

# 'S Series'

DC Power Supplies

## Service Manual



## **GENERAL**

### **Service Handling Precautions**

Service work should only be carried out by skilled engineers. Please note that the tracks on the printed circuit board are very fine and may lift if subjected to excessive heat. Use only a miniature temperature controlled soldering iron and remove all solder with solder wick or suction before attempting to remove a component.

### **Dismantling the Instrument**

#### **WARNING !**

Opening the instrument is likely to expose live parts. The instrument shall be disconnected from all voltage sources before any adjustment, replacement or maintenance and repair during which it shall be opened. If afterwards any adjustment, maintenance or repair of the opened instrument under voltage is inevitable, it shall be carried out only by a skilled person who is aware of the hazards involved.

1. Remove the 8 side screws (plus 2 top screws on triple units or 2 handle screws on dual units) holding the case upper.
2. Lift off the case upper.
3. To remove a main (linear supply) pcb, remove the 4 nylon fixing screws and remove the 3 control knobs, which are retained by grub screws. The pcb can now be pulled clear of the front panel and the wiring harness allows it to be rotated clear of the case lower. To remove the logic supply pcb, remove the 4 M3 screws through the rear panel.
4. Transistors Q5, Q6 and Q7 on the linear supplies and Q1, Q2 D10 and SCR1 on the logic supply are insulated from the heatsinks.
5. Reassemble in reverse order.

### **Operating Voltage**

See the Power Supply section on page 8 for details of changing the operating voltage of single and dual units. See page 20 for details of changing triple units.

## TECHNICAL SPECIFICATION

<b>Output Voltage Setting:</b>	By coarse and fine controls; resolution better than 5mV across the range.
<b>Output Current Setting:</b>	By single logarithmic control.
<b>Output Mode:</b>	The power supply operates in constant current or constant voltage modes with automatic cross-over. A display annunciator indicates constant current mode.
<b>Output Switch:</b>	Isolates the output and permits voltage and current limits to be set up before connecting the load.
<b>Output Terminals:</b>	4mm terminals on 19mm (.75") spacing.
<b>Output Impedance:</b>	
Constant Voltage:	Typically <5mOhm at 1kHz
Constant Current:	Typically 50kOhm with voltage limit at maximum
<b>Output Protection:</b>	Up to maximum output voltage +20 Volts forward; diode clamped for reverse voltages and up to 3A reverse current.
<b>Load Regulation:</b>	<0.01% of maximum output for 50% load change
<b>Line Regulation:</b>	<0.01% of maximum output for 10% line voltage change
<b>Ripple and Noise:</b>	Typically <1mV rms
<b>Transient Response:</b>	<20usec to within 50mV of setting for 90% load change.
<b>Temperature Coefficient:</b>	Typically <100ppm/°C
<b>Meter Type:</b>	Independent autoranging 0.5" 3.5-digit LCDs for voltage and current indication.
<b>Meter Resolution:</b>	
Voltage:	10mV up to 20V, 100mV above 20V
Current:	1mA up to 2A, 10mA above 2A
<b>Meter Accuracy:</b>	
Voltage:	0.2% of reading + 1 digit
Current:	0.5% of reading + 1 digit
<b>Power Requirements:</b>	
Input Voltage:	Internally set for 110, 120, 220 or 240VAC 50/60Hz
Input Voltage Range:	+/- 10% of voltage setting
Power Consumption:	150VA for single units, 300VA for dual units
<b>Environmental Operating Range:</b>	5°C to 40°C, 20% to 80% RH
<b>Environmental Storage Range:</b>	-20°C to +60°C
<b>Size:</b>	160mm wide x 160mm high x 238mm deep single unit 308mm wide x 160mm high x 238mm deep dual unit
<b>Weight:</b>	4.9kg single unit 9.6kg dual unit

## FUNCTIONAL DESCRIPTION

The relationship between the major circuit elements are shown in the block diagram opposite.

The pass transistors are mounted on heatsinks at the rear of the instrument. They are controlled by the error amplifiers via the diode gate.

The diode gate provides automatic cross over of constant voltage and constant current.

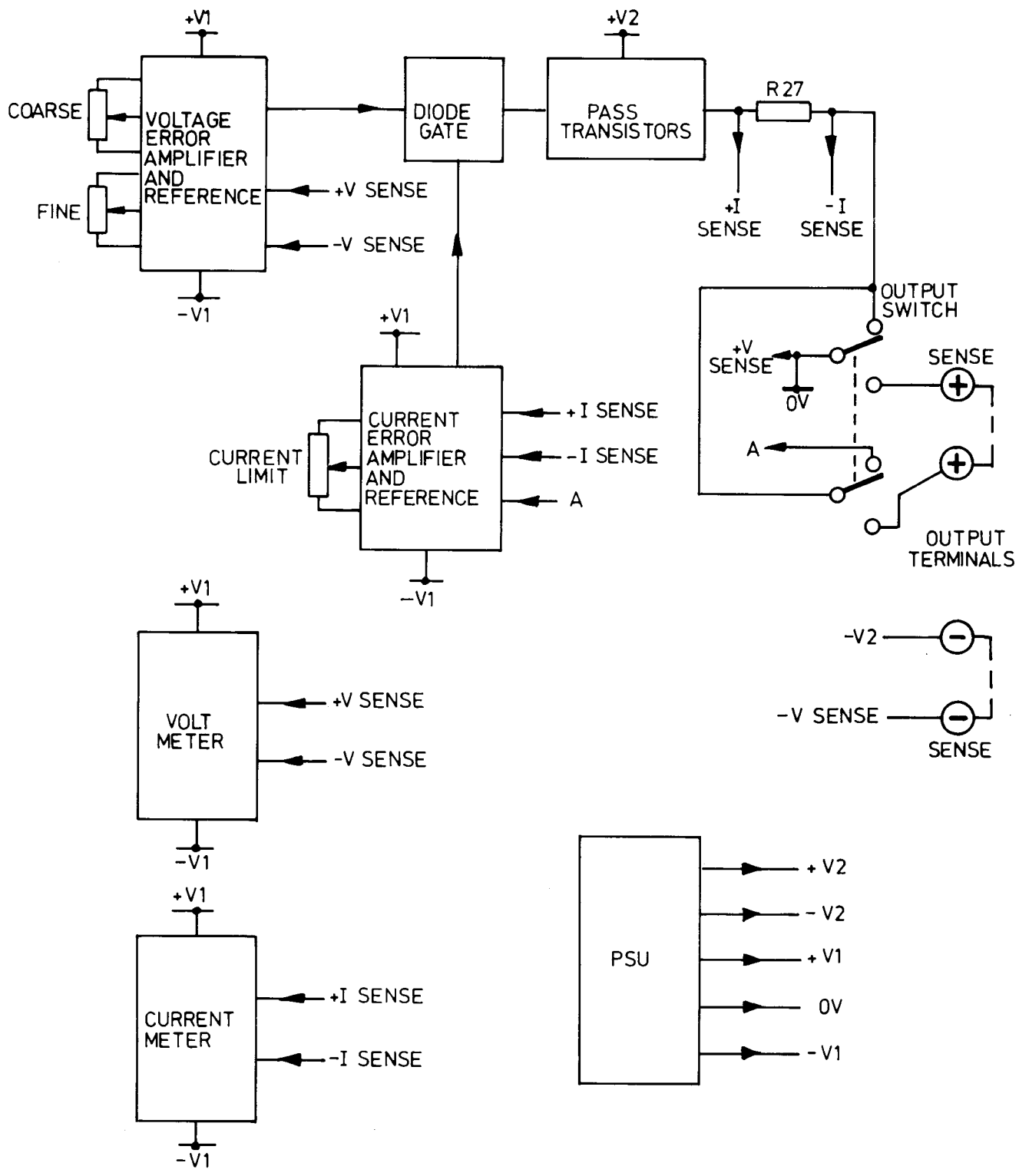
In the constant voltage mode the error voltage amplifier maintains the constant output voltage, set by the coarse and fine controls, independent of load; the voltage is sensed across the output terminals.

In the constant current mode, or when the preset current limit is reached, the current error amplifier overrides the voltage error amplifier via the diode gate and maintains constant output current independent of load resistance; the current is sensed across R27.

The output voltage is displayed by the digital voltmeter. This block also incorporates the autorange circuitry and decimal point drive.

The digital current meter block also incorporates the autorange circuitry, drive circuitry for the constant current annunciator and control logic which allows the set current limit to be displayed.

The power supply provides high voltage and power for the output (V2) and a split low voltage supply for the control circuitry (V1).



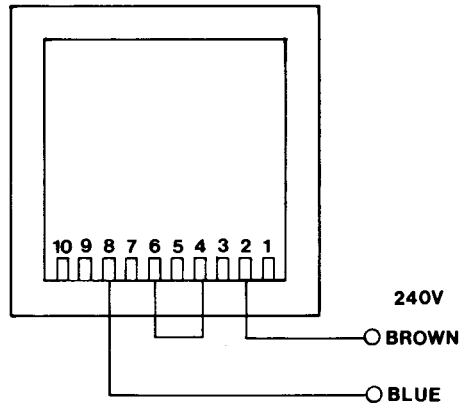
Functional Block Diagram

## CIRCUIT DESCRIPTIONS

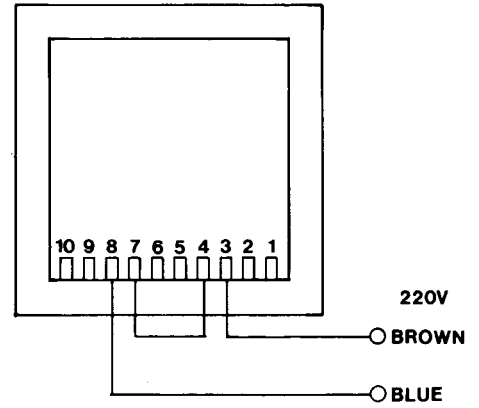
### Power Supply - Mains Operating Voltage

The operating voltage of the instrument is shown on the rear panel label. Should it be necessary to change the operating voltage, follow the appropriate diagram below.

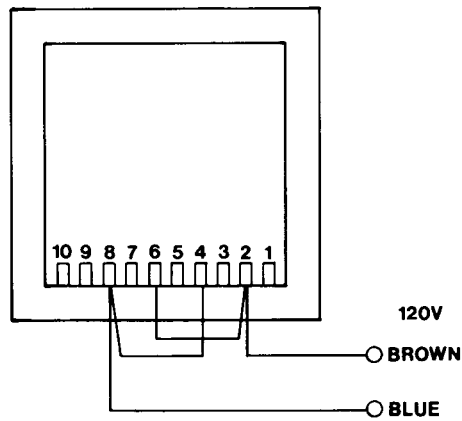
240V Operation



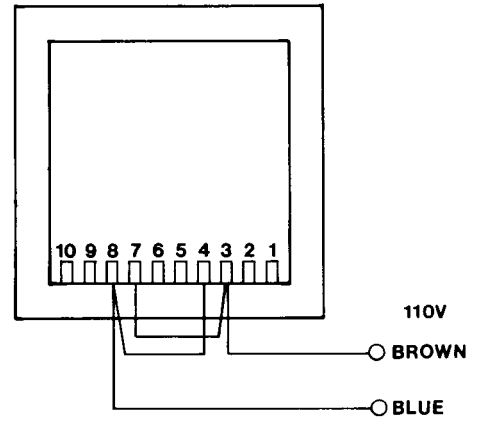
220V Operation



120V Operation



110V Operation



If a change is made, the operating voltage label and fuse should be changed.

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The correct fuse type is:-

1A 250V HRC time-lag, 20mm for 220-240V)	)	single units
2A 250V HRC time-lag, 20mm for 110-120V)	)	
2A 250V HRC time-lag, 20mm for 220-240V)	)	dual units
4A 250V HRC time-lag, 20mm for 110-120V)	)	

**WARNING ! THIS INSTRUMENT MUST BE EARTHED**

Any interruption of the protective conductor inside or outside the instrument or disconnection of the protective earth terminal is likely to make the instrument dangerous. Intentional interruption is prohibited.

**Power Supply - DC Requirements**

Pins 22 and 23 on the mains transformer of the 30V 2A supplies provide 34Vrms off load and this is rectified by the bridge rectifier D1 to D4; C1 is the reservoir capacitor. The off load voltage across C1 is approximately 46V.

Pins 22 and 23 on the mains transformer of the 15V 4A supplies provide 19Vrms off load and this is rectified by the bridge rectifier BR1; C1 and C26 are the reservoir capacitors. The off load voltage across C1/C26 is approximately 26V.

R14 discharges the reservoir capacitors when the unit is turned off with no load connected; C6 and R1 form a damping network. The voltage across the reservoir capacitors supplies the pass transistors.

Diodes D5 to D8 rectify the centre-tapped 20V winding on pins 18 to 20 and with reservoir capacitors C4 and C5 provide approximately +/-13V.

Regulators IC10 and IC11 with diodes D22 and D23 provide regulated +/-5V6 supplies for the error amplifiers and digital metering.

The above circuitry is on a separate pcb.

**Pass Transistors**

Q6 and Q7 are mounted on separate heatsinks and must be H (hometaxial) types. They are in parallel and current sharing is provided by emitter resistors R24 and R25. Driver transistor Q5 shares one of the heatsinks and altogether Q5, Q6 and Q7 make up a darlington emitter follower stage. R23 is on one of the heatsinks and R24, R25, R26 are on the main board; On 15V 4A units, R24 and R25 are on the power supply board. R26 provides a discharge path for C9 when no load is connected.

**Diode Gate**

Q8 is an emitter follower, the base of which is controlled by either of the two error amplifiers via diodes D12 and D13.

**Voltage Error Amplifier**

It should be noted that 0V is referred to the positive output terminal; this means that the voltage from the error amplifier is small, sufficient to turn on the driver and pass transistors and overcome resistive losses.

IC3a is a summing amplifier; when VR2 is fully clockwise pin 2 is at 0V.

Feedback is from the negative output terminal via R19 to pin 3 where it is summed with the current from VR1. Fine control of the output voltage is achieved with VR2 which moves the pseudo ground of IC3a. D11 limits the output swing of IC3a below 0V. D10 is a 2.45V voltage reference which is also used by the voltmeter circuitry. VR5 sets the maximum output voltage.

### **Current Error Amplifier**

If the preset current limit is reached, IC4b overrides the voltage error amplifier via the diode gate. Output current is sensed by measuring the volt drop across R27 and this is compared to the voltage on the wiper of VR3 by IC4b. D17 limits the output swing of IC4b below 0V. VR8 sets maximum output current and VR12 trims the offset of IC4b so that the set current limit and the output current limit are equal. This is done at low output current levels (100mA). D25 is a 2.45V voltage reference which is also used by the current meter.

### **Output Switch**

SW2a switches the +V sense connection between the supply output and the sense terminal itself. This is to overcome SW2b's contact resistance with the output on and to maintain feedback when the output is off. D15 prevents the feedback loop from going completely open between switch positions.

SW2b switches the supply output to the output terminal. When the output switch is in the off position, 'A' is connected to 0V which signals the current meter to display the set current limit.

**Note:** SW2 contacts are gold plated on silver and the correct replacement type must be used. Note also that if SW2 is disconnected it **must** be rewired the same way round. This is because SW2a must have gold contacts while the gold on SW2b contacts will have been vapourised due to the high switching current and will have normal silver contacts as a result.

### **Voltmeter**

IC1 is a standard 3.5 digit panel meter IC. This is a dual slope A to D complete with display drivers. R57 and C14 define the clock frequency of approximately 40kHz which, if necessary, can be checked using a x10 oscilloscope probe on pin 38. R56 and C12 are the integrator components and C11 the auto zero capacitor. C13 is the reference capacitor and R58, R59 and C15 are input filter-components.

R16 and R17 attenuate the output voltage to suit IC1. The voltmeter auto-ranges on the 30V 2A supplies between the high and low ranges by IC3b switching the meter reference. The output of the comparator IC3b is high when the output is below 19V and low when the output voltage is above 19V. The switching point is adjusted by VR4; R5 provides positive feedback which gives approximately +/-0.5V of hysteresis at the output terminals. Q1 inverts IC3b's output, providing complementary control signals. These drive the analogue switches in IC8 selecting the two references for the high and low ranges. They also select the decimal point via IC9. The decimal point is off when in-phase with the back-plane signal, and on when in anti-phase. VR7 trims the voltmeter on the low range and VR6 trims the high range.

### **Current Meter**

IC2 is the same type as that used in the voltmeter. The control signal 'A' from the output switch drives Q10 and IC5b which provides complementary drive signals to IC7a and b. With the output switch on, IC7a connects the meter to R27 to measure output current.



With the output switch off, IC7b connects the meter to VR3 to display the current limit setting.

The current meter autoranges on the 15V 4A supplies; VR9 sets the change over point and IC4a selects the appropriate meter reference. The output of comparator IC4a is high when the current reading is below 1.9A and low when the current reading is above 1.9A. R41 provides positive feedback and some hysteresis.

When current limit is reached, IC4b takes control via the diode gate; Q9 is turned on which enables low frequency oscillator IC5c and d which flashes the triangle in the display. Note that the ground lead of IC5 is connected to the -V1 supply whilst the ground lead of IC6 is connected to DGI, which is generated by IC2 for the LCD and is between 4 and 6 volts with respect to +V1. Level shifting is provided by R54 and R63.

### **Protection**

D16 provides protection against reverse voltages. D9, D14, Q2, Q3 and Q4 provide protection against forward voltages.

## **CALIBRATION**

### **Equipment Required**

4.5 digit multimeter with 10Amp range and better than 0.1% accuracy on both voltage and current.

### **30V 2A Supplies**

Turn the 3 front panel controls to maximum, output switch on. (Shorting bars must be fitted between the output and sense terminals).

Connect a voltmeter to the output terminals and adjust VR5 for 30.7V to 30.9V.

Adjust VR6 so that both voltmeters read the same.

Reduce the output voltage to approximately 15V and adjust VR7 so that both voltmeters read the same.

Set the output to 19V and adjust VR4 so that the meter auto-ranges at a point between 18.4V and 19.6V.

Connect an ammeter across the output terminals and adjust VR8 to give 2.07A to 2.09A.

Reduce the current limit control to give approximately 1.8A output and adjust VR10 so that both current meters read the same.

Set the output switch to off, short the output terminals and set the current limit control to approximately 100mA on the internal meter. Note the reading, set the output switch to on, and adjust VR12 so that the meter still reads the same.

### **15V 4A Supplies**

Turn the 3 front panel controls to maximum, output switch on. (Shorting bars must be fitted between the output and sense terminals).

Connect a voltmeter to the output terminals and adjust VR5 for 15.3V to 15.5V.

Adjust VR7 so that both voltmeters read the same.

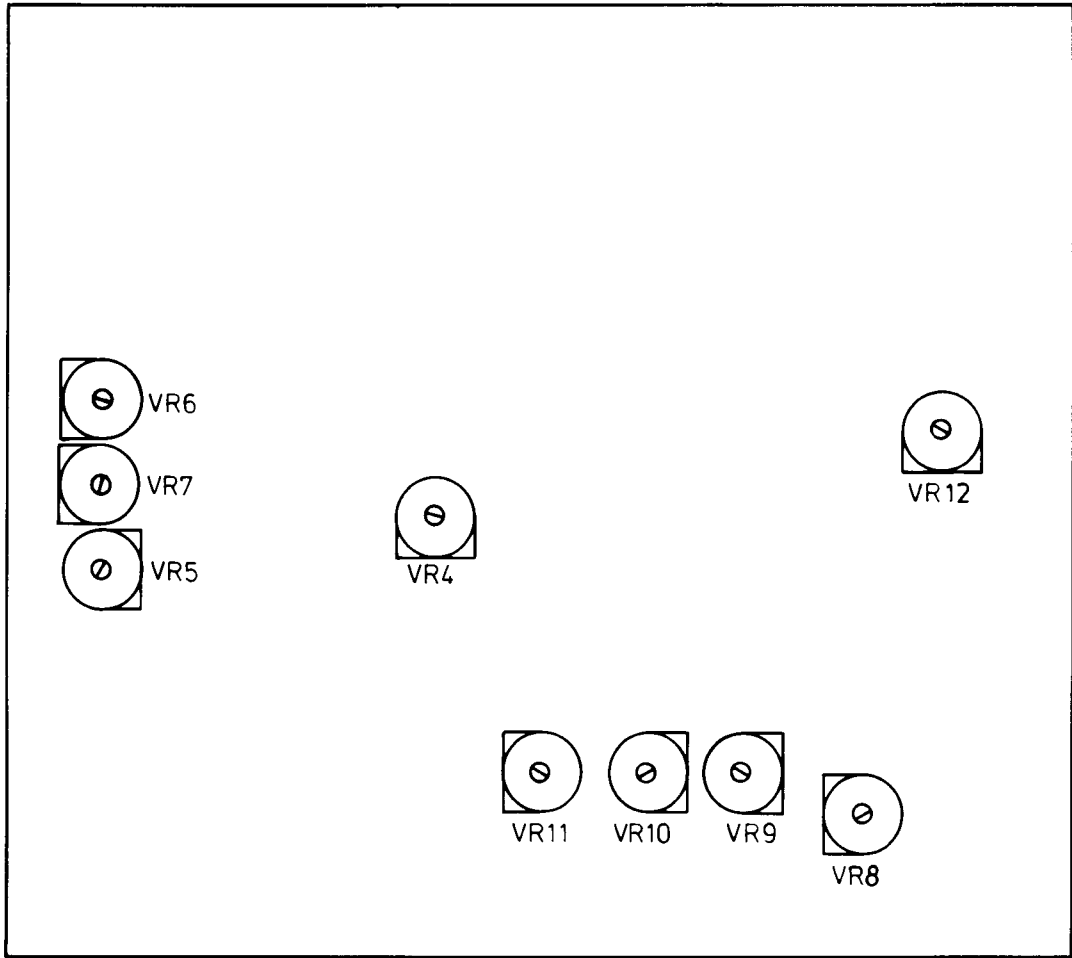
Connect an ammeter across the output terminals and adjust VR8 to give 4.10A to 4.15A.

Adjust VR11 so that both ammeters read the same.

Reduce the output current to approximately 1.5A and adjust VR10 so that both ammeters read the same.

Set the output current to 1.9A and adjust VR9 so that the current meter auto-ranges at a point between 1.84A and 1.96A.

Set the output switch to off, short the output terminals and set the current limit control to approximately 100mA on the internal meter. Note the reading, set the output switch to on, and adjust VR12 so that the meter still reads the same.



**LOCATION OF CALIBRATION POINTS  
(VIEWED FROM COMPONENT SIDE)**

## TECHNICAL SPECIFICATION TS3023S

See page 5 for specifications of the main outputs.

### LOGIC OUTPUT

<b>Output Voltage Range:</b>	4 to 6 Volts
<b>Output Current:</b>	4 Amps minimum; current limit approxiamtely 5 Amps.
<b>Output Switch:</b>	Isolates the output and permits output voltage to be set before connecting the load.
<b>Output Terminals:</b>	4mm terminals on 19mm (.75") spacing.
<b>Over-Voltage Protection:</b>	Dual-speed circuit giving typically 20msec up to 7 Volts and typically 2usec above 7 Volts.
<b>Output Protection:</b>	Clamped by the over-voltage protection circuit for forward voltages over 7 Volts and up to 3 Amps forward current. Diode clamped for reverse voltages and up to 3 Amps reverse current.
<b>Load Regulation:</b>	<0.5% for 50% load change.
<b>Line Regulation:</b>	<0.5% for 10% line voltage change.
<b>Ripple and Noise:</b>	<20mV rms, <50mV pk-pk.
<b>Meter Type:</b>	0.5" 3.5 digit LCD for voltage or current.
<b>Meter Resolution:</b>	
Voltage:	10mV
Current:	10mA
<b>Meter Accuracy:</b>	
Voltage:	0.5% of reading + 1 digit
Current:	0.5% of reading + 1 digit

### GENERAL

#### Power Requirements

Input Voltage:	Internally set for 110,120,220 or 240 VAC 50/60Hz. Input Voltage Range: +/- 10% of voltage setting.
Power Consumption:	300VA

#### Environmental Operating

**Range:** 5°C to 40°C, 20% to 80% RH.

#### Environmental Storage

**Range:** -20°C to 60° C.

**Size:** 386mm wide x 160mm high x 238mm deep.

**Weight:** 11.0kg

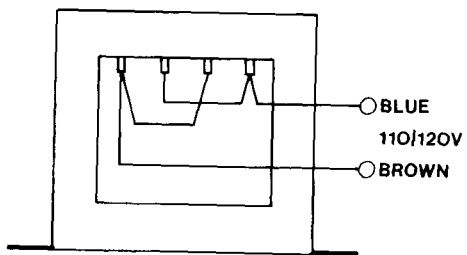
## MAINS OPERATING VOLTAGE

The TS3023 has 3 transformers, 2 for the 30V 2A sections and 1 for the 5V 4A section.

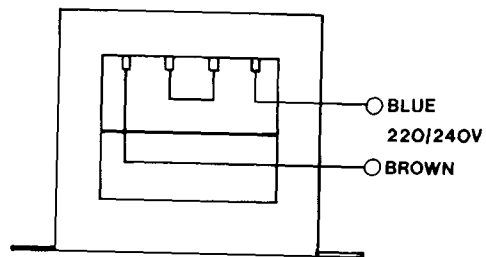
See page 8 for fuse ratings and operating voltage change of the 30V 2A sections.

To change the operating voltage of the 5V 4A section, follow the appropriate diagram below.

110/120V Operation



220/240V Operation



## **CIRCUIT DESCRIPTION 5V 4A**

### **Power Supply - DC Requirements**

With 240V input, T1 and T2 on the mains transformer provide 20Vrms on load. This gives approximately 24V on C1.

T3 and T4 provide 15Vrms giving 20V on C2, Zener diode D9 gives a regulated 10V output for IC2.

### **Switching Regulator**

The switching regulator is configured as a step down or buck regulator operating at 25kHz.

Q1 and Q2 form a PNP darlington switch. L1 smooths the output by storing energy when the switch is closed, and supplies energy via D10 when the switch is open. C4 is the reservoir capacitor. R31 provides a minimum load. L2 and C5 provide additional smoothing.

Regulation is provided by the control IC, IC1. The reference voltage is adjusted by VR1 to give an output range of 4V to 6V. This reference is compared to the voltage on the + sense terminal and the duty cycle is varied to the switching transistor to maintain regulation.

If the voltage drop across the current sense resistor reaches 200mV the drive to the switching transistor is terminated limiting the output current.

Shut down of the regulator occurs if the output voltage falls by 100mV, determined by R13 and R14. Q4 is turned off allowing C6 to charge up via R34 turning on the transistor connected to pin 10 of IC1. This turns the regulator off and the voltage on pin 5 of IC6B falls further and results in the power supply being latched off. Recovery is achieved by turning the mains supply off for sufficient time for C6 to discharge (approximately 20 seconds). Frequency compensation for the feedback is provided by C10, C11 and R12.

### **Over Voltage Protection**

IC7 is an OVP IC and compares the voltage on pin 2 with an internal reference (typically 2.6V). If the voltage on pin 2 exceeds the reference, the output drive to SCR1 is enabled after a delay generated by C3. This mode of protection functions for output voltages between 6.4V and 7V and takes typically 20ms. If the output exceeds 7V, SCR1 is fired instantly via pin 5.

## **Metering**

IC2 is a standard DVM IC and is the same type as used in other sections of the power supply.

With the output switch off, Q3 is off turning IC4A off and IC4B on via inverter IC4D, so that the meter reads output voltage.

With the output switch on, IC4B is turned off and IC4A is turned on, so that the meter reads output current by measuring the voltage across R7.

VR3 calibrates the meter for current measurement; it is also the meter reference so VR3 must be adjusted before VR2, which calibrates the voltmeter mode.

Opto-coupler IC3 provides level shifting between the control circuitry and the LCD drivers. When the power supply goes into current limit, the LED inside IC3 is turned off which turns the photo-transistor off, enabling low frequency oscillator IC5B and IC5A which flashes the delta sign in the display.

## **CALIBRATION**

Equipment required: 3.5 digit multimeter with a 10AMP range.

Connect a 4AMP load to the output terminals (1R2 resistor), switch the output on and adjust the voltage control as necessary to give approximately 4 AMPS on external ammeter. Adjust VR3 so that the meters read the same. VR3 is located on the display pcb.

Remove the 4A load and connect a voltmeter to the output. Note the reading on the external meter, switch the output off and adjust VR2 so that the meter reads the same. Switch the output on and off to check the reading on each meter. VR2 is located on the pcb which is fastened to the rear panel.

## **SERVICING NOTES**

IC1 must be a Unitorde 'A' Part. Q1, D10 and SCR1 must be the specified parts. C4 and C5 are low ESR types. A temporary short may be put across C6 to disable the shut down and ease trouble shooting.

**PARTS LIST**

**PCB Assembly 15V 4A 44115-0060**

**Resistors**

Ref	Description	Part No	Ref	Description	Part No
R1	47RJ W25 CF	23185-0470	R55	Not used	
R2	10KJ W25 CF	23185-3100	R56	100KJ W25 CF	23185-4100
R3	100KJ W25 CF	23185-4100	R57	118KF W25 MF	23202-4118
R4	22KJ W25 CF	23185-3220	R58	100KJ W25 CF	23185-4100
R5	Not used		R59	100KJ W25 CF	23185-4100
R6	Zero ohm link	23185-0000	R60	100KJ W25 CF	23185-4100
R7	Not used		R61	100KJ W25 CF	23185-4100
R8	Not used		R62	22KJ W25 CF	23185-3220
R9	20K0F W25 MF	23202-3200	R63	180KJ W25 CF	23185-4180
R10	750RF W25 MF	23202-1750			
R11	560RJ W25 CF	23185-1560	VR4	Not used	
R12	27KJ W25 CF	23185-3270	VR5	2K2 Cermet	23379-2220
R13	7K50F W25 MF	23202-2750	VR6	Not used	
R14	6K8J W50 CF	23179-2680	VR7	220R Cermet	23379-1220
R15	10KJ W25 CF	23185-3100	VR8	1K0 Cermet	23379-2100
R16	10K0F W25 MF	23202-3100	VR9	220R Cermet	23379-1220
R17	1M00F W25 MF	23202-5100	VR10	220R Cermet	23379-1220
R18	Not used		VR11	2K2 Cermet	23379-2220
R19	51K0F W25 MF	23202-3510	VR12	100K CF	23377-4100
R20	1K8J W25 CF	23185-2180			
R21	47RJ W25 CF	23185-0470			
R22	10KJ W25 CF	23185-3100			
R23	See Heatsink Assy 2				
R24	0R33J 2W5 WW	23274-0010			
R25	0R33J 2W5 WW	23274-0010			
R26	2K2J W50 CF	23179-2220			
R27	0R10J 7W0 WW	23271-0008			
R28	10KJ W25 CF	23185-3100			
R29	100KJ W25 CF	23185-4100			
R30	2M7J W25 CF	23185-5270			
R31	10KJ W25 CF	23185-3100			
R32	1K00F W25 MF	23202-2100			
R33	3K90F W25 MF	23202-2390			
R34	1K00F W25 MF	23202-2100			
R35	9K10F W25 MF	23202-2910			
R36	665RF W25 MF	23202-1665			
R37	750RF W25 MF	23202-1750			
R38	20K0F W25 MF	23202-3200			
R39	11K5F W25 MF	23202-2115			
R40	7K50F W25 MF	23202-2750			
R41	2M7J W25 MF	23202-5270			
R42	Not used				
R43	to				
R48	100KJ W25 CF	23185-4100			
R49	118KF W25 MF 50PPM	23202-4118			
R50	100KJ W25 CF	23185-4100			
R51	100KJ W25 CF	23185-4100			
R52	1M00F W25 MF	23202-5100			
R53	1M00F W25 MF	23202-5100			
R54	100KJ W25 CF	23185-4100			

**Capacitors**

C1	4700U	63V Elec	23556-0217
C2	10U	35V Elec	23557-0647
C3	10U	35V Elec	23557-0647
C4	100U	50V Elec	23557-0610
C5	100U	50V Elec	23557-0610
C6	100NM	250V P/E	23621-0312
C7	100NK	63V P/E	23620-0246
C8	100NK	63V P/E	23620-0246
C9	100U	63V Elec	23557-0249
C10	100NK	63V P/E	23620-0246
C11	330NK	63V P/E	23620-0227
C12	100NJ	100V P/E	23620-0207
C13	330NK	63V P/E	23620-0227
C14	100PG	63V Cer	23427-0322
C15	330NK	63V P/E	23620-0227
C16	330NK	63V P/E	23620-0227
C17	100NJ	100V P/E	23620-0207
C18	330NK	63V P/E	23620-0227
C19	330NK	63V P/E	23620-0227
C20	100PG	63V Cer	23427-0322
C21	330NK	63V P/E	23620-0227
C22	100NK	63V P/E	23620-0246
C23	100NK	63V P/E	23620-0246
C24	47PG	63V Cer	23427-0329
C25	47PG	63V Cer	23427-0329
C26	4700U	63V Elec	23556-0217



**Semiconductors**

Ref	Description	Part No
D1	Not used	
D2	Not used	
D3	Not used	
D4	Not used	
D5	1N4002	25115-0907
D6	1N4002	25115-0907
D7	1N4002	25115-0907
D8	1N4002	25115-0907
D9	Not used	
D10	ZN404	27161-0120
D11	1N4148	25021-0901
D12	1N4148	25021-0901
D13	1N4148	25021-0901
D14	1N4002	25115-0907
D15	1N4002	25115-0907
D16*	1N5401	25117-0020
D17	to	
D23	1N4148	25021-0901
D24	1N4002	25115-0907
D25	ZN404	27161-0120

\*D16 is wired across the Red and Black output terminals.

Q1	ZTX214	25341-0214
Q2	ZTX239/BC549	25380-0229
Q3	ZTX239/BC549	25380-0229
Q4	ZTX239/BC549	25380-0229
Q5	See Heatsink Assy 2	
Q6	See Heatsink Assy 2	
Q7	See Heatsink Assy 1	
Q8	ZTX239/BC549	25380-0229
Q9	ZTX214	25341-0214
Q10	ZTX239/BC549	25380-0229

Ref	Description	Part No
IC1	7106RCPL	27153-0003
IC2	7106RCPL	27153-0003
IC3	TL072CP	27106-0606
IC4	TL072CP	27106-0606
IC5	4011BE	27226-0110
IC6	4070BE	27226-0700
IC7	4066BE	27226-0660
IC8	4066BE	27226-0660
IC9	4070BE	27226-0700
IC10	78L05ACP	27160-0011
IC11	79L05ACP	27160-0012

LCD 3.5 Digit LCD (2) 26100-0070

**Other Parts on PCB Assy 15V**

Description	Part No
Zero Ohm Resistors (PCB Links) 44 off	23185-0000
PCB	35515-1030

## Resistors

Ref	Description	Part No	Ref	Description	Part No
R1	47RJ W25 CF	23185-0470	R60	100KJ W25 CF	23185-4100
R2	10KJ W25 CF	23185-3100	R61	100KJ W25 CF	23185-4100
R3	100KJ W25 CF	23185-4100	R62	22KJ W25 CF	23185-3220
R4	22KJ W25 CF	23185-3220	R63	180KJ W25 CF	23185-4180
R5	22MJ W25 CF	23221-0030			
R6	68K0F W25 MF	23202-3680			
R7	11K5F W25 MF	23202-3115	VR4	100K CF	23377-4100
R8	7K50F W25 MF	23202-2750	VR5	2K2 Cermet	23379-2220
R9	20K0F W25 MF	23202-3200	VR6	2K2 Cermet	23379-2220
R10	750RF W25 MF	23202-1750	VR7	220R Cermet	23379-1220
R11	560RJ W25 CF	23185-1560	VR8	2K2 Cermet	23379-2220
R12	56KJ W25 CF	23185-3560	VR9	Not used	
R13	7K50F W25 MF	23202-2750	VR10	220R Cermet	23379-1220
R14	6K8J W50 CF	23179-2680	VR11	Not used	
R15	10KJ W25 CF	23185-3100	VR12	100K CF	23377-4100
R16	10K0F W25 MF	23202-3100			
R17	1M00F W25 MF	23202-5100			
R18	470KF W25 MF	23202-4470			
R19	100KF W25 MF	23202-4100			
R20	1K8J W25 CF	23185-2180			
R21	47RJ W25 CF	23185-0470			
R22	10KJ W25 CF	23185-3100			
R23	See Heatsink Assy 2				
R24	0R68J 2W5 WW	23284-0010			
R25	0R68J 2W5 WW	23284-0010			
R26	2K2J W50 CF	23179-2220			
R27	0R10J 7W0 WW	23271-0008			
R28	10KJ W25 CF	23185-3100			
R29	100KJ W25 CF	23185-4100			
R30	2M7J W25 CF	23185-5270			
R31	10KJ W25 CF	23185-3100			
R32	1K00F W25 MF 50PPM	23202-2100			
R33	9K10F W25 MF	23202-2910			
R34	1K8J W25 CF	23185-2180			
R35	Not used				
R36	Not used				
R37	750RF W25 MF 50PPM	23202-1750			
R38	20K0F W25 MF 50PPM	23202-3200			
R39	Not used				
R40	Not used				
R41	Not used				
R42	Not used				
R43	to				
R48	100KJ W25 CF	23185-4100			
R49	118KF W25 MF 50PPM	23202-4118			
R50	100KJ W25 CF	23185-4100			
R51	100KJ W25 CF	23185-4100			
R52	1M00F W25 MF	23202-5100			
R53	1M00F W25 MF	23202-5100			
R54	100KJ W25 CF	23185-4100			
R55	Not used				
R56	100KJ W25 CF	23185-4100			
R57	118KF W25 MF	23202-4118			
R58	100KJ W25 CF	23185-4100			
R59	100KJ W25 CF	23185-4100			

## Capacitors

C1	4700U 63V Elec	23556-0217
C2	10U 35V Elec	23557-0647
C3	10U 35V Elec	23557-0647
C4	100U 50V Elec	23557-0610
C5	100U 50V Elec	23557-0610
C6	100NM 250V P/E	23621-0312
C7	100NK 63V P/E	23620-0246
C8	100NK 63V P/E	23620-0246
C9	100U 63V Elec	23557-0249
C10	100NK 63V P/E	23620-0246
C11	330NK 63V P/E	23620-0227
C12	100NJ 100V P/E	23620-0207
C13	330NK 63V P/E	23620-0227
C14	100PG 63V Cer	23427-0322
C15	330NK 63V P/E	23620-0227
C16	330NK 63V P/E	23620-0227
C17	100NJ 100V P/E	23620-0207
C18	330NK 63V P/E	23620-0227
C19	330NK 63V P/E	23620-0227
C20	100PG 63V Cer	23427-0322
C21	330NK 63V P/E	23620-0227
C22	100NK 63V P/E	23620-0246
C23	100NK 63V P/E	23620-0246
C24	47PG 63V Cer	23427-0329
C25	47PG 63V Cer	23427-0329

## Semiconductors

## Other Parts on PCB Assy 30V

Ref	Description	Part No	Description	Part No
D1	1N5401	25117-0020	Zero Ohm Resistors	
D2	1N5401	25117-0020	(PCB Links) 44 off	23185-0000
D3	1N5401	25117-0020	PCB	35515-0950
D4	1N5401	25117-0020		
D5	1N4002	25115-0907	<b>Rear Mounted Heatsink Assys</b>	
D6	1N4002	25115-0907	<b>for all S series PSUs</b>	
D7	1N4002	25115-0907		
D8	1N4002	25115-0907	Note: 30V Single, Dual & Triple	
D9	1N4148	25021-0901	PSUs use identical Heatsink Assys,	
D10	ZN404	27161-0120	The 15V 4A PSU Heatsink Assys	
D11	1N4148	25021-0901	use the same components but are	
D12	1N4148	25021-0901	wired differently.	
D13	1N4148	25021-0901		
D14	1N4002	25115-0907	<b>Heatsink Assembly 1</b>	
D15	1N4002	25115-0907	consisting of:	
D16*	1N5401	25117-0020		
D17 to			<b>Description</b>	<b>Part No</b>
D23	1N4148	25021-0901	Heatsink Type 1	20670-0090 (*)
D24	1N4002	25115-0907	2N3055H (Q7)	25386-0010
D25	ZN404	27161-0120	Transistor Mount	20611-0007
			Mica Washer	20613-0010
			Screw M3 x 12mm1 2 off	20234-0025
			Washer M3 2 off	20030-0263
			Solder tag M3	22451-0203
			Nut M3 2 off	20210-0101
			<b>Heatsink Assembly 2</b>	
			consisting of:	
			<b>Description</b>	<b>Part No</b>
			Heatsink Type 2	20670-0100 (*)
			2N3055H	
			(Q5, Q6) 2 off	25386-0010
			Transistor Mount 2 off	20611-0007
			Mica Washer 2 off	20613-0010
			Screw M3 x 12mm1 4 off	20234-0025
			Washer M3 2 off	20030-0263
			Solder tag M3 2 off	22451-0203
			Nut M3 4 off	20210-0101
			47RJ W25 CF (R23)	23185-0470
			(*) See manufacturing changes on	
			page 26.	
LCD	3.5 Digit LCD (2)	26100-0070		

\*D16 is wired across the Red and Black output terminals.

**PCB Assembly Logic Supply 44115-0070**  
**consisting of:**

**Resistors**

Ref	Description	Part No
R1	1K0J W25 CF	23285-2100
R2	10R0F W60 MF	23226-0100
R3	10R0F W60 MF	23206-0100
R4	100RJ W25 CF	23185-1100
R5	820RF W60 MF	23206-1820
R6	820RF W60 MF	23206-1820
R7	0R033J 4W MR	23271-0009
R8	1K69F W25 MF	23202-2169
R9	1K10F W25 MF	23202-2110
R10	1K69F W25 MF	23202-2169
R11	2K2J W25 CF	23185-2220
R12	62KJ W25 CF	23187-3620
R13	3K90F W25 MF	23202-2390
R14	200KJ W25 CF	23187-4200
R15	200RF W25 MF	23202-1200
R16	200RF W25 MF	23202-1200
R17	3K60F W25 MF	23202-2360
R18	3K90F W25 MF	23202-2390
R19	36K0F W25 MF	23202-3360
R20	3K90F W25 MF	23202-2390
R21	100KJ W25 CF	23185-4100
R22	118KF W25 MF	23202-4118
R23	100KJ W25 CF	23185-4100
R24	100KJ W25 CF	23185-4100
R25	1M0J W25 CF	23185-5100
R26	1M0J W25 CF	23185-5100
R27	1M0J W25 CF	23185-5100
R28	1M0J W25 CF	23185-5100
R29	1M0F W25 MF	23202-5100
R30	1M0F W25 MF	23202-5100
R31	200RF W25 MF	23202-1200
R32	100RJ W25 CF	23185-1100
R33	47RJ W25 CF	23185-0470
R34	36K0F W25 MF	23202-3360
R35	100RJ W25 CF	23185-1100
R36	36K0F W25 MF	23202-3360
R37	6K81F W25 MF	23202-2681
R38	3K90F W25 MF	23202-2390
R39	1K0J W25 CF	23185-2100
VR1	Pot 10K Lin	23347-0130
VR2	PS/H 100R Cermet	23379-1100
VR3	PS/H 2K2 Cermet	23379-2220

**Capacitors**

Ref	Description	Part No
C1	3300U 40V Elec	23556-0218
C2	100U 25V Elec	23557-0650
C3	1U0 63V Elec	23557-0609
C4	1000U 10V Low ESR	23557-0810

**Capacitors (continued)**

Ref	Description	Part No
C5	1000U 10V Low ESR	23557-0810
C6	100U 25V Elec	23557-0650
C7	100NK 63V P/E	23620-0246
C8	100NK 63V P/E	23620-0246
C9	10NJ 400V P/E	23621-0310
C10	4N7K 100V P/E	23620-0245
C11	100PG 63V Cer	23427-0322
C12	100NK 63V P/E	23620-0246
C13	330NK 63V P/E	23620-0227
C14	330NK 63V P/E	23620-0227
C15	100PG 63V Cer	23427-0322
C16	330NK 63V P/E	23620-0227
C17	330NK 63V P/E	23620-0227
C18	330NK 63V P/E	23620-0227
C19	100NK 63V P/E	23620-0246
C20	100NK 63V P/E	23620-0246
*C21	100NS 63V Cer	23438-0007
C22	1N0Z 500V Cer	23424-0445
C23	100NK 63V P/E	23620-0246
C24	10NZ 63V Cer	23427-0325

\*Note C21 is fitted across the output terminals

**Semiconductors**

Ref	Description	Part No
D1	1N5401	25117-0020
D2	1N5401	25117-0020
D3	1N5401	25117-0020
D4	1N5401	25117-0020
D5	1N4002	25115-0907
D6	1N4002	25115-0907
D7	1N4002	25115-0907
D8	1N4002	25115-0907
D9	10V Zener	25130-0239
*D10	10TQ030	25115-0710
D11	1N4002	25115-0907
D12	1N4002	25115-0907
D13	1N4148	25021-0901
D14	1N4148	25021-0901
D15	1N4148	25021-0901
D16	6V2 Zener	25130-0220

*Q1	BDT92	25334-0012
*Q2	BD234	25334-0009
Q3	ZTX214	25341-0214
Q4	ZTX239/BC549	25380-0229
*SCR	BT151-500R	25210-0010

\*Note D10,Q1,Q2,SCR are fitted to the Heatsink Assy on PCB

**Semiconductors (continued)**

<b>Ref</b>	<b>Description</b>	<b>Part No</b>
IC1	UC3524AN	27160-0310
IC2	7106RCPL	27153-0003
IC3	CNY17-3	27001-0020
IC4	4066B	27226-0660
IC5	4070B	27226-0700
IC6	LM358	27106-0513
IC7	MC3423P1	27102-0010
LCD	3.5 Digit LCD	26100-0070

**Other Parts on Logic Supply PCB Assy**

<b>Description</b>	<b>Part No</b>
Heatsink	31512-0310
Washer (SIL-PAD)	4 off 20613-0006
Bush, TO220	3 off 20611-0003
Screw M3 x 10mmL	4 off 20234-0011
Washer M3	4 off 20030-0263
Washer M3 s/proof	6 off 20037-0301
Stud M3 x 8mmL (for heatsink)	2 off 20205-0600
Screw M4 x 30mmL cheese head nylon (for L1)	20224-0210
Nut M4 nylon (for L1)	20210-0201
16 Pin IC Socket	22574-0120
14 Pin IC Socket	2 off 22574-0119
8 Pin IC Socket	2 off 22574-0118
Zero ohm resistor	14 off 23185-0000
Fuse Clips	2 off 22312-0240
Fuse 5 Amp A/S FS2	22315-0237
Inductor 200uH 4A L1	22154-0010
Inductor 2.2uH L2	22042-0100
Inductor 7 Turns L3	22152-0010
Inductor 6.8uH L4	22042-0110
PCB	35515-1040

**Connector Assy 16 Way Inter PCB**

consisting of:

Cable 16 Way IDC Flat  
7.5 ins off 10148-0001  
Connector transition 16 Way  
2 off 22575-0047

**Parts Common to all PSUs**

Description	Part No
Clip, capacitor for C1	20655-0520
Switch, rocker SW1	22219-0100 (*)
Switch, rocker SW2,3,4	22219-0110 (*)
Fuseholder	22300-0210 (*)
Shroud for fuseholder	22458-0001
Knob, black	20657-0002
Cap, black for knob	20657-0009
Pot, 1K0 lin, VR1	23348-0060
Pot, 1K0 lin, VR2	23348-0020
Pot, 10K log, VR3	23348-0030
Terminal, Red	22571-0670
Terminal, Black	22571-0680
Terminal, Green	22571-0690
Shorting bar (output terminals)	35331-0080
Bezel for displays	31711-0020
Solder tag 4BA (output terminals)	22451-0200
Washer 4BA shakeproof (output terminals)	20037-0247
Diode 1N5401 (D16) (output terminals)	25117-0020
Bracket, switch support for SW1,2,3	31512-0270
Washer M3 (Heatsink to rear panel etc )	20030-0263
Grommet 3109A black (for heatsink wiring)	22443-0002
Foot	20662-0510
Solder tag,s/prf 6BA (Earth wire to earth tag)	20037-0400
Screw No 6 x 3/8"l Self tap (C1, Case and Feet securing)	20062-0700
Screw No 6 x 1/2"l Self tap (Transformer securing)	20662-0710
Captive Nut (Transformer, C1, and Case securing)	20213-0010
Screw M3 x 8mmL Nylon (PCB to front panel and Heatsink cover to spacers)	20224-0200
Screw M5 x 5mmL (Earth tag to lower case)	20234-0017
Cable tie for wiring	20653-0204
Spacer M3 x 30mmL Hex studded (Heatsink mounting)	20661-0236
Spacer M3 x 30mm round clearance (Heatsink mounting)	20661-0243
Screw M3 x 40mmL (Heatsink (cover))	20234-0038

**Parts Common (continued)**

Description	Part No
Bush, strain relief (for mains cable)	22448-0220
Mains cable cut from	10175-0110
Label, wiring instructions	37541-0490
Mains lead with Euro plug	22491-0200
Mains lead with USA plug	22491-0210
Handle	29211-0110
Serial No label	37522-0160
End caps for carton	20664-0190
Guarantee card	48581-0230
Instruction Book	48511-0050

**Additional Parts Common to 15V  
and 30V Single PSUs**

Description	Part No
Case, upper	33536-0630
Case, lower	33536-0700 (*)
Warning Label - 240V	37559-0100
Warning Label - 220V	37559-0110
Warning Label - 120V	37559-0120
Warning Label - 110V	37559-0130
Carton	38114-0130

**Additional Parts Common to 15V  
and 30V Single & Dual PSUs**

Description	Part No
Cover, heatsink	31512-0130 (*)

**Additional Parts Common to 30V  
Dual and Triple PSUs**

Description	Part No
Bracket, handle/case	33111-0180
Warning label - 240V	37559-0140
Warning label - 220V	37559-0150
Warning label - 120V	37559-0160
Warning label - 110V	37559-0170

**Additional Parts Common to 30V  
Single, Dual & Triple PSUs**

Description	Part No
Transformer 30V	22115-0070

(\*) See manufacturing changes on page 26.

**Additional Parts unique to 15V PSU**

Description	Part No
Faceplate	33331-1320 (*)
Ceramic beads for R24,25	22482-0010
Bridge Rectifier BR1	25211-0300
Push-on Tags for BR1	22454-0041
Transformer	22115-0090

**Additional Parts unique to 30V  
Single PSU**

Description	Part No
Faceplate	33331-1310 (*)

**Additional Parts unique to 30V  
Dual PSU**

Description	Part No
Faceplate	33331-1110 (*)
Case, upper	33536-0650
Case, lower	33536-0710 (*)
Carton	38114-0140

**Additional Parts unique to Triple PSU**

Description	Part No
Faceplate	33331-1390 (*)
Case, upper	33536-0720
Case, lower	33536-0730 (*)
Cover, Heatsinks	31512-0230 (*)
Cover, Heatsinks	31512-0310
Screw M4 x 6mmL (for case brackets)	20234-0034
Screw M3 x 8mmL (for case brackets)	20234-0012
Bracket, switch support (for SW4)	31512-0290
Res 84K5F W25 CF (R101)	23202-3845
Trimpot 10K Cermet (VR101)	23379-3100
Spacers Hex M3 x 30mmL (Logic Supply PCB to Case)	20661-0247
Transformer, Logic Supply	22115-0100
Attachment parts for transformer	
Screw M4 x 6mmL	20234-0028
Washer M4	20030-0266
Washers/proof M4	20037-0304
Nut M4	20210-0102

**Fuses**

Description	Part No
1A Anti surge HRC (for 220/240V Single PSUs)	22315-9501
2A Anti surge HRC (for 110/120V Single PSUs and 220/240V Dual & Triple PSUs)	22315-9502
4A Anti surge HRC (for 110/120V Dual & Triple PSUs)	22315-9503

(\*) See manufacturing changes on  
page 26.

## MANUFACTURING CHANGES

From mid-91 new switches (both AC mains and DC output) and fuseholder were introduced, necessitating changes to all chassis, faceplate and heatsink covers. At the same time the heatsink mounting holes in the chassis were changed to accommodate a standard pre-drilled heatsink. Early and new parts are not interchangeable; the earlier switches and fuseholders are available as spares.

Units using the new parts can be easily identified because the DC output terminals are mounted on a small pcb. The new part numbers are as follows:

Description	Original Part	New Part
Heatsink type 1	20670-0090	20670-9001
Heatsink type 2	20670-0100	20670-9001
Spacer (Heatsinks)	20661-0236	20661-0242
Spacer (Heatsinks)	20661-0243	20661-9302
Bushes (Heatsinks)	-	20611-9305
Switch, rocker SW1	22219-0100	22219-0060
Switch, rocker SW2,3,4	22219-0110	22219-0080
Fuseholder	22300-0210	22300-9301
Single chassis	33536-0700	33536-0900
Single heatsink cover	31512-0130	31512-0370
Faceplate TS1541S	33331-1320	33331-1740
Faceplate TS3021S	33331-1310	33331-1730
Faceplate TS3022S	33331-1110	33331-1390
Dual chassis	33536-0710	33536-0910
Faceplate TS3023S	33331-1390	33331-1760
Triple chassis	33536-0730	33536-0920
Triple heatsink cover	31512-0230	31512-0340

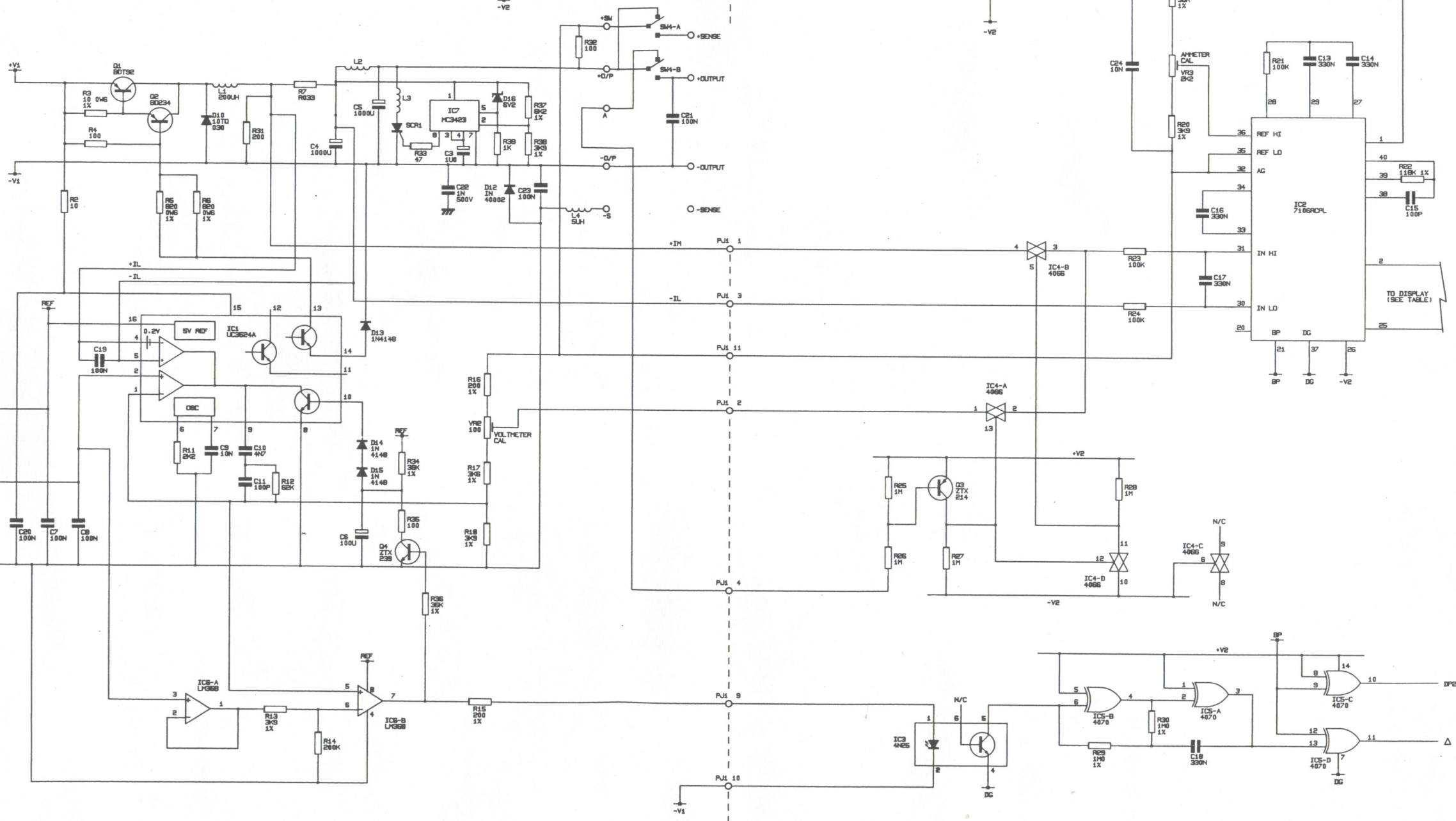
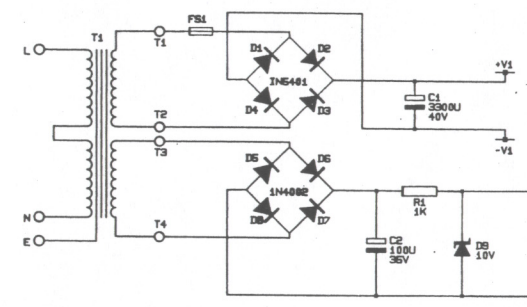
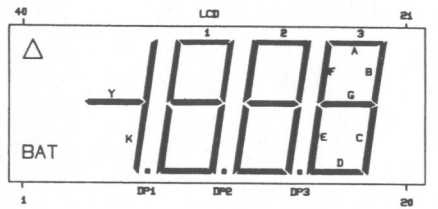
### Additional Parts (Per each output)

PCB (terminals)	-	35515-1210
Screw 4BA (terminals)	-	20134-9005
Spacer 4BA (terminals)	-	20661-0257
Washer (green earth terminal)	-	22571-0691



LCD/IC INTERCONNECTIONS

LCD PIN NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SEGMENT	BP	Y	K					DP1	E1	D1	C1	DP2	E2	DE	C2	DP3	E3	D3	C3	BP
IC NO.	2	2	2					2	2	2	5	2	2	2	2	2	2	2	2	2
IC PIN NO.	21	21	19					21	18	15	24	10	14	9	10	21	8	2	3	4
LCD PIN NO.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
SEGMENT	A3	F3	G3	B2	A2	F2	G2	BP	B1	A1	F1	G1					BP	Δ	BP	BAT
IC NO.	2	2	2	2	2	2	2	2	2	2	2	2					2	5	2	2
IC PIN NO.	5	6	7	11	12	13	25	21	16	23	17	22					21	11	21	21

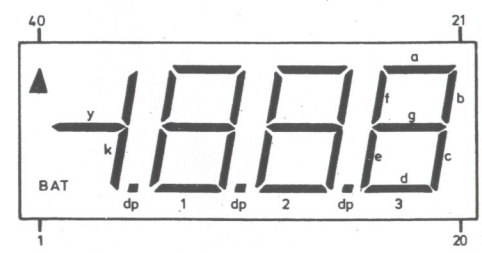
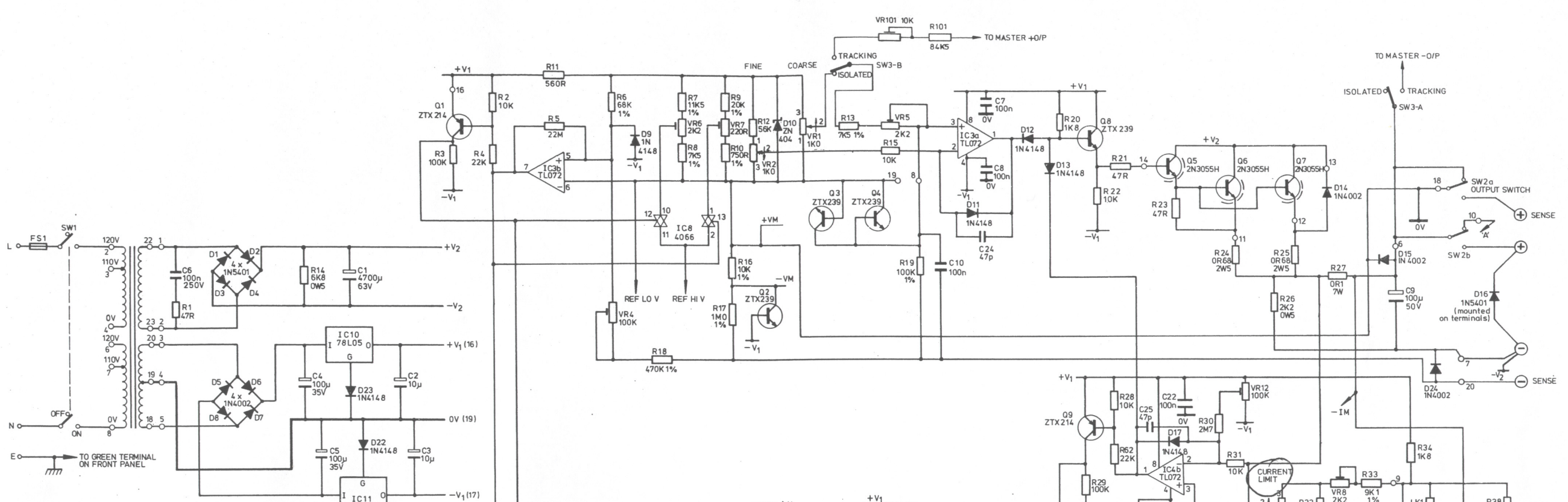


DISPLAY PCB

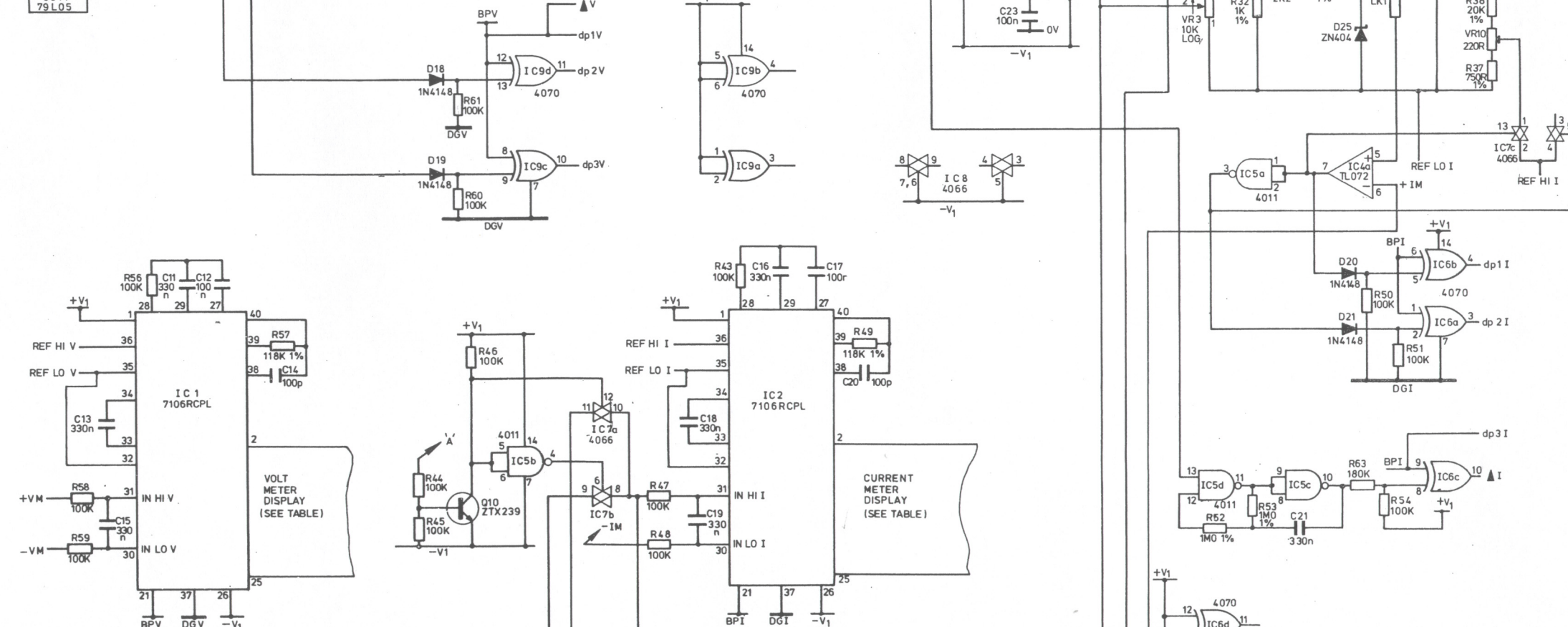
MAIN PCB

DISPLAY PCB

TS3023S  
5V-4A SECTION

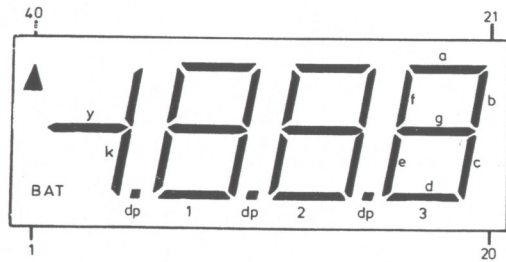
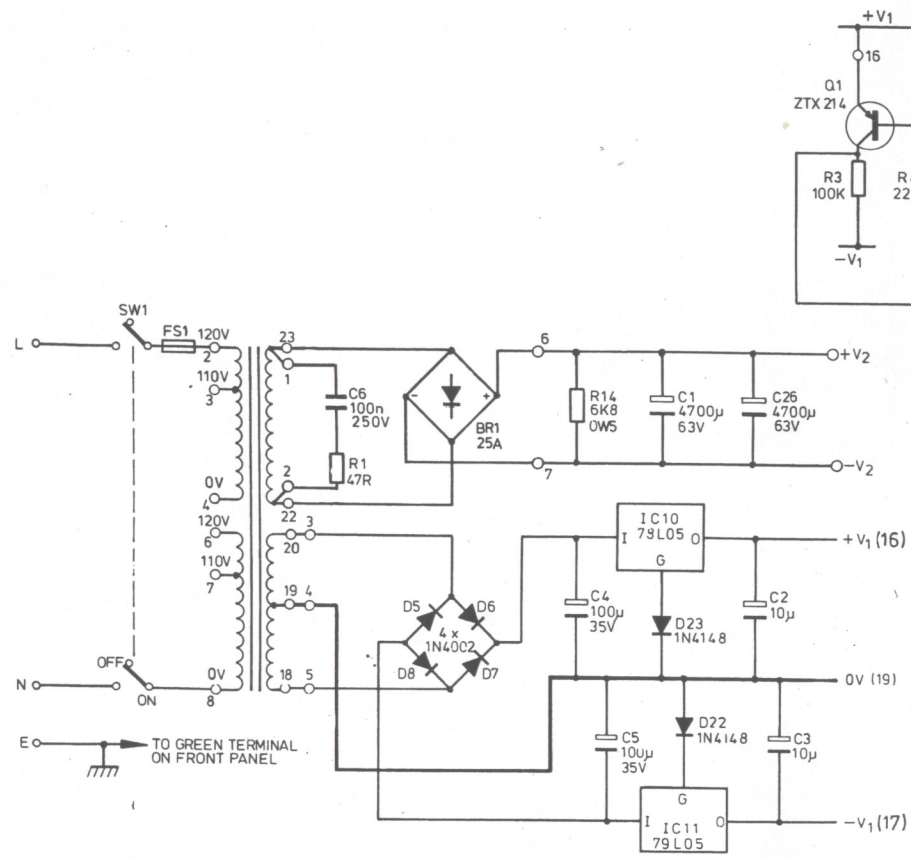


LCD/IC INTERCONNECTIONS														
LCD PIN No	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEGMENT	BP	y	k	-	-	-	-	dp1	e1	d1	c1	dp2	e2	d2
IC PIN No (V)	1	1	1	-	-	-	-	1	1	1	1	9	1	1
IC PIN No (I)	2	2	2	-	-	-	-	6	2	2	2	6	2	2
LCD PIN No	15	16	17	18	19	20	21	22	23	24	25	26	27	28
SEGMENT	c2	dp3	e3	d3	c3	b3	a3	f3	g3	b2	a2	f2	g2	BP
IC PIN No (V)	1	9	1	1	1	1	1	1	1	1	1	1	1	1
IC PIN No (I)	2	2	2	2	2	2	2	2	2	2	2	2	2	2
LCD PIN No	29	30	31	32	33	34	35	36	37	38	39	40	-	-
SEGMENT	b1	a1	f1	g1	-	-	-	BP	▲	BP	BAT	-	-	-
IC PIN No (V)	1	1	1	1	-	-	-	1	1	1	1	1	-	-
IC PIN No (I)	2	2	2	2	-	-	-	2	6	2	2	2	-	-



SLAVE UNIT ONLY SHOWN

TS3021S/22S/23S  
30V-2A SECTIONS



LCD/IC INTERCONNECTIONS		1	2	3	4	5	6	7	8	9	10	11	12	13	14
SEGMENT		BP	y	k	-	-	-	-	dp1	e1	d1	c1	dp2	e2	d2
C PIN No (V)		1	1	1	-	-	-	-	21	18	15	24	11	14	9
C PIN No (I)		2	2	2	-	-	-	-	6	4	18	15	24	3	14
SEGMENT		c2	dp3	e3	d3	c3	b3	a3	f3	g3	b2	a2	f2	g2	BP
C PIN No (V)		1	9	1	1	1	1	1	1	1	1	1	1	1	1
C PIN No (I)		2	2	2	2	2	2	2	2	2	2	2	2	2	2
SEGMENT		b1	a1	f1	g1	-	-	-	BP	▲	BP	BAT	-	-	-
C PIN No (V)		1	1	1	1	-	-	-	1	1	1	1	-	-	-
C PIN No (I)		2	2	2	2	-	-	-	2	2	2	2	-	-	-

