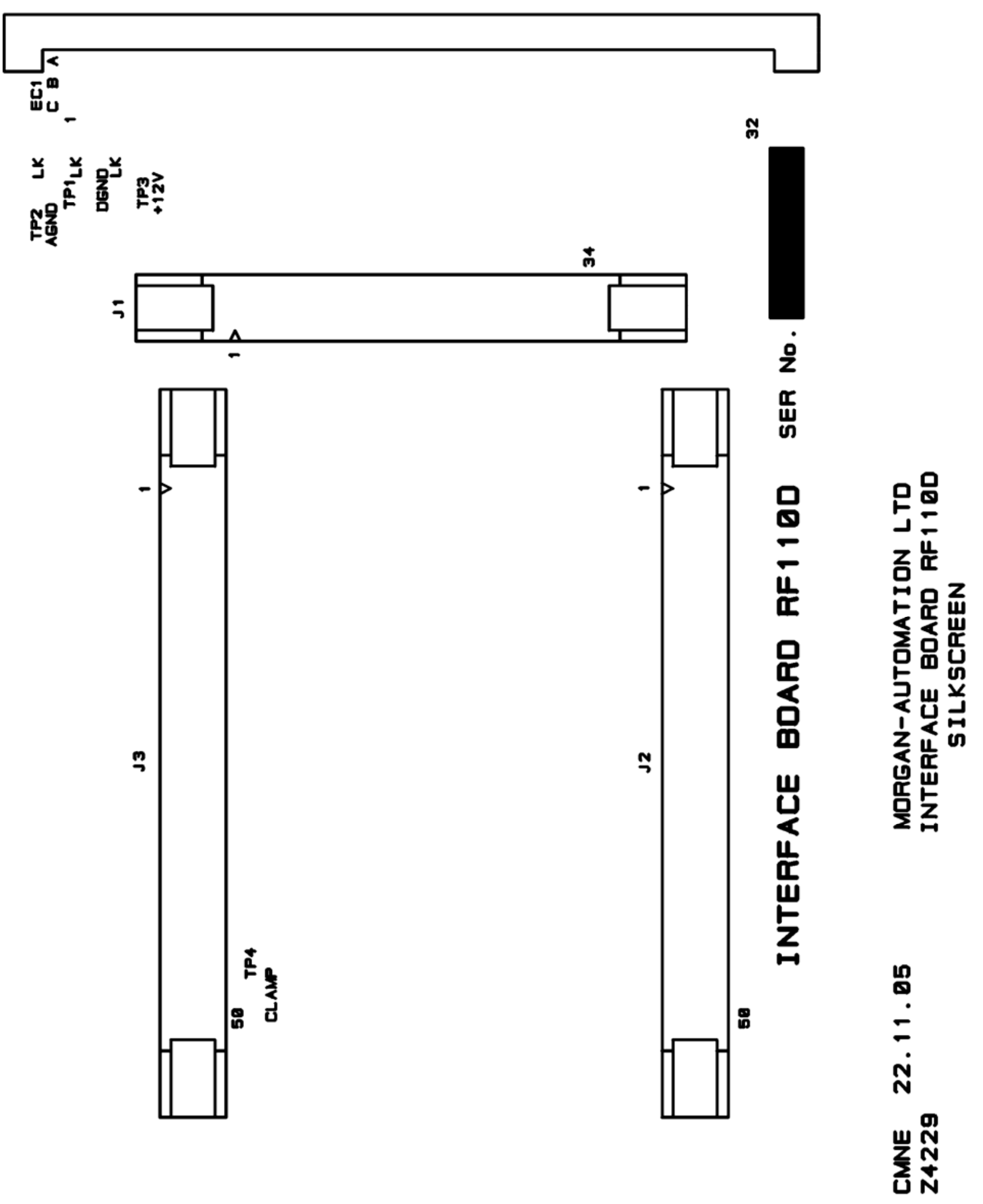


Figure 6.20 Interface Board – RF110D – Component Layout

6.11 Computer Mother Board RF111B

Components

R1	LINK			
R2	4K7	±5%	0.25watt	Carbon Film
R3	LINK			
R4	LINK			
R5	LINK			
R6	30K	±1%	0.25watt	Metal Film
R7	30K	±1%	0.25watt	Metal Film
R8	NOT FITTED			
R9	NOT FITTED			
R10	NOT FITTED			
R11	10K	±1%	0.25watt	Metal Film
R12	10K	±1%	0.25watt	Metal Film
R13	1K	±1%	0.25watt	Metal Film
R14	LINK			
R15	NOT FITTED			
R16	1K	±1%	0.25watt	Metal Film
R17	1K	±1%	0.25watt	Metal Film
R18	1K	±1%	0.25watt	Metal Film
R19	1K	±1%	0.25watt	Metal Film
R20	1K	±1%	0.25watt	Metal Film
R21	1K	±1%	0.25watt	Metal Film
R22	NOT FITTED			
R23	NOT FITTED			
R24	10K	±1%	0.25watt	Metal Film
R25	10K	±1%	0.25watt	Metal Film
R26	10K	±1%	0.25watt	Metal Film
R27	10K	±1%	0.25watt	Metal Film
R28	4K7	±5%	0.25watt	Carbon Film

RA1	4K7	8 commoned resistor network
RA2	4K7	8 commoned resistor network
RA3	4K7	8 commoned resistor network
RA4	4K7	8 commoned resistor network
RA5	4K7	8 commoned resistor network
RV1	10k	potentiometer

Computer Mother Board RF111B contd

C1	100nF	63v	Polyester
C2	100nF	63v	Polyester
C3	100nF	63v	Polyester
C4	100nF	63v	Polyester
C5	100nF	63v	Polyester
C6	100nF	63v	Polyester
C7	100nF	63v	Polyester
C8	100nF	63v	Polyester
C9	100nF	63v	Polyester
C10	100nF	63v	Polyester
C11	100nF	63v	Polyester
C12	100nF	63v	Polyester
C13	100nF	63v	Polyester
C14	10nF	100v	Polyester
C15	10nF	100v	Polyester
C16	NOT FITTED		
C17	100nF	63v	Polyester
C18	100nF	63v	Polyester
C19	100nF	63v	Polyester
C20	100nF	63v	Polyester
C21	100nF	63v	Polyester
C22	100nF	63v	Polyester
C23	100nF	63v	Polyester
C24	100nF	63v	Polyester
C25	100nF	63v	Polyester
C26	10MF	63v	Polyester
C27	100nF	63v	Polyester
C28	10nF	100v	Polyester
C29	10MF	63v	Polyester
C30	10nF	100v	Polyester
C31	100nF	63v	Polyester
C32	100nF	63v	Polyester
C33	100nF	63v	Polyester
C34	100nF	63v	Polyester
C35	100nF	63v	Polyester
C36	100nF	63v	Polyester
C37	100nF	63v	Polyester
C38	100nF	63v	Polyester
C39	10MF	63v	Polyester
C40	100nF	63v	Polyester
C41	100nF	63v	Polyester
C42	100nF	63v	Polyester
C43	100nF	63v	Polyester
C44	470nF	63v	Polyester
C45	470nF	63v	Polyester

Computer Mother Board RF111B contd

C46	NOT FITTED		
C47	4700MF 25v		Electrolytic
D1	LM4040	2.5	2.5v Voltage Reference
D2	IN4002		
D3	IN5355 5watt		18v Zener
L1	10µH		Inductor
SW1	8way DIL Switch		
U1	74HCT 688		
U2	74HCT 245		
U3	74HCT 138		
U4	74HCT 240		
U5	74HCT 138		
U6	74HCT 273		
U7	ULN2803A		
U8	74HCT 273		
U9	ULN2803A		
U10	74HCT 273		
U11	ULN2803A		
U12	74HCT 273		
U13	ULN2803A		
U14	74HCT 273		
U15	ULN2803A		
U16	74HCT 273		
U17	ULN2803A		
U18	74HCT 273		
U19	UWR - 5/3000		
U21	74HCT 273		
U22	4050		
U23	4050		
U24	74HCT 273		
U25	4050		
U26	74HCT 273		
U27	4050		
U28	74HCT 273		
U29	4050		
U30	4.9152MHz		
U31	ADC 12138CIN		
U32	TL072		
U33	DAC 7614		
U34	LMC 662CN		
U35	LMC 662CN		
U36	MC7812		

Computer Mother Board RF111B contd

J1	64 way PC104 Header
J2	50 way boxed header with short latches
J3	51 way boxed header with short latches
J4	4 way connector
J5	10 way connector

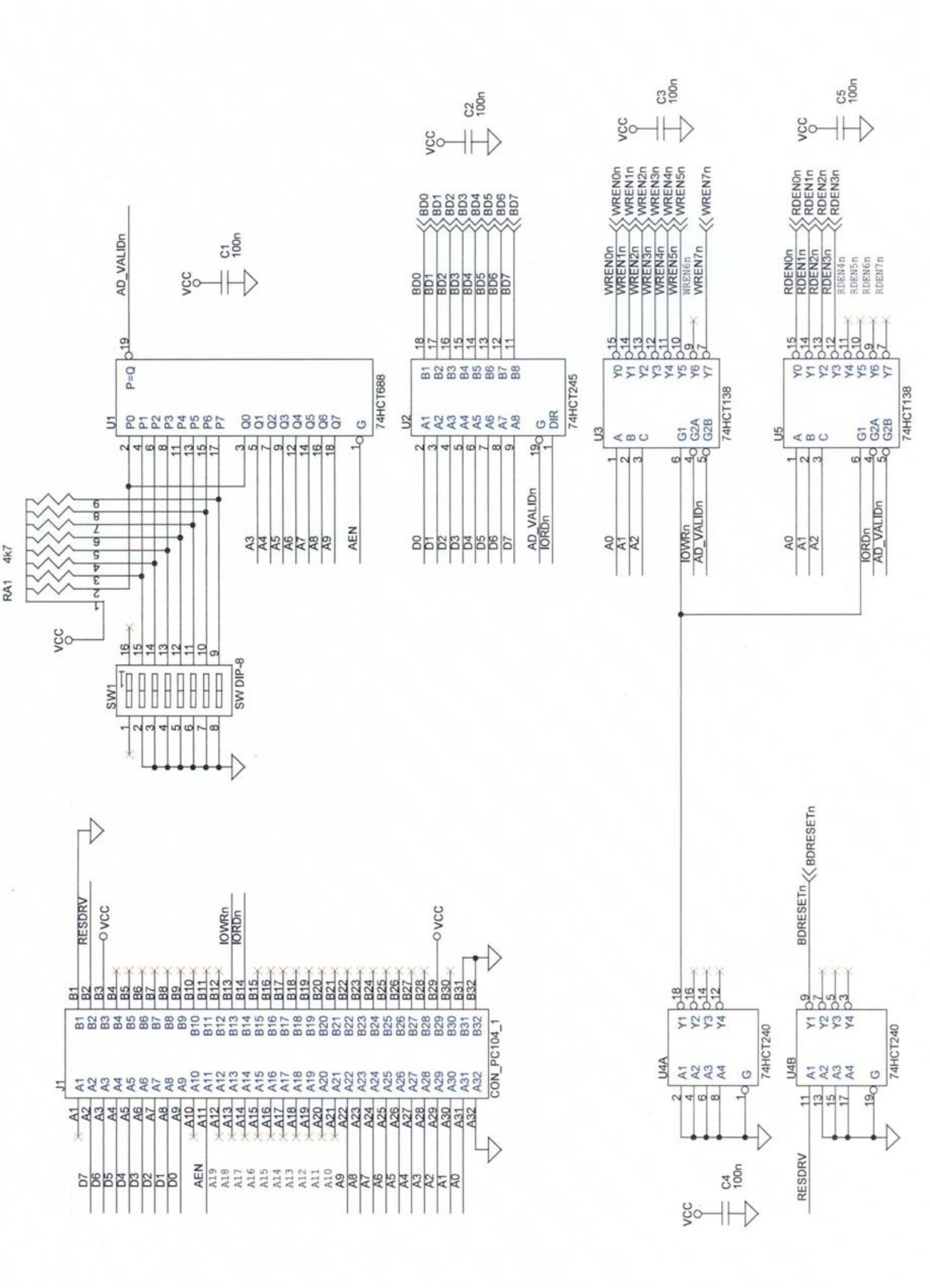


Figure 6.21 Computer Motherboard RF111B – Circuit Diagram – Bus Interface

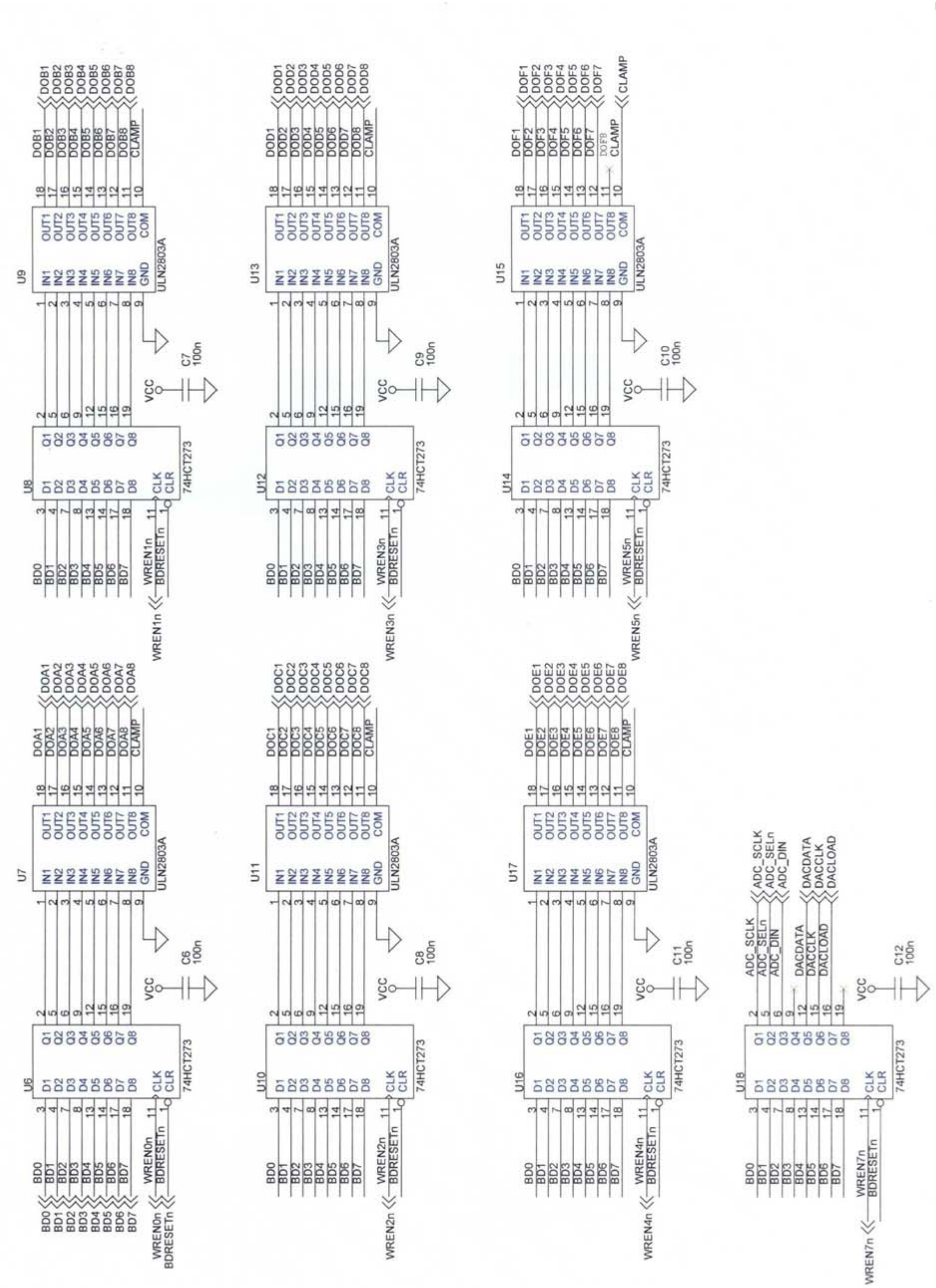


Figure 6.22 Computer Motherboard – RF111B – Circuit Diagram – Digital Outputs

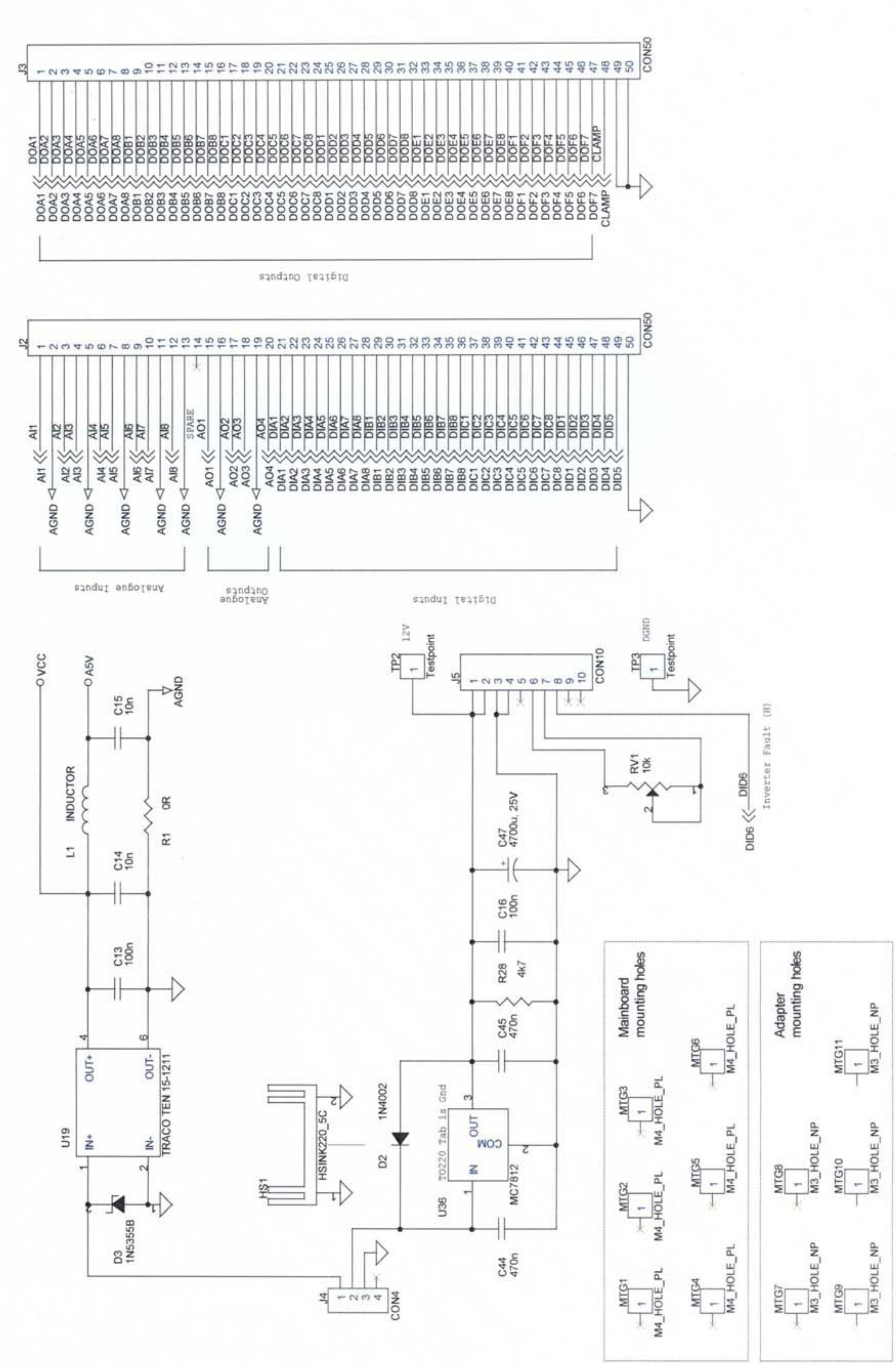


Figure 6.23 Computer Mother Board – RF111B – Circuit Diagram – Ribbon Connectors and PSU

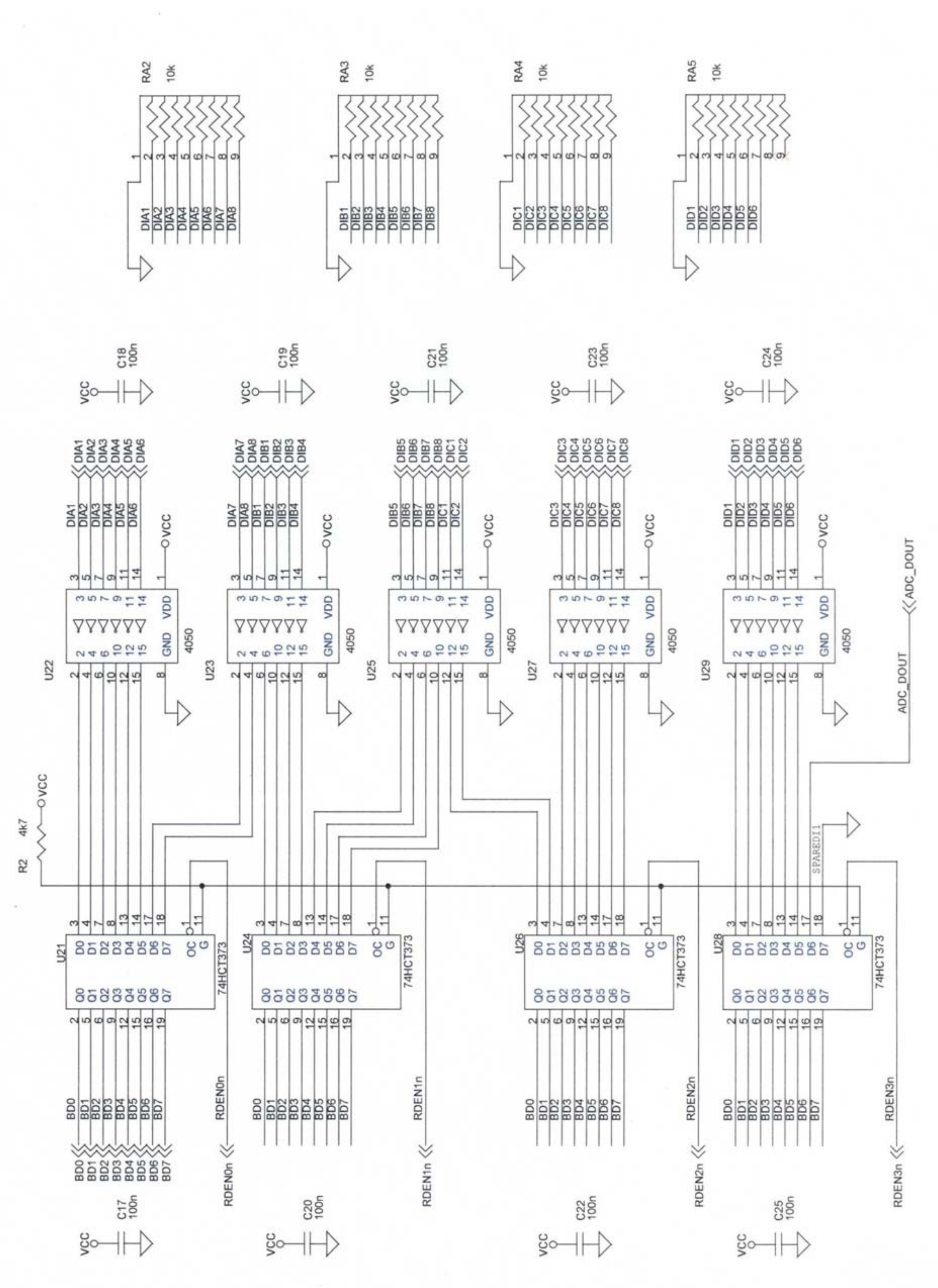


Figure 6.24 Computer Motherboard – RF111B – Circuit Diagram – Digital Inputs

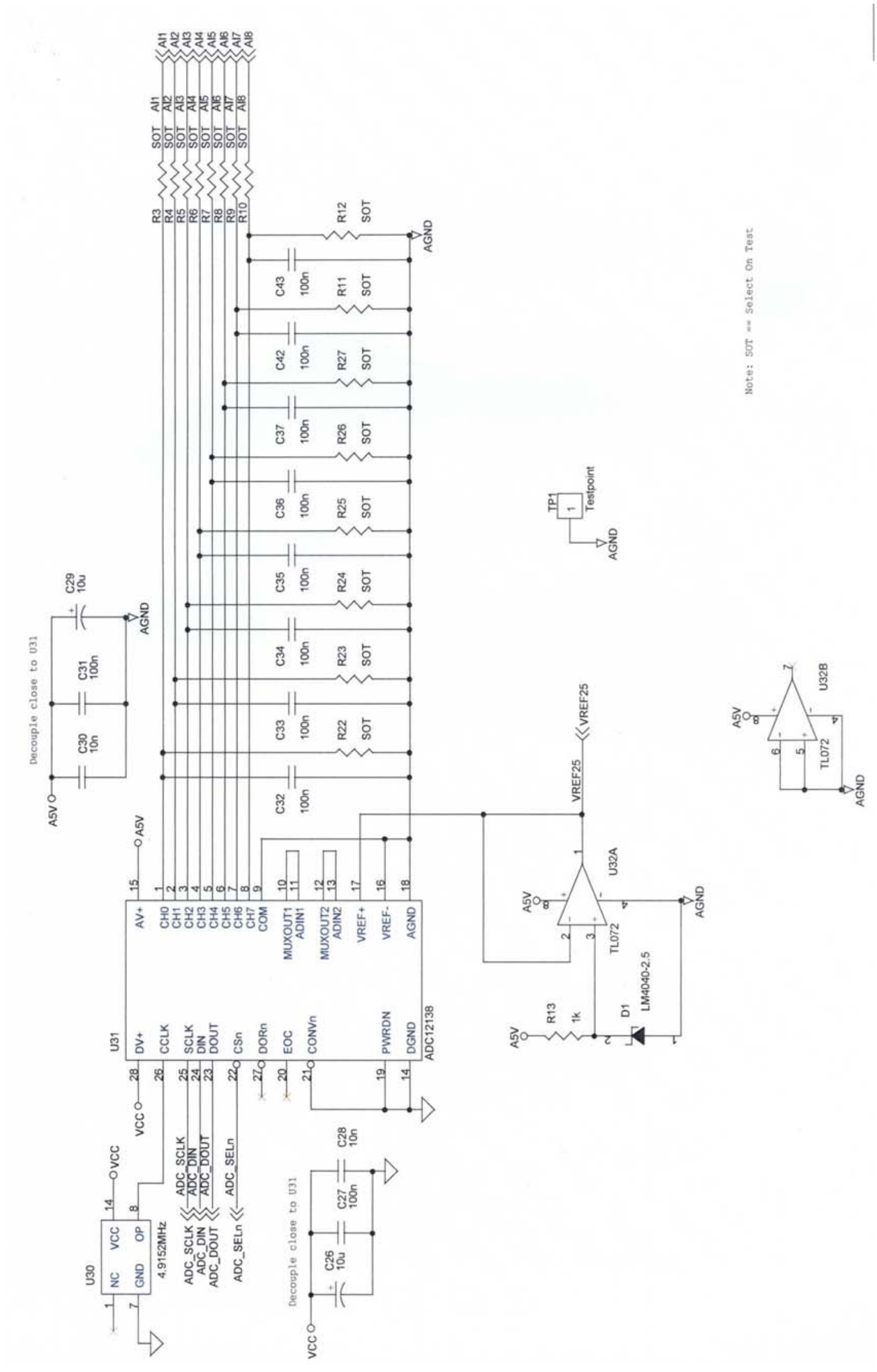


Figure 6.25 Computer Motherboard – RF111B – Circuit Diagram – Analog Inputs

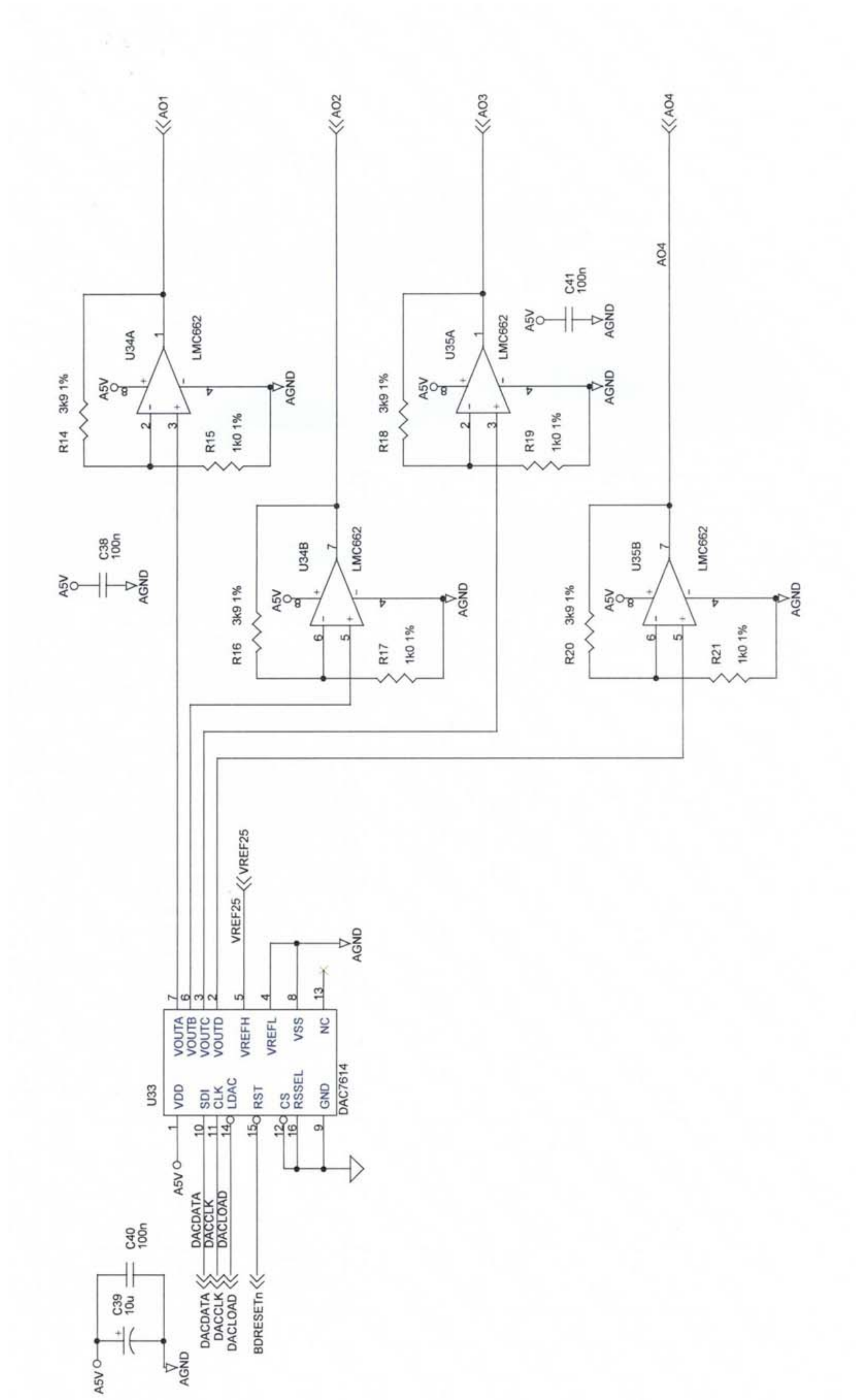


Figure 6.26 Computer Motherboard RF111B – Circuit Diagram – Analog Ouputs

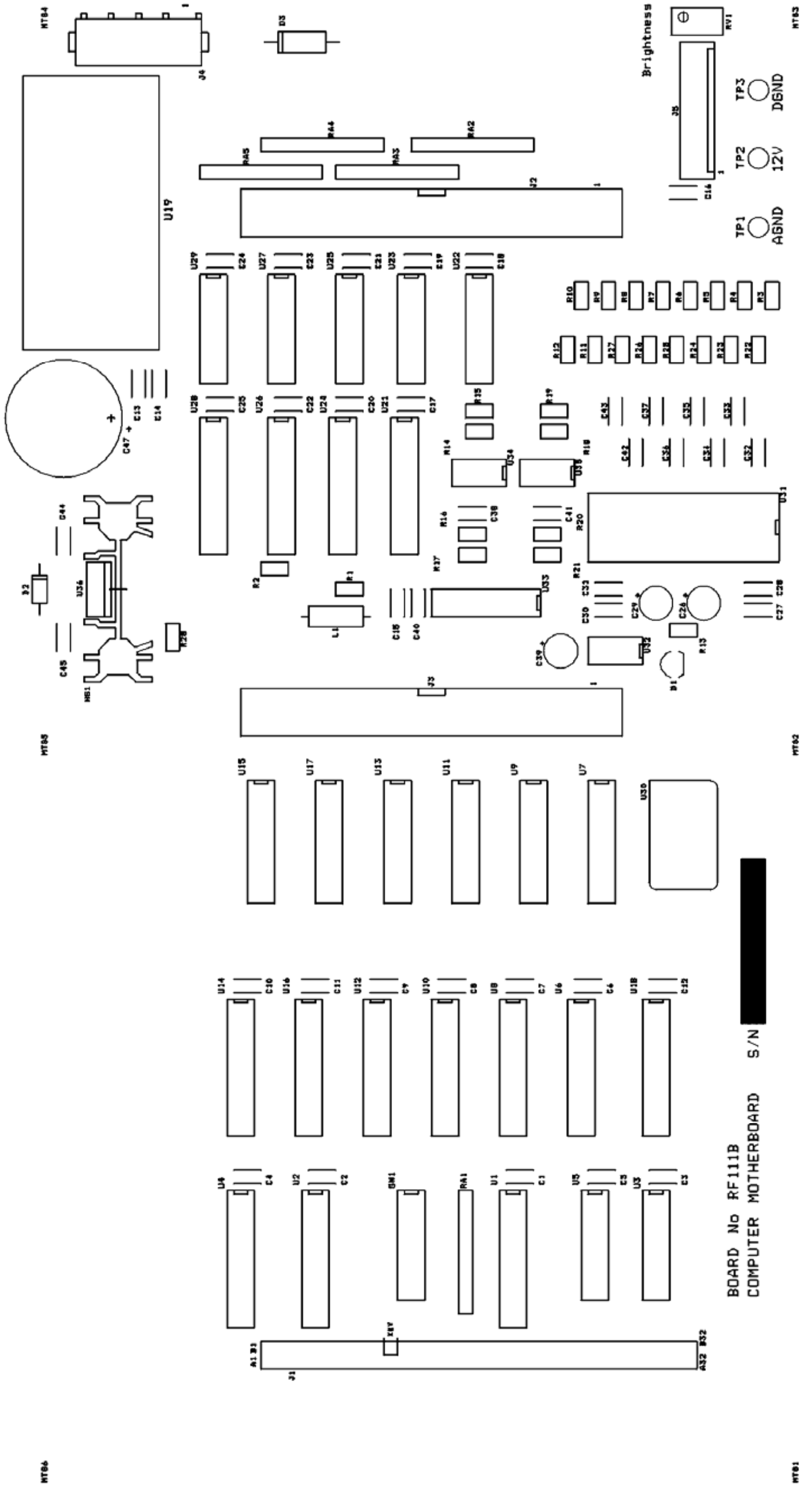


Figure 6.27 Computer Motherboard – RF111B – Computer Layout

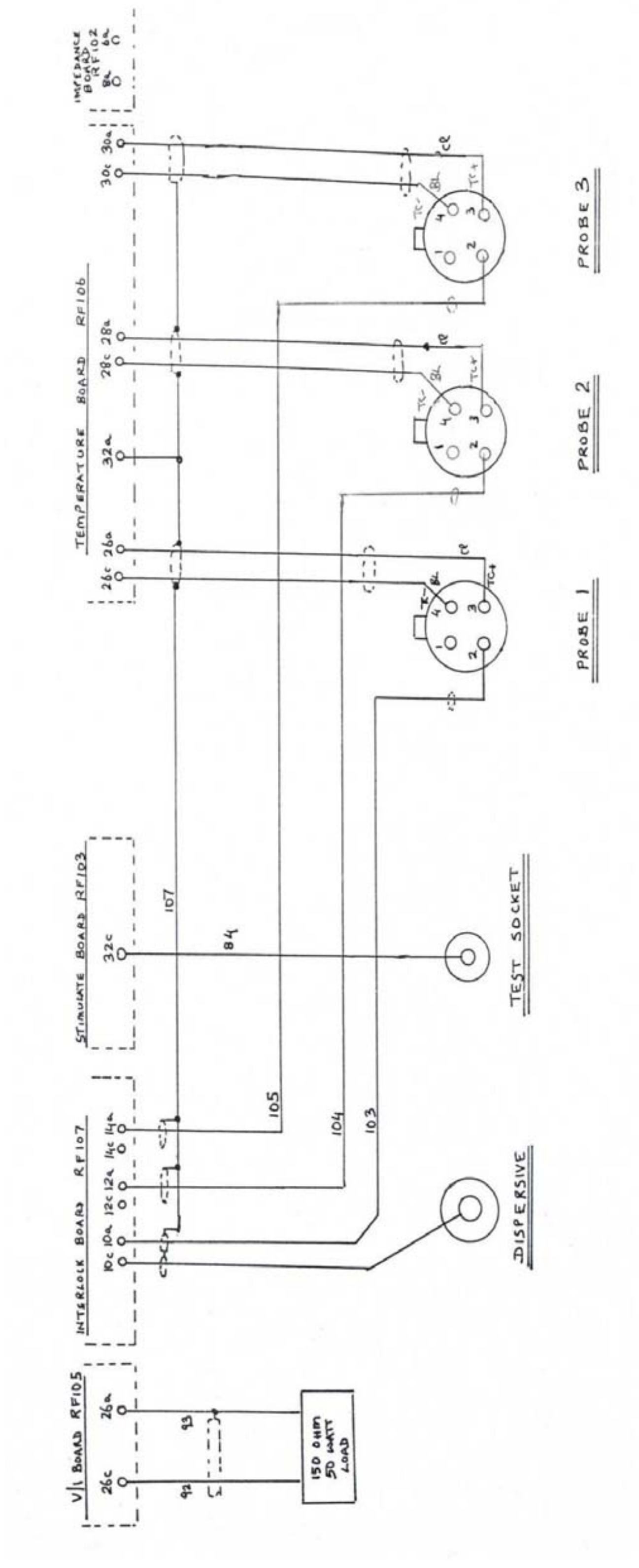


Figure 6.28 Front Panel Wiring Figure

6.29 General System Schematic