

FOR SERVICE MANUALS
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SINCLAIR / Thurlby PL Series
Power Supplies

SERVICE MANUAL

PL-310

PL-154

PL-320

14284

Introduction

The PL series of power supplies are fully variable series regulated units incorporating separate digital meters for voltage and current. Separate voltage and current control circuits enable them to operate in constant voltage or constant current mode from 0 to 31 volts at 0 to 1.1 amps or 2.2 amps. (0 to 15 volts at 3.98 amps - PL154)

In addition to the AC input switch, there is a DC output switch. When this switch is 'off', in addition to disconnecting the +ve output, the current meter is caused to read the value of the current control setting. The current meter decimal points are used to indicate the mode as follows:

- | | |
|-------------------------|---|
| Decimal points off | - output switch 'on', constant voltage operation, meter reading output current. |
| Decimal points on | - output switch 'off', meter reading current limit setting. |
| Decimal points flashing | - output switch 'on', constant current operation, meter reading output current. |

A damping switch is incorporated on the current meter input. This provides a long time constant which averages out rapidly fluctuating load currents.

The input to the voltage control circuit and voltage meter are brought out to the front panel terminals labelled 'sense'. These are normally connected to the output terminals by shorting bars, but can be connected to the output at the load via separate leads in order to eliminate inaccuracies caused by lead resistances.

Quad Mode Dual versions incorporate push button switches enabling Isolated, Parallel, Series, or Series Tracking operations to be selected.

General and Safety

This manual has been prepared to aid the experienced engineer in the maintenance and repair of Thurlby PL Series power supplies. It should be used in conjunction with the owners instruction manual.

Recalibration or repair should only be attempted by skilled personnel in conjunction with high quality test equipment. If the user is in any doubt as to his competence to carry out the work, the supply should be returned to Thurlby Electronics Ltd or their agents overseas for the work to be carried out.

The equipment is AC line powered and must only be dismantled by personnel conversant with the hazards of working on line powered equipment. When working on the unit with the cover removed, the protective earth conductor must be connected to line ground, and the sleeving and shrouds covering AC line live and neutral conductors must be in place.

The equipment must be disconnected from line power whilst being dismantled, and power should only be applied when essential for carrying out testing and adjustment.

Dismantling the Equipment

The cover is removed by removing the two screws through the handle, and the two screws on each side. On Dual and K units a further four screws must be removed from the top.

The front panel may be disconnected from the chassis by removing the two front feet and the self-tapping screws directly between them. This allows the front panel to be laid downwards giving improved access to the rear of the PCB. All preset adjustments are accessible through the PCB.

Should it be necessary to gain access to the front of the PCB, this should be done by removing the four screws from the front of the front panel. This will allow the PCB, heatsink bracket, and displays to be removed as a complete assembly.

SPECIFICATION

Input Voltage:	110, 120, 220, 240V AC \pm 10% at 48-63Hz.
Output:	0-31 Volts nominal (0-15.5V PL154) 0-1.1A nominal (PL310), 0-2.2A (PL320) 0-3.9A (PL154)
Output Terminations:	4mm terminals on 19mm (3/4") spacing DC output switch
Sensing:	Remote via 4mm terminals or Direct via shorting links (provided)
Line Stability:	<0.01% of maximum output for 10% line change
Load Regulation:	<0.01% of maximum output for 50% Load change
Ripple and Noise:	<1mV typically
Output Impedance:	<5mOhms typically at 1kHz
Temperature Coefficient	<0.01%/degC typically
Transient Response:	<20usecs typically to <50mV of setting for 100% load change
Constant Current Output Impedance:	50KOhms typically with voltage limit at maximum
Voltage Controls:	Continuously variable by coarse and fine controls, setability 0.005 Volts.
Current Limit:	Continuously variable from 0 to 110% of maximum current rating. Automatic indication of constant current operation
Mode Selection: (Dual Unit only)	Isolated, True parallel, Series or Series Tracking via front panel switches
Meters:	Dual 3 3/4 digit (4000 count) with 12.5mm (1/2") LEDs. Reading rate 4 per second

5 (cont)

Maximum Voltage: Voltage 0.01 Volts over entire range
Current 0.001 Amps over entire range

Maximum Accuracy: Voltage 0.1% reading \pm 0.05% full scale
20 - 25 C Current 0.3% reading \pm 0.1% full scale.

Current Meter Damping: Normally 20msec switchable to 2 secs for averaging of rapidly varying loads

Operating Temperature Range: 0 - 45degC

Dimensions: 235mm x 175mm x 155mm (9.25 x 6.9 x 6.15") single
235mm x 175mm x 345mm (9.25 x 6.9 x 13.6") dual
235mm x 175mm x 310mm (9.25 x 6.9 x 12.15")K

Electrical Safety: Designed and manufactured to comply with IEC 348.

CIRCUIT DESCRIPTION

Block Diagram

The transformer incorporates two secondary windings, one which produces the main supply powering the output, and another which produces an auxilliary supply powering the control and metering circuits.

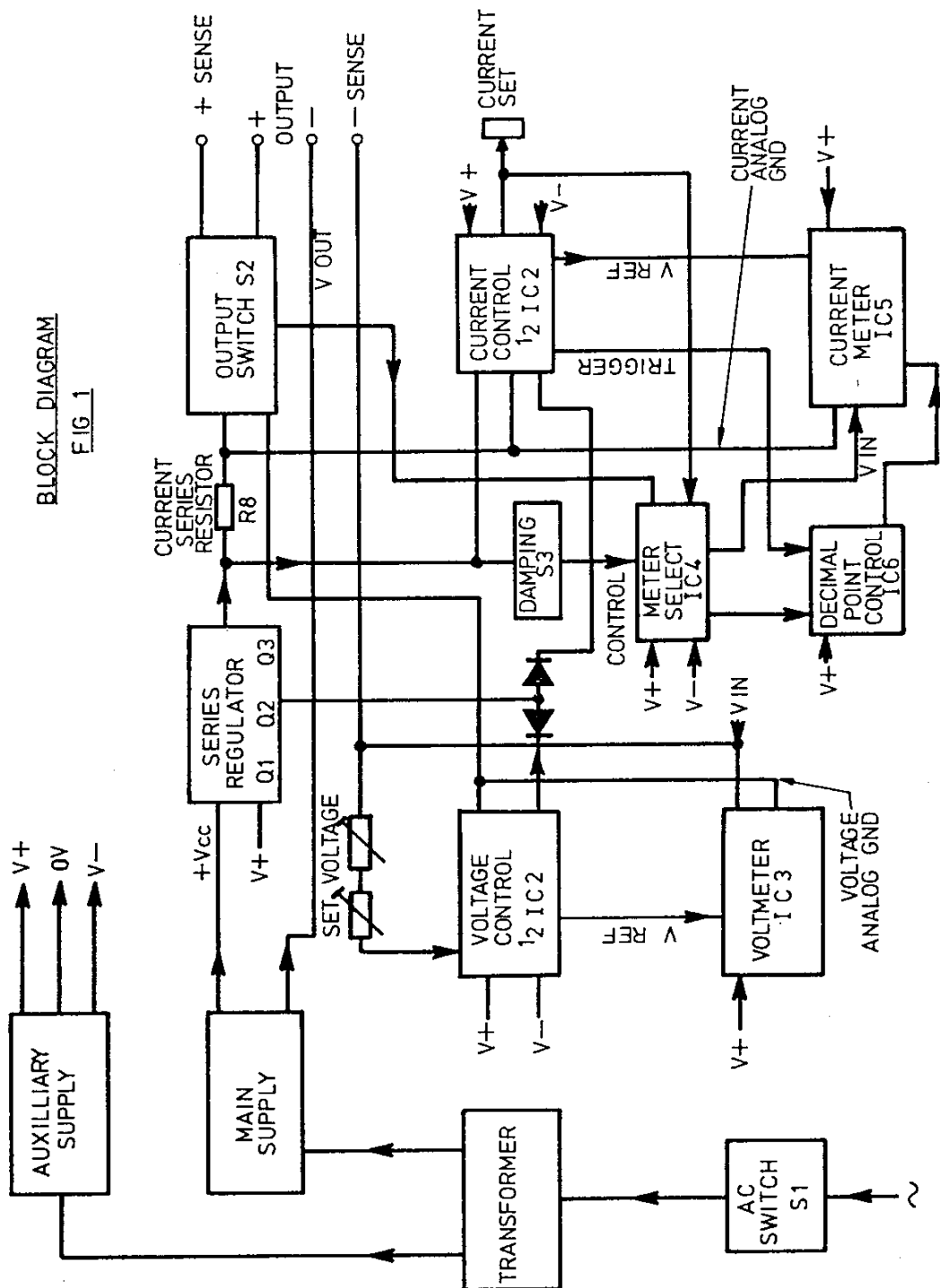
The series regulator is placed in the positive output of the main supply, but because of the way in which the control and metering circuits operate, it is convenient to label the output of the series regulator as 0 volts, and to regard the negative side of the main supply as being the controlled output voltage (-V out).

The auxilliary supply provides stabilised symmetrical voltage outputs V+ and V- with the common point connected to the +ve output via the output switch and the +ve sense.

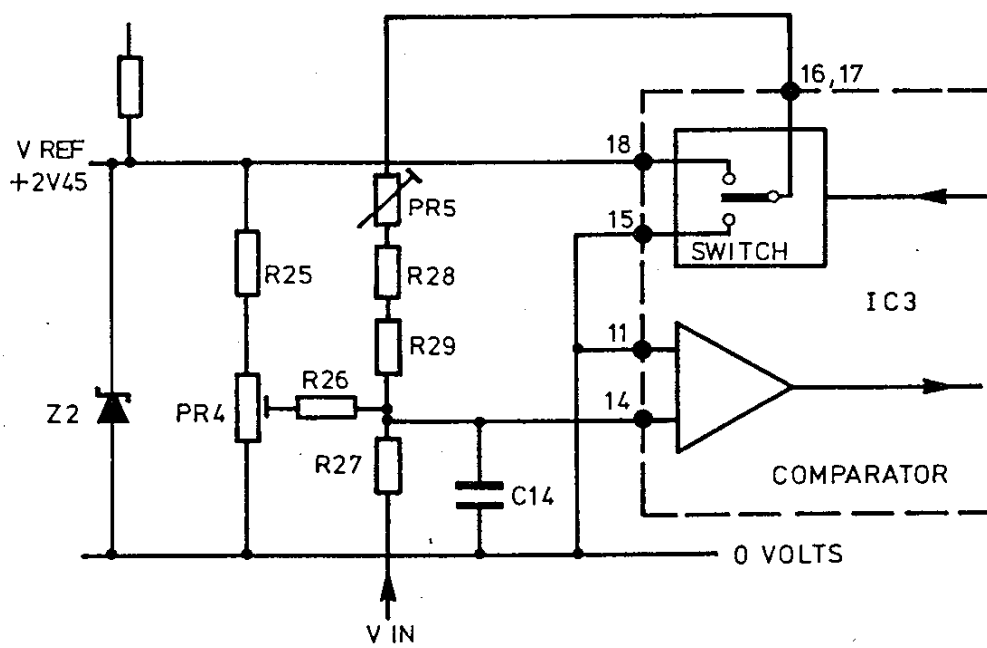
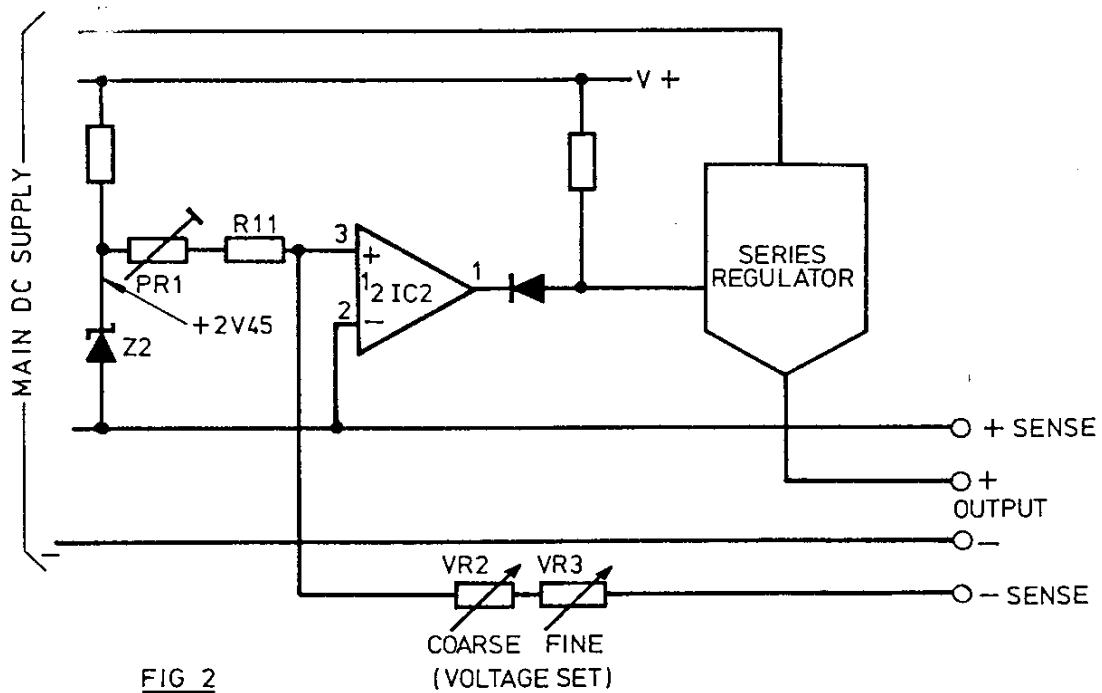
The series regulator is controlled by the 'voltage control circuit' until the output current flowing reaches the current limit setting, upon which the 'current control circuit' takes over. This circuit operates by monitoring the voltage across the current sense resistor R8. The current meter monitors either the voltage across R8 or the voltage from the current set control VR1, depending upon the state of the 'meter select circuit' which is controlled by S2.

The Main Supply

This consists of a full bridge rectifier D5 to D8 feeding the reservoir capacitor C6. The full load secondary winding voltage is 36V rms and R2 and C5 form a damping network. With nominal mains input, the voltage across C6 with no load current is about 55 Volts, falling to about 40 Volts at full load with 5 Volts pk-pk ripple (30V and 24V on PL154).



BLOCK DIAGRAM
FIG. 1



The Series Regulator

This consists of NPN Darlington Pass Transistors Q2 and Q3 driven by emitter follower Q1 which is itself driven by resistor R15. The stage is controlled by pulling the base of Q1 low via either D14 or D15.

In 2 Amp versions, Q3 is replaced by a parallel combination of four transistors with current sharing resistors.

The Auxilliary Supply

This consists of twin full wave rectified supplies from a 21 Volt centre tapped winding, D1 and D2 feeding C1 for the positive supply, and D3 and D4 feeding C2 for the negative. The positive supply V+ is a high current supply (approx. 400mA) which is series regulated by the 3 terminal regulator ICI. This is a 5 Volt regulator, but its output is raised by diode D9 to be +5.7 Volts \pm 0.2 Volts. The negative supply V- is a low current supply (approx 5mA) shunt regulated by zener diode Z1 to be -5.6 Volts \pm 0.4 Volts.

The common point of the supply is connected to the output of the main supply series regulator at point 11. This point is the Zero volt reference point for the whole circuit.

The Voltage Control Circuit

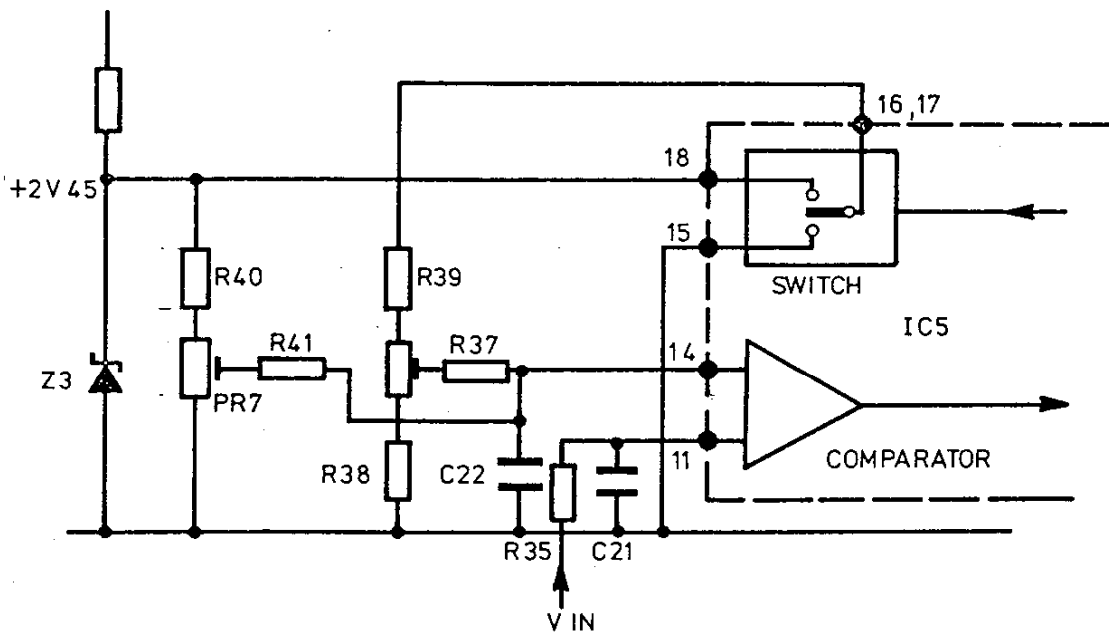
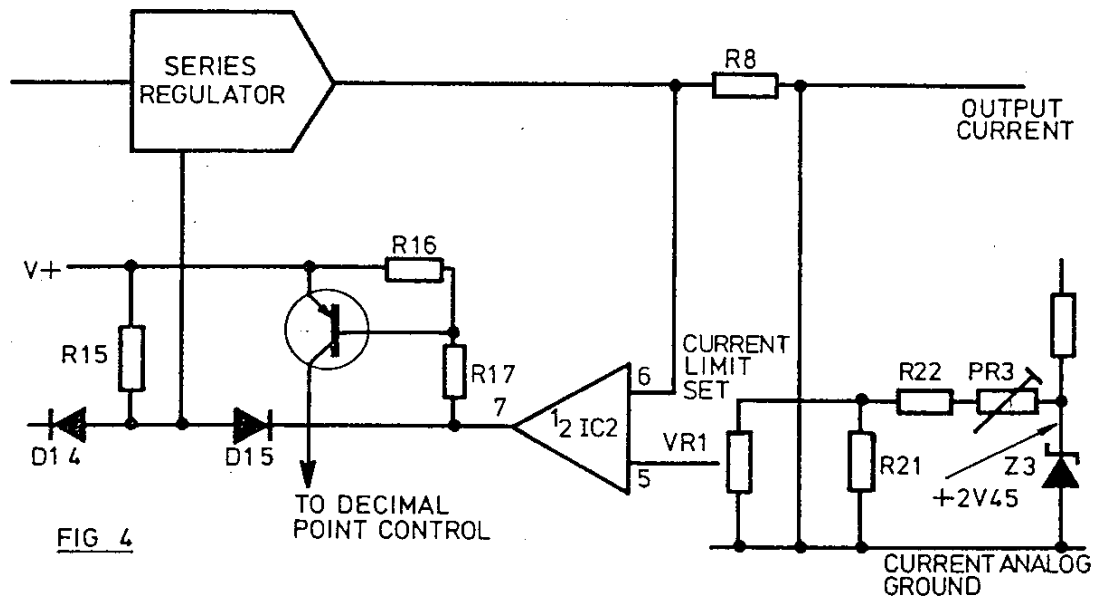
The operation of the voltage stabilisation is most easily explained in conjunction with the simplified diagram Fig 2. Voltage reference diode Z2 generates a highly stable voltage of 2.45 volts; this feeds current into the positive input of the op-amp, forcing the output up and allowing the series regulator to turn on and thus -V out to increase. It continues to increase until an equal current is being taken out via VR2 and VR3. Thus the circuit stabilises with -V out equal to $2.45 \times \frac{(VR2 + VR3)}{(PR1 + R11)}$ volts.

PR1 is set such that with VR2 + VR3 at maximum, -V out = -31 volts.

Resistors R10 and R12 produce a small offset voltage that ensures that the output can always be brought down to zero. R13, D12 and D13 limit the maximum excursion at pin 3. D16 limits the maximum negative output excursion and C11 provides HF compensation.

The Voltmeter

The voltmeter is a 3 3/4 digit (4000 count) meter using a single CMOS IC (IC3) providing direct seven segment drive to a multiplexed 4 digit LED display DS1. It is unipolar, measuring voltages from 0 to -39.99 volts with a resolution of 10mV. IC3 is run between 0 and the V+ rail, C17 and C16 are decoupling electrolytics. The circuit operates at about 4 readings per second set by the clock components C15 and R30.



The analogue subsection is shown in simplified form in Fig 3. The digital control circuitry within IC3 is triggered by the CMOS comparator and controls a switch which switches continuously between a reference voltage and ground. This reference voltage is derived from Z2, the reference diode used in the voltage control circuit. The system forms a feedback loop which maintains the voltage at pin 14 equal to that at pin 11 (ground), and IC3 counts the proportion of the total time within a conversion period that the switch connects to Vref. By making the accumulated count equal N, and the conversion period equal to 4000 counts, the conversion equation becomes:

$$\frac{N}{4000} \left(\frac{2.45}{R28 \times PR5 \times R29} \right) - \frac{V_{in}}{R27} = 0$$

Thus the displayed count is proportional to V in and can be adjusted by altering R28 (select on test) or PR5 (set full scale). PR4 is a zero set control which compensates for comparator offset voltage by feeding a small current into C14 via R26.

The display segments are driven directly by IC3, whilst the digits are driven by inverting NPN transistors Q5 to Q8. R42 limits the display current to about 200mA. The decimal point has a fixed position to the right of the second most significant digit. Since all four decimal points are connected together, the decimal point drive has to be synchronised with the appropriate digit drive; this is done by Q9.

The Current Control Circuit

The operation of the current stabilisation circuit is most easily explained in conjunction with the simplified diagram Fig 4. Reference diode Z3 provides a highly stable voltage of +2.45 volts above the Current Analogue ground (this is normally equal to 0 volts but can be higher if remote sense is being used). This voltage is potted down by PR3, R22, and R21, and applied to the positive input of the op-amp via the current control VR1. This voltage forces the op-amp output positive allowing the Series Regulator to be controlled by the Voltage Control Circuit until the output current flowing in R8 reaches a point where an equal voltage appears on the negative input, upon which the output falls turning off the series regulator and maintaining a constant current equal to $\frac{V_{in} \text{ (pin 5)}}{R8}$

When this occurs, Q4 turns on providing a signal to the current meter decimal point control circuit.

R18, R19 and PR2 provide an offset voltage null control. R20 provides a balanced source impedance, and R50 and C26 provide HF compensation.

Current Meter

The Current Meter is a 3 3/4 digit (4000 count) meter using a single CMOS IC (IC5) providing direct segment drive to a multiplexed 4 digit LED display DS2. It is unipolar, measuring voltages between 0 and +2 volts with a resolution of 0.5mV. This is converted to a resolution of 1mA by measuring across the 0.5R resistor R8. IC5 is run between 0 and the V+ rail, C18, and C19 are decoupling electrolytics. The circuit operates at about 4 readings per second set by the clock components R36 and C20.

The analogue subsection is shown in simplified form in Fig 5. The digital control circuitry within IC5 is triggered by the CMOS comparator and controls a switch which switches continuously between a reference voltage and ground. This reference voltage is derived from Z3, the reference diode used in the current control circuit. It is reduced by the potential divider R38, PR6 and R39 to produce Vref equal to 2 volts. The system forms a feedback loop which maintains the voltage at pin 14 equal to that at pin 11 (V in), and IC5 counts the proportion of the total time within a conversion period that the switch connects to the reference voltage. By making the accumulated count equal N and the conversion period equal to 4000 counts, the conversion equation becomes:-

$$\frac{N}{4000} \times V_{ref} = V_{in} \text{ or } N = 4000 \frac{V_{in}}{V_{ref}}$$

where $V_{ref} = V_{Z3} \times \frac{R38}{R38 + R39}$ (ignoring PR6)

thus the displayed count is proportional to V in and can be adjusted by altering R39 (select on test) or PR6 (set full scale).

PR7 is a zero set control which compensates for comparator offset voltage by feeding a small current into R37 via R41. R37, C22 and R23, C21 filter the inputs to the comparator.

The display segments are driven directly by IC5 whilst the digits are drive by inverting NPN transistors Q11 to Q14. R48 limits the display current to about 200mA.

Meter Select Circuit

The voltage applied to the current meter can be either the voltage generated across R8 or the voltage on the slider of VR1. This is selected by IC4 which contains an inverter and two analogue switches. The control signal for IC4 comes from Q15 which is driven on or off by the position of the DC output switch S2 via R31. Q15 also provides an output to the decimal point control circuit. With S2 'off', Q15 is on and IC4 connects the current meter to VR1 to read the current limit setting.

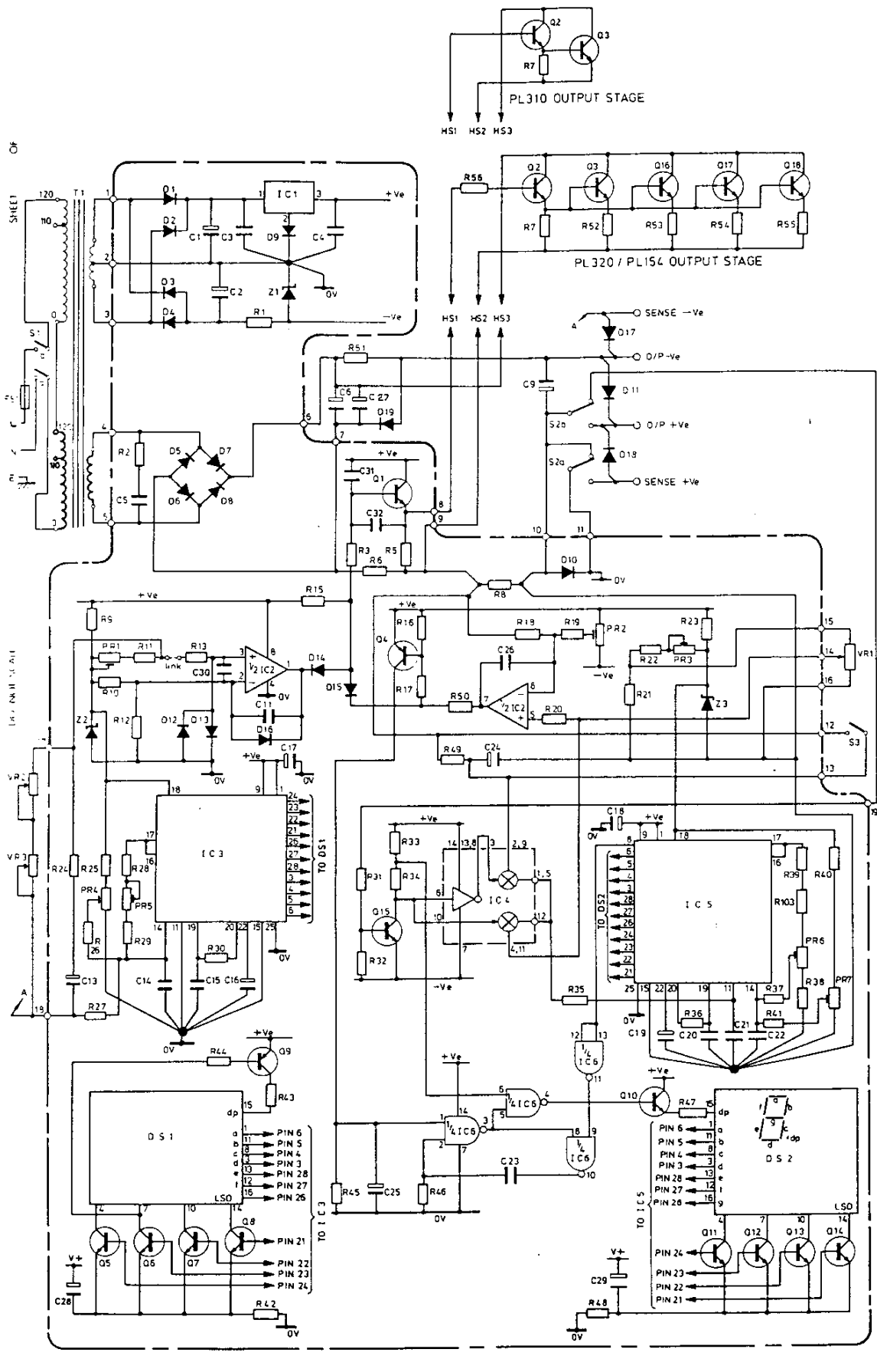
Damping Switch

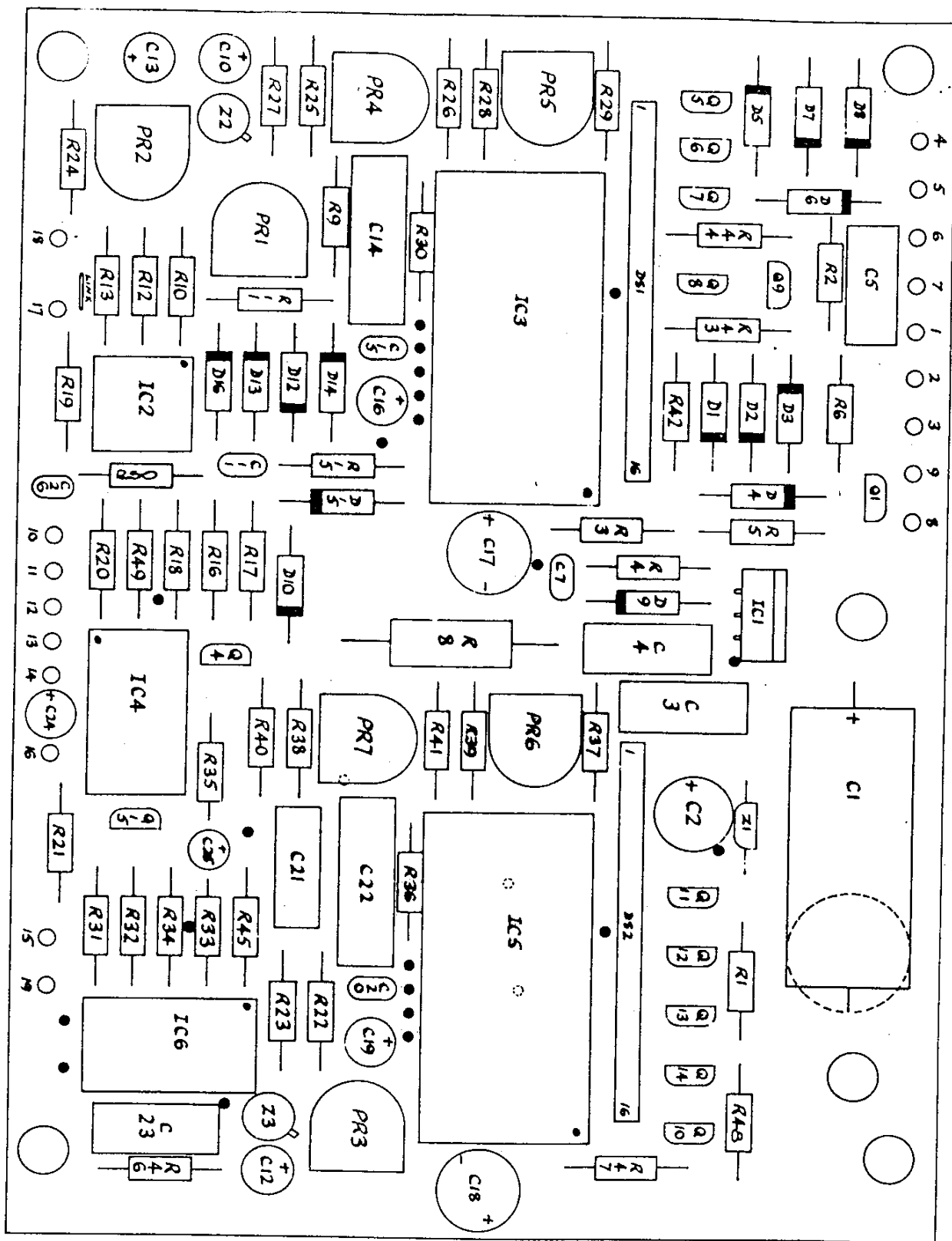
The voltage generated across R8 is applied to C24 via the damping switch S3. When this switch is 'off', the the contacts are closed and C24 has no effect, but when S3 is 'on' the contacts open and the voltage is applied to C24 via R49 producing a long time constant.

Decimal Point Control Circuit

The Current Meter decimal points are driven by IC6 via the emitter follower Q10. With the DC output switch S2 'off' a signal from Q15 turns the decimal points permanently on. With S2 'on' the decimal points turn off unless Q4 is turned on by the current control circuit operating. This causes IC6 to operate as a monostable triggered by the 'conversion complete' signal from pin 8 of IC5, and with a time constant defined by C23 and R46. This results in flashing decimal points.

Of





Quad-Mode Dual Link Unit

The Link Unit incorporates a bank of four switches which allow four modes of operation to be obtained.

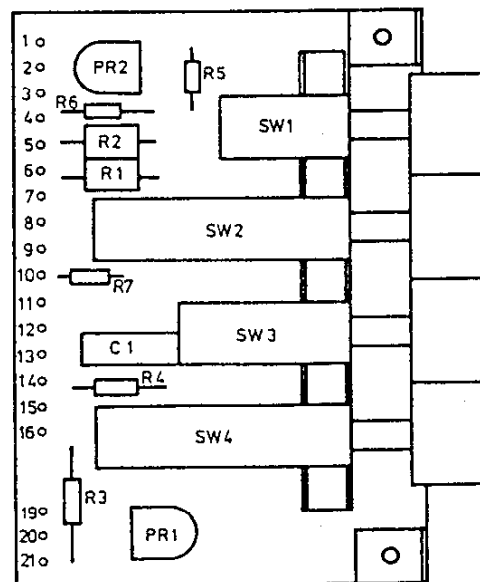
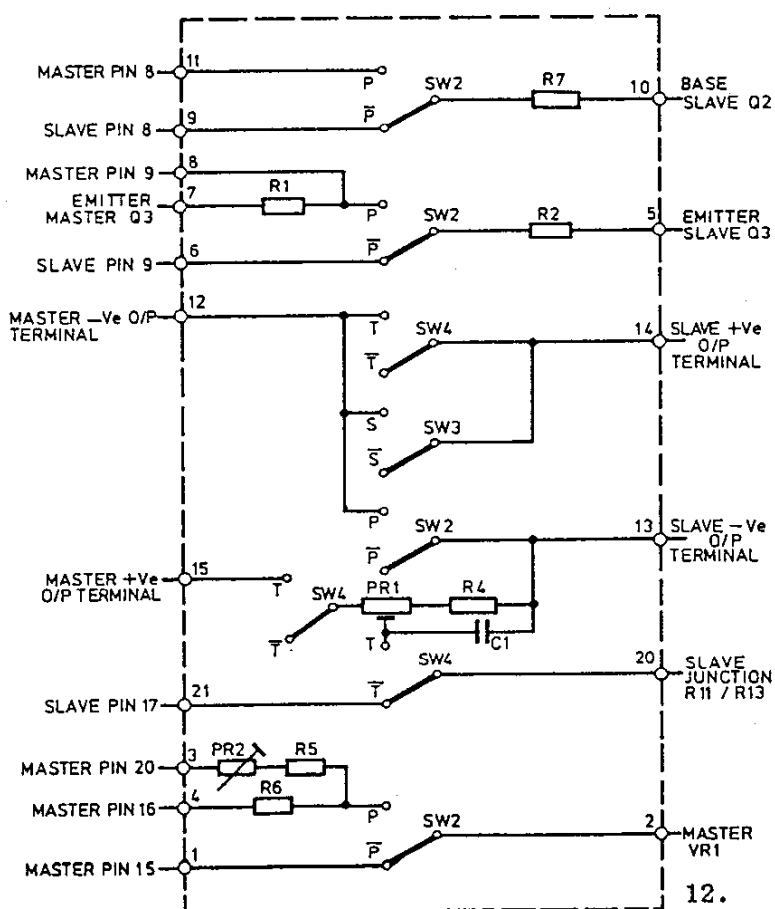
Isolated: SW1 (Release) depressed. All interconnection between the two units is removed.

Parallel: SW2 depressed. The Slave unit pass transistors are driven from Q1 on the Master PCB, and their output is combined with that of the Master unit, thus doubling its current capability. VR1 on the Master unit is disconnected from the junction of R21 and R22 and connected to a network generating twice the control voltage. The Slave unit becomes inoperative.

Series: SW2 depressed. The Slave unit positive terminal is connected to the Master unit negative terminal.

Tracking: SW4 depressed. As for Series, but additionally the +ve input to the Slave unit voltage control op-amp is disconnected from the junction of VR2 and R11 and is instead connected to a potential divider connected between Master unit +ve output and Slave unit -ve output. This maintains the voltage at the Slave +ve output (and hence the Master -ve output) equal to 1/2 of the total output voltage, thus producing tracking supplies of $\pm 30V$ controlled from VR2 and VR3 on the Master unit. VR2 and VR3 on the Slave unit become inoperative.

QUAD-MODE DUAL MODULE



CALIBRATION PROCEDURE

Re-calibration to original specification requires only the following equipment:-

- (i) A 4 1/2 digit voltmeter of accuracy $<0.05\%$ reading ± 1 digit on the 200V range.
- (ii) A 3 1/2 digit current meter of accuracy $<0.1\%$ reading ± 1 digit on the 2A range,
or
- (iii) A resistor of value known to $<0.5\%$ at 1 amp in conjunction with (i).

The unit may be re-calibrated to a lower specification using less precise equipment.

Procedure is as follows:

- (a) Connect voltmeter to output. Turn VR2 to minimum. Adjust VR3 for an output voltage of 0.02 volts. Adjust PR4 for PL voltmeter reading of 0.02V.
- (b) Turn VR2 and VR3 to maximum. Adjust PR5 for PL voltmeter reading exactly equal to V out.
- (c) Adjust PR1 for V out = 32.00 ± 10 digits. (15.50 on PL154)
- (d) Connect a 15k 5% resistor across the output Adjust PR7 for PL Current meter reading of 002mA. (001 on PL154)
- (e) Connect current meter or shunt resistor across the output. Set VR1 for 1 amp output current. Adjust PR6 for PL current meter reading exactly equal to I out.
- (f) Disconnect Load. Set VR1 to maximum. Adjust PR3 for current limit setting of 1100 ± 5 digits (PL310) or 2200 ± 10 digits (PL320) or 3.980 (PL154).
- (g) Set VR2 and VR3 to maximum. Set VR1 to minimum. Adjust PR2 such that output voltage collapses to about 10 volts.

Quad-Mode Dual Calibration

PR1 (mounted at the bottom of the PCB) adjusts the tracking accuracy when in tracking mode. Set master to 30 volts, switch both DC output switches on. Select Tracking mode and adjust PR1 for equal readings on the two voltmeters.

PR2 (mounted at the top of the PCB) adjusts the max. current limit setting when in parallel mode. Set master current limit to maximum, switch both DC output switches off, select Parallel mode, and adjust PR2 for a reading of 2200 ± 10 (PL310 Dual) or 3980 ± 20 (PL320 Dual) on the master current meter.

PL310 Electrical Parts List

All resistors are 1/4W 5% Carbon Film unless otherwise stated.

<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>	<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>
R1	560R	23180-107	R53	Not fitted	
R2	470R	23180-131	R54	Not fitted	
R3	100R	23180-204	R55	Not fitted	
R4	Not fitted		R56	Not fitted	
R5	1k	23180-148	R103	Not fitted (s/c)	
R6	2k2 1/2 W.	23182-302			
R7	100R	23180-204	PR1	1k Carbon	23376-002
R8	0.5R W/W	23274-901	PR2	100k Carbon	23376-003
R9	1k	23180-148	PR3	1k Carbon	23376-002
R10	820k	23180-171	PR4	100k Carbon	23376-003
R11	3k6 1% MF	23203-323	PR5	4k7 Cermet	23376-503
R12	3k3	23180-162	PR6	4k7 Cermet	23376-503
R13	3k3	23180-162	PR7	100k Carbon	23376-003
R14	Not fitted				
R15	1k8	23180-141			
R16	3k9	23180-101	VR1	10k Log.	23347-501
R17	2k2	23180-168	VR2	50k Lin. W/W	23357-201
R18	10k	23180-163	VR3	1k Lin.	23347-101
R19	10M	23180-129			
R20	10k	23180-163			
R21	1k 1% MF	23203-318	C1	1000uF 16V Elec.	23550-201
R22	2k7 1% MF	23203-315	C2	220uF 35V Elec.	23557-109
R23	1k	23180-148	C3	0.1uF Polyester	23620-001
R24	100R	23180-204	C4	0.1uF Polyester	23620-001
R25	560k	23180-197	C5	0.1uF Polyester	23620-001
R26	10M	23180-129	C6	2200uF 63V Elec.	23556-102
R27	2M7 1% MF	23203-343	C7	Not fitted	
R28	Select-on-test		C8	Not fitted	
R29	150k 1% MF	23203-314	C9	33uF 100V	23550-202
R30	12k	23180-157	C10	Not fitted	
R31	220k	23180-164	C11	47pF Ceramic	23427-205
R32	100k	23180-158	C12	Not fitted	
R33	100k	23180-158	C13	1uF 50V Low Leak.	23557-501
R34	100k	23180-158	C14	0.22uF Polyester	23620-002
R35	100k	23180-158	C15	100pF Ceramic	23427-200
R36	12k	23180-157	C16	10uF 16V Elec.	23557-114
R37	100k	23180-158	C17	470uF 10V Elec.	23557-115
R38	100k 1% MF	23203-328	C18	470uF 10V Elec.	23557-115
R39	Select-on-test		C19	10uF 16V Elec.	23557-114
R40	220k	23180-164	C20	100pF Ceramic	23427-200
R41	10M	23180-129	C21	0.22uF Polyester	23620-002
R42	10R 1/2W	23182-303	C22	0.22uF Polyester	23620-002
R43	47R	23180-153	C23	0.1uF Polyester	23620-001
R44	1k	23180-148	C24	10uF 16V Elec.	23557-114
R45	220k	23180-164	C25	2u2 63V Elec.	23557-116
R46	2M2	23180-177	C26	47pF Ceramic	23427-205
R47	10R	23180-138	C27	Not fitted	
R48	10R 1/2W	23182-303	C28	Not fitted	
R49	100k	23180-158	C29	Not fitted	
R50	470R	23180-131	C30	Not fitted	
R51	Not fitted (s/c)		C31	Not fitted	
R52	Not fitted		C32	Not fitted	

PL310 Electrical Parts List - Continued

<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>	<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>
D1	1N4003	25115-001	IC1	LM340-T-5	27160-003
D2	1N4003	25115-001	IC2	LM358	27106-002
D3	1N4003	25115-001	IC3	ADD3701	27153-703
D4	1N4003	25115-001	IC4	CD4007	27164-506
D5	1N4003	25115-001	IC5	ADD3701	27153-703
D6	1N4003	25115-001	IC6	CD4011	27203-001
D7	1N4003	25115-001			
D8	1N4003	25115-001			
D9	1N4148	25021-001	DS1	4 Dig. Display	25061-503
D10	1N4003	25115-001	DS2	4 Dig. Display	25061-503
D11	1N4003	25115-001			
D12	1N4148	25021-001			
D13	1N4148	25021-001	PL310Dual PCB Parts List		
D14	1N4148	25021-001	R1	0.47R 1/2W MF	23215-302
D15	1N4148	25021-001	R2	0.47R 1/2W MF	23215-302
D16	1N4148	25021-001	R3	100k 1% MF	23203-328
D17	1N4003	25115-001	R4	100k 1% MF	23203-328
D18	1N4003	25115-001	R5	2k7	23180-113
D19	Not fitted		R6	3k3	23180-162
			R7	22R	23180-160
Z1	5V6 Zener	25130-207	PR1	4k7 Cermet	23376-503
Z2	ZN404	27161-801	PR2	1k Carbon	23376-002
Z3	ZN404	27161-801	C1	0.22uF Polyester	23620-002
Q1	ZTX450	25383-401			
Q2	2N3055	25386-201			
Q3	2N3055	25386-201			
Q4	ZTX214	25341-200			
Q5	ZTX450	25383-401			
Q6	ZTX450	25383-401			
Q7	ZTX450	25383-401			
Q8	ZTX450	25383-401			
Q9	ZTX214	25341-200			
Q10	ZTX450	25383-401			
Q11	ZTX450	25383-401			
Q12	ZTX450	25383-401			
Q13	ZTX450	25383-401			
Q14	ZTX450	25383-401			
Q15	ZTX450	25383-401			

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PL320 Electrical Parts List

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Ref.	Description	Part No.	Ref.	Description	Part No.
R1	560R	23180-107	R53	1R 1/2W MF	23215-303
R2	470R	23180-131	R54	1R 1/2W MF	23215-303
R3	100R	23180-204	R55	1R 1/2W MF	23215-303
R4	Not fitted		R56	22R	23180-160
R5	1k	23180-148	R103	Not fitted (s/c)	
R6	2k2 1/2 W.	23182-302			
R7	47R	23180-153	PR1	1k Carbon	23376-002
R8	0.5R W/W	23274-901	PR2	100k Carbon	23376-003
R9	1k	23180-148	PR3	1k Carbon	23376-002
R10	820k	23180-171	PR4	100k Carbon	23376-003
R11	3k6 1% MF	23203-323	PR5	4k7 Cermet	23376-503
R12	3k3	23180-162	PR6	4k7 Cermet	23376-503
R13	3k3	23180-162	PR7	100k Carbon	23376-003
R14	Not fitted				
R15	1k8	23180-141			
R16	3k9	23180-101	VR1	10k Log.	23347-501
R17	2k2	23180-168	VR2	50k Lin. W/W	23357-201
R18	10k	23180-163	VR3	1k Lin.	23347-101
R19	10M	23180-129			
R20	10k	23180-163			
R21	3k3	23180-162	C1	1000uF 16V Elec.	23550-201
R22	2k7 1% MF	23203-315	C2	220uF 35V Elec.	23557-109
R23	1k	23180-148	C3	0.1uF Polyester	23620-001
R24	100R	23180-204	C4	0.1uF Polyester	23620-001
R25	560k	23180-197	C5	0.1uF Polyester	23620-001
R26	10M	23180-129	C6	2200uF 63V Elec.	23556-102
R27	2M7 1% MF	23203-343	C7	Not fitted	
R28	Select-on-test		C8	Not fitted	
R29	150k 1% MF	23203-314	C9	33uF 100V	23550-202
R30	12k	23180-157	C10	Not fitted	
R31	220k	23180-164	C11	47pF Ceramic	23427-205
R32	100k	23180-158	C12	Not fitted	
R33	100k	23180-158	C13	1uF 50V Low Leak.	23557-501
R34	100k	23180-158	C14	0.22uF Polyester	23620-002
R35	100k	23180-158	C15	100pF Ceramic	23427-200
R36	12k	23180-157	C16	10uF 16V Elec.	23557-114
R37	100k	23180-158	C17	470uF 10V Elec.	23557-115
R38	100k 1% MF	23203-328	C18	470uF 10V Elec.	23557-115
R39	Select-on-test		C19	10uF 16V Elec.	23557-114
R40	220k	23180-164	C20	100pF Ceramic	23427-200
R41	10M	23180-129	C21	0.22uF Polyester	23620-002
R42	10R 1/2W	23182-303	C22	0.22uF Polyester	23620-002
R43	47R	23180-153	C23	0.1uF Polyester	23620-001
R44	1k	23180-148	C24	10uF 16V Elec.	23557-114
R45	220k	23180-164	C25	2u2 63V Elec.	23557-116
R46	2M2	23180-177	C26	47pF Ceramic	23427-205
R47	10R	23180-138	C27	2200uF 63V Elec	23556-102
R48	10R 1/2W	23182-303	C28	Not fitted	
R49	100k	23180-158	C29	Not fitted	
R50	470R	23180-131	C30	Not fitted	
R51	10k 1W CF	23183-101	C31	Not fitted	
R52	1R 1/2W MF	23215-303	C32	Not fitted	

PL320 Electrical Parts List - Continued

<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>	<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>
D1	1N4003	25115-001	IC1	LM340-T-5	27160-003
D2	1N4003	25115-001	IC2	LM358	27106-002
D3	1N4003	25115-001	IC3	ADD3701	27153-703
D4	1N4003	25115-001	IC4	CD4007	27164-506
D5	1N5401	25115-003	IC5	ADD3701	27153-703
D6	1N5401	25115-003	IC6	CD4011	27203-001
D7	1N5401	25115-003			
D8	1N5401	25115-003			
D9	1N4148	25021-001	DS1	4 Dig. Display	25061-503
D10	1N4003	25115-001	DS2	4 Dig. Display	25061-503
D11	1N4003	25115-001			
D12	1N4148	25021-001			
D13	1N4148	25021-001			
D14	1N4148	25021-001			
D15	1N4148	25021-001			
D16	1N4148	25021-001			
D17	1N4003	25115-001			
D18	1N4003	25115-001			
D19	1N5401	25115-003			
Z1	5V6 Zener	25130-207			
Z2	ZN404	27161-801			
Z3	ZN404	27161-801			

PL320Dual PCB Parts List

R1	0.27R W/W	23274-002
R2	0.27R W/W	23274-002
R3	100k 1% MF	23203-328
R4	100k 1% MF	23203-328
R5	470R	23180-131
R6	6k8	23180-180
R7	22R	23180-160
PR1	4k7 Cermet	23376-503
PR2	1k Carbon	23376-002
C1	0.22uF Polyester	23620-002

Q1	ZTX450	25383-401
Q2	TIP31A	25386-300
Q3	2N3055	25386-201
Q4	ZTX214	25341-200
Q5	ZTX450	25383-401
Q6	ZTX450	25383-401
Q7	ZTX450	25383-401
Q8	ZTX450	25383-401
Q9	ZTX214	25341-200
Q10	ZTX450	25383-401
Q11	ZTX450	25383-401
Q12	ZTX450	25383-401
Q13	ZTX450	25383-401
Q14	ZTX450	25383-401
Q15	ZTX450	25383-401
Q16	2N3055	25386-201
Q17	2N3055	25386-201
Q18	2N3055	25386-201

PL154 Electrical Parts List

All resistors are 1/4W 5% Carbon Film unless otherwise stated.

Ref.	Description	Part No.	Ref.	Description	Part No.
R1	560R	23180-107	R53	0.47R 1/2W MF	23215-302
R2	Not fitted		R54	0.47R 1/2W MF	23215-302
R3	100R	23180-204	R55	0.47R 1/2W MF	23215-302
R4	Not fitted		R56	22R	23180-160
R5	1k	23180-148	R103	Select-on-test	
R6	680R 1/2 W.	23182-306			
R7	47R	23180-153	PR1	1k Carbon	23376-002
R8	0R1 Bulk Metal	23315-003	PR2	100k Carbon	23376-003
R9	1k	23180-148	PR3	1k Carbon	23376-002
R10	820k	23180-171	PR4	100k Carbon	23376-003
R11	7k15 1% MF	23203-370	PR5	4k7 Cermet	23376-503
R12	3k3	23180-162	PR6	4k7 Cermet	23376-503
R13	3k3	23180-162	PR7	100k Carbon	23376-003
R14	Not fitted				
R15	1k8	23180-141			
R16	10k	23180-163	VR1	10k Log.	23347-501
R17	22k	23180-114	VR2	50k Lin. W/W	23357-201
R18	10k	23180-163	VR3	1k Lin.	23347-101
R19	10M	23180-129			
R20	10k	23180-163			
R21	680R	23180-124	C1	1000uF 16V Elec.	23550-201
R22	2k7 1% MF	23203-315	C2	220uF 35V Elec.	23557-109
R23	1k	23180-148	C3	0.1uF Polyester	23620-001
R24	100R	23180-204	C4	0.1uF Polyester	23620-001
R25	560k	23180-197	C5	Not fitted	
R26	10M	23180-129	C6	10000uF 40V Elec	23556-103
R27	2M7 1% MF	23203-343	C7	Not fitted	
R28	Select-on-test		C8	Not fitted	
R29	150k 1% MF	23203-314	C9	100uF 40V	23550-202
R30	12k	23180-157	C10	Not fitted	
R31	220k	23180-164	C11	47pF Ceramic	23427-205
R32	100k	23180-158	C12	Not fitted	
R33	100k	23180-158	C13	1uF 50V Low Leak.	23557-501
R34	100k	23180-158	C14	0.22uF Polyester	23620-002
R35	100k	23180-158	C15	100pF Ceramic	23427-200
R36	12k	23180-157	C16	10uF 16V Elec.	23557-114
R37	22k	23180-114	C17	220uF 10V Elec.	23557-111
R38	100k 1% MF	23203-328	C18	220uF 10V Elec.	23557-111
R39	Select-on-test		C19	10uF 16V Elec.	23557-114
R40	220k	23180-164	C20	100pF Ceramic	23427-200
R41	10M	23180-129	C21	0.22uF Polyester	23620-002
R42	12R 1/2W	23182-305	C22	0.22uF Polyester	23620-002
R43	47R	23180-153	C23	0.1uF Polyester	23620-001
R44	1k	23180-148	C24	10uF 16V Elec.	23557-114
R45	220k	23180-164	C25	2u2 63V Elec.	23557-116
R46	2M2	23180-177	C26	47pF Ceramic	23427-205
R47	10R	23180-138	C27	Not fitted	
R48	12R 1/2W	23182-305	C28	100uF 10V Elec.	23557-100
R49	100k	23180-158	C29	100uF 10V Elec.	23557-100
R50	470R	23180-131	C30	Not fitted	
R51	Not fitted		C31	Not fitted	
R52	0.47 1/2W MF	23215-302	C32	Not fitted	

PL154 Electrical Parts List - Continued

<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>	<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>
D1	1N4003	25115-001	IC1	LM340-T-5	27160-003
D2	1N4003	25115-001	IC2	LM358	27106-002
D3	1N4003	25115-001	IC3	ADD3701	27153-703
D4	1N4003	25115-001	IC4	CD4007	27164-506
D5)		IC5	ADD3701	27153-703
D6)Bridge		IC6	CD4011	27203-001
D7)Rectifier	25211-401			
D8)				
D9	1N4148	25021-001	DS1	4 Dig. Display	25061-503
D10	1N4003	25115-001	DS2	4 Dig. Display	25061-503
D11	1N4003	25115-001			
D12	1N4148	25021-001			
D13	1N4148	25021-001			
D14	1N4148	25021-001			
D15	1N4148	25021-001			
D16	1N4148	25021-001			
D17	1N4003	25115-001			
D18	1N4003	25115-001			
D19	Not Fitted				
Z1	5V6 Zener	25130-207			
Z2	ZN404	27161-801			
Z3	ZN404	27161-801			
Q1	ZTX450	25383-401			
Q2	TIP31A	25386-300			
Q3	2N3055	25386-201			
Q4	ZTX214	25341-200			
Q5	ZTX450	25383-401			
Q6	ZTX450	25383-401			
Q7	ZTX450	25383-401			
Q8	ZTX450	25383-401			
Q9	ZTX214	25341-200			
Q10	ZTX239	25380-251			
Q11	ZTX450	25383-401			
Q12	ZTX450	25383-401			
Q13	ZTX450	25383-401			
Q14	ZTX450	25383-401			
Q15	ZTX239	25380-251			
Q16	2N3055	25386-201			
Q17	2N3055	25386-201			
Q18	2N3055	25386-201			

K MODULE - INTRODUCTION

The PL310K and PL320K are triple output supplies which consist of a standard PL310 or PL320 linked with a K1 or K2 module respectively.

The K module incorporates two separate outputs, a fully variable 0 to 30 volt output and a high current 4 to 6 volt output with overvoltage crowbar and remote sense. Both supplies are isolated and floating.

The 30 volt supply has no metering and a fixed current limit of 0.55A (K1) or 1.1A (K2). A switch enables the output either to be set independently via a calibrated knob, or to become a series tracking slave to the PL310/320.

The 5 volt supply has a digital current meter and a fixed current limit of 3.65 amps (K1) or 7.3 amps (K2) with a foldback characteristic. A user adjustable dual speed overvoltage crowbar is incorporated.

CIRCUIT DESCRIPTION

5 Volt Section

All the supplies for this section are generated by a single 11 volt winding. The main supply is from bridge rectifier BR1 into reservoir capacitor C3. Diodes D1 and D2 provide an equal positive supply which is not loaded by the output. C1, D3, D4, C4, form a voltage doubler which is stabilised to -5.6 volts by Z1. A stabilised rail of +5.7 volts is generated by IC1 and D6 from the main supply.

The series regulator TR9, TR10, TR11 is placed in the positive side of the mains supply, and is driven by TR8 from R39.

Voltage control amplifier IC2a sets the output voltage equal to

$$\frac{R32 + R28}{R28}$$

times the voltage on the slider of VR1. This voltage is derived from the reference diode Z3. IC2c is a ground line buffer which keeps the negative sense terminal high impedance.

When the output current exceeds the level set by PR2 to be approximately

$$\frac{R16}{R15 + R16} \times \frac{2.45}{R17}$$

of the series regulator via D8. TR7 provides a foldback characteristic to the current limit if the output voltage falls below 4 volts.

When pin 1 of IC2b goes low TR6 turns on causing the astable oscillator TR1, TR2 to flash the current meter decimal points via TR5.

IC2d senses the output voltage via PR5, and if it exceeds the preset threshold, turns on the thyristor TH1 via D9. The operation of this circuit is delayed by C9 to avoid triggering by transient spikes. If the output approaches 10 Volts, however, TR1 is turned on instantaneously via Z4. When TH1 is on, TR4 is turned on, causing permanent illumination of the current meter decimal points via TR5 to indicate that the output has been crowbarred. The supply must be turned off, or the output short circuited, to reset this circuit.

The output current flowing through R17 is measured, and displayed by IC3. The operation of this circuit is identical to that for the PL310/320 current meter.

30 Volt Section

The operation of this section is very similar to the standard PL310/320 supply.

The main supply is generated by a 36 Volt winding into bridge rectifier D102 to 105 and reservoir capacitor C103. The Series regulator TR102 to TR104 is placed in the positive side.

The auxilliary supply is generated by a 36 Volt winding into D101 and C102 and is split into +10 Volts and -5.6 Volts by zener diodes Z101 and Z102. The centre point of this supply is connected to the output positive terminal. Diode Z103 provides a reference voltage both for the voltage control amplifier IC101a and the current control amplifier IC101b.

In 'isolated' mode the wire-wound variable resistor VR101 sets the output voltage equal to $5V6 \times \frac{VR101}{R105 + R101}$ and controls the output via D107.

In 'Tracking' mode, the positive input of IC101a is disconnected from VR101 and connected to the slider of PR103. At the same time the positive output terminal becomes linked to the negative output terminal of the PL310/320 supply. Since R116 and R117 are equal this causes the output voltage to become equal to that set on the 'Master' supply.

When the output current exceeds the level set by PR102 to be approximately $\frac{R107}{R105 \times R107} \times \frac{5V6}{R115}$, IC101b controls the output via D108. Thus the supply

automatically into constant current mode. As pin 1 of IC101b goes low it turns off TR101 and allows the LED LD101 to come on, thus indicating an overload condition.

FOR SERVICE MANUALS
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K1 Module Calibration Procedure

5V Section

1. Set voltage control to maximum. Adjust PR1 for an output voltage of $6.000V \pm 0.004V$. Set output to 5.000V and check that the knob pointer lines up with the 5V marker. Slacken grub screw and reposition if necessary.
2. Connect a 4k7 resistor across the output terminals and adjust PR3 for a current meter reading of 001mA.
3. Load the unit to 3.5A, monitor the output current with a multimeter and adjust PR4 for a current meter reading equal to the output current.
4. Increase the load until current limit is reached and check that limit current is 3650mA. Adjust PR2 if necessary.

30V Section

1. Set mode switch to isolated. Set voltage control to maximum. Adjust PR101 for an output of $30.00 \pm 0.10V$. Set output voltage to 15.00V and check that the knob pointer lines up with the 15V marker. Slacken grub screw and reposition if necessary.
2. Monitoring the load current, load the output until the current limit LED comes on. Check that the current limits at 550mA, adjust PR102 if necessary.
3. Set PL310 output voltage to 30.00 and switch on output switch. Set K1 30V output to maximum and switch to tracking mode.
5. Adjust PR103 for an output voltage of 30.00V.

K2 Module Calibration Procedure

5V Section

1. Set voltage control to maximum. Adjust PR1 for an output voltage of $6.000V \pm 0.004V$. Set output to 5.000V and check that the knob pointer lines up with the 5V marker. Slacken grub screw and reposition if necessary.
2. Connect a 470R resistor across the output terminals and adjust PR3 for a current meter reading of .01A.
3. Load the unit to 7.0A, monitor the output current with a multimeter and adjust PR4 for a current meter reading equal to the output current.
4. Increase the load until current limit is reached and check that limit current is 7.35A. Adjust PR2 if necessary.

30V Section

1. Set mode switch to isolated. Set voltage control to maximum. Adjust PR101 for an output of $30.00 \pm 0.10V$. Set output voltage to 15.00V and check that the knob pointer lines up with the 15V marker. Slacken grub screw and reposition if necessary.
2. Monitoring the load current, load the output until the current limit LED comes on. Check that the current limits at 1100A, adjust PR102 if necessary.
3. Set PL320 output voltage to 30.00 and switch on output switch. Set K2 30V output to maximum and switch to tracking mode.
5. Adjust PR103 for an output voltage of 30.00V.

K1 Module Electrical Parts List

All resistors are 1/4W 5% Carbon Film unless otherwise stated.

<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>	<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>
R1	3k3	23180-162	R51	Not fitted	
R2	150k	23180-144	R52	Not fitted	
R3	560k	23180-197	R53	100k	23180-158
R4	3k3	23180-162	R54	Not fitted	
R5	330R	23180-112	R101	680R	23180-124
R6	3k3	23180-162	R102	2k7	23180-113
R7	3k3	23180-162	R103	4k7	23180-194
R8	Not fitted		R104	1k	23180-148
R9	5k6	23180-142	R105	6k8 1% MF	23203-304
R10	47R	23180-153	R106	47k	23180-181
R11	10k	23180-163	R107	2k0	23180-206
R12	10k	23180-163	R108	3k3	23180-162
R13	680R	23180-124	R109	5k6	23180-142
R14	680R	23180-124	R110	10k	23180-163
R15	3k0 1% MF	23203-359	R111	470R	23180-131
R16	3k0 1% MF	23203-359	R112	1k8	23180-141
R17	0.68R 2.5W W/W	23274-003	R113	Not fitted	
R18	0.68R 2.5W W/W	23274-003	R114	47R	23180-153
R19	1k 1% MF	23203-318	R115	0.47R 1/2W MF	23215-302
R20	2k0 1% MF	23203-302	R116	470k 1% MF	23203-340
R21	47k	23180-181	R117	470k 1% MF	23203-340
R22	100k	23180-158	R118	Not fitted	
R23	10k	23180-163	R119	Not fitted	
R24	100k	23180-158	R120	Not fitted	
R25	100k	23180-158			
R26	10k	23180-163			
R27	5k6	23180-142	PR1	500R Carbon	23376-006
R28	11k 1% MF	23203-306	PR2	1k Carbon	23376-002
R29	1M	23180-137	PR3	100k Carbon	23376-003
R30	3k3	23180-162	PR4	4k7 Cermet	23376-503
R31	1k8	23180-141	PR5	100k Carbon	23376-301
R32	18k 1% MF	23203-324			
R33	100k	23180-158			
R34	68k 1% MF	23203-344	PR101	5k Carbon	23376-010
R35	Select-on-test		PR102	1k Carbon	23376-002
R36	62k 1% MF	23203-320	PR103	25k Carbon	23376-011
R37	150k	23180-144			
R38	10M	23180-129			
R39	4k7	23180-194	VR1	50k Lin. W/W	23357-201
R40	12k	23180-157	VR101	50k Lin. W/W	23357-201
R41	1k	23180-148			
R42	47R	23180-153			
R43	680R	23180-124			
R44	220k	23180-164			
R45	120k	23180-103			
R46	3k3	23180-162			
R47	10R 1/2W	23182-303			
R48	100R 1/2W	23182-301			
R49	470R	23180-131			
R50	470R	23180-131			

K1 Module Electrical Parts List - continued

All resistors are 1/4W 5% Carbon Film unless otherwise stated.

<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>	<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>
C1	47uF 25V Elec.	23557-112	Z1	5V6 Zener	25130-207
C2	100uF 25V Elec.	23557-108	Z2	ZN404	27161-801
C3	10000uF 40V Elec.	23556-103	Z3	ZN404	27161-801
C4	220uF 16V Elec.	23557-102	Z4	10V Zener	25130-200
C5	47uF 10V Elec.	23557-110	Z101	10V Zener	25130-200
C6	1uF 63V Elec.	23557-103	Z102	5V6 Zener	25130-207
C7	1uF 63V Elec.	23557-103	Z103	5V6 Zener	25130-207
C8	2u2 63V Elec.	23557-116			
C9	1uF 63V Elec.	23557-103			
C10	10uF 16V Elec.	23557-114	TR1	ZTX239	25380-251
C11	1nF Ceramic	23427-203	TR2	ZTX239	25380-251
C12	1uF 63V Elec.	23557-103	TR3	ZTX239	25380-251
C13	0.22uF Polyester	23620-002	TR4	ZTX239	25380-251
C14	0.1uF Polyester	23620-001	TR5	ZTX214	25341-200
C15	10uF 16V Elec.	23557-114	TR6	ZTX214	25341-200
C16	1uF 63V Elec.	23557-103	TR7	ZTX214	25341-200
C17	220uF 10V Elec.	23557-111	TR8	ZTX450	26383-401
C18	100pF Ceramic	23427-200	TR9	TIP31A	25386-300
C19	0.1uF Polyester	23620-001	TR10	2N3055	25386-201
C20	1uF 63V Elec.	23557-103	TR11	ZTX450	25383-401
C21	100uF 25V	23550-203	TR12	ZTX450	25383-401
C22	Not fitted		TR13	ZTX450	25383-401
C101	0.1uF Polyester	23620-001	TR14	ZTX450	25383-401
C102	100uF 40V Elec.	23557-105	TR15	Not fitted	
C103	1000uF 63V Elec.	23556-101	TR101	ZTX239	25380-251
C104	2u2 63V Elec.	23557-116	TR102	TIP31A	25386-300
C105	0.22uF Polyester	23620-002	TR103	Not fitted	
C106	Not fitted		TR104	2N3055	25386-201
C107	47pF Ceramic	23427-205			
C108	33uF 100V Elec.	23550-202	BR1	KBL02	25211-301
			TH1	TAG666-100	25801-501
D1	1N4003	25115-001	IC1	LM340T-5	27160-003
D2	1N4003	25115-001	IC2	LM324N	27106-001
D3	1N4003	25115-001	IC3	ADD3701	27153-703
D4	1N4003	25115-001	IC101	LM358N	27106-002
D5	1N4148	25021-001			
D6	1N4148	25021-001	DS1	4 Dig. Display	25061-503
D7	1N4148	25021-001	LD101	LED	25061-101
D8	1N4148	25021-001			
D9	1N4148	25021-001			
D10	1N4003	25115-001			
D101	1N4003	25115-001			
D102	1N4003	25115-001			
D103	1N4003	25115-001			
D104	1N4003	25115-001			
D105	1N4003	25115-001			
D106	1N4148	25021-001			
D107	1N4148	25021-001			
D108	1N4148	25021-001			
D109	1N4003	25115-001			

K2 Module Electrical Parts List

All resistors are 1/4W 5% Carbon Film unless otherwise stated.

<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>	<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>
R1	3k3	23180-162	R51	Not fitted	
R2	150k	23180-144	R52	0.22R W/W	23274-001
R3	560k	23180-197	R53	100k	23180-158
R4	3k3	23180-162	R54	220R	23180-139
R5	330R	23180-112	R101	680R	23180-124
R6	3k3	23180-162	R102	2k7	23180-113
R7	3k3	23180-162	R103	4k7	23180-194
R8	3k3	23180-162	R104	1k	23180-148
R9	5k6	23180-142	R105	6k8 1% MF	23203-304
R10	47R	23180-153	R106	56k	23180-170
R11	10k	23180-163	R107	2k0	23180-206
R12	10k	23180-163	R108	3k3	23180-162
R13	680R	23180-124	R109	5k6	23180-142
R14	680R	23180-124	R110	10k	23180-163
R15	30k 1% MF	23203-367	R111	470R	23180-131
R16	3k0 1% MF	23203-359	R112	1k8	23180-141
R17	R068 Bulk Metal	23315-002	R113	47R	23180-153
R18	R068 Bulk Metal	23315-002	R114	1R2 1/2W MF	23215-304
R19	1k 1% MF	23203-318	R115	0.22R 1/2W MF	23215-301
R20	2k0 1% MF	23203-302	R116	470k 1% MF	23203-340
R21	47k	23180-181	R117	470k 1% MF	23203-340
R22	100k	23180-158	R118	18k	23180-201
R23	1k8	23180-141	R119	Not fitted	
R24	100k	23180-158	R120	330R	23180-130
R25	100k	23180-158			
R26	10k	23180-163			
R27	5k6	23180-142	PR1	500R Carbon	23376-006
R28	11k 1% MF	23203-306	PR2	1k Carbon	23376-002
R29	1M	23180-137	PR3	100k Carbon	23376-003
R30	3k3	23180-162	PR4	4k7 Cermet	23376-503
R31	1k8	23180-141	PR5	100k Carbon	23376-301
R32	18k 1% MF	23203-324			
R33	100k	23180-158			
R34	68k 1% MF	23203-344	PR101	5k Carbon	23376-010
R35	Select-on-test		PR102	1k Carbon	23376-002
R36	62k 1% MF	23203-320	PR103	25k Carbon	23376-011
R37	150k	23180-144			
R38	10M	23180-129			
R39	4k7	23180-194	VR1	50k Lin. W/W	23357-201
R40	12k	23180-157	VR101	50k Lin. W/W	23357-201
R41	1k	23180-148			
R42	47R	23180-153			
R43	680R	23180-124			
R44	220k	23180-164			
R45	120k	23180-103			
R46	3k3	23180-162			
R47	10R 1/2W	23182-303			
R48	100R 1/2W	23182-301			
R49	470R	23180-131			
R50	470R	23180-131			

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K2 Module Electrical Parts List - continued

All resistors are 1/4W 5% Carbon Film unless otherwise stated.

<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>	<u>Ref.</u>	<u>Description</u>	<u>Part No.</u>
C1	47uF 25V Elec.	23557-112	Z1	5V6 Zener	25130-207
C2	100uF 25V Elec.	23557-108	Z2	ZN404	27161-801
C3	10000uF 40V Elec.	23556-103	Z3	ZN404	27161-801
C4	220uF 16V Elec.	23557-102	Z4	10V Zener	25130-200
C5	47uF 10V Elec.	23557-110	Z101	10V Zener	25130-200
C6	1uF 63V Elec.	23557-103	Z102	5V6 Zener	25130-207
C7	1uF 63V Elec.	23557-103	Z103	5V6 Zener	25130-207
C8	2u2 63V Elec.	23557-116			
C9	1uF 63V Elec.	23557-103			
C10	10uF 16V Elec.	23557-114	TR1	ZTX239	25380-251
C11	1nF Ceramic	23427-203	TR2	ZTX239	25380-251
C12	1uF 63V Elec.	23557-103	TR3	ZTX239	25380-251
C13	0.22uF Polyester	23620-002	TR4	ZTX239	25380-251
C14	0.1uF Polyester	23620-001	TR5	ZTX214	25341-200
C15	10uF 16V Elec.	23557-114	TR6	ZTX214	25341-200
C16	1uF 63V Elec.	23557-103	TR7	ZTX214	25341-200
C17	220uF 10V Elec.	23557-111	TR8	ZTX450	26383-401
C18	100pF Ceramic	23427-200	TR9	TIP31A	25386-300
C19	0.1uF Polyester	23620-001	TR10	2N3055	25386-201
C20	1uF 63V Elec.	23557-103	TR11	ZTX450	25383-401
C21	100uF 25V	23550-203	TR12	ZTX450	25383-401
C22	10000uF 40V	23556-103	TR13	ZTX450	25383-401
C101	0.1uF Polyester	23620-001	TR14	ZTX450	25383-401
C102	100uF 40V Elec.	23557-105	TR15	2N3055	25386-200
C103	2200uF 63V Elec.	23556-102	TR101	ZTX239	25380-251
C104	2u2 63V Elec.	23557-116	TR102	TIP31A	25386-300
C105	0.22uF Polyester	23620-002	TR103	2N3055	25386-200
C106	Not fitted		TR104	2N3055	25386-201
C107	47pF Ceramic	23427-205			
C108	33uF 100V Elec.	23550-202	BR1	26MB5A	25211-401
			TH1	TAG666-100	25801-501
D1	1N4003	25115-001	IC1	LM340T-5	27160-003
D2	1N4003	25115-001	IC2	LM324N	27106-001
D3	1N4003	25115-001	IC3	ADD3701	27153-703
D4	1N4003	25115-001	IC101	LM358N	27106-002
D5	1N4148	25021-001			
D6	1N4148	25021-001	DS1	4 Dig. Display	25061-503
D7	1N4148	25021-001	LD101	LED	25061-101
D8	1N4148	25021-001			
D9	1N4148	25021-001			
D10	1N5401	25115-003			
D101	1N4003	25115-001			
D102	1N4003	25115-001			
D103	1N4003	25115-001			
D104	1N4003	25115-001			
D105	1N4003	25115-001			
D106	1N4148	25021-001			
D107	1N4148	25021-001			
D108	1N4148	25021-001			
D109	1N4003	25115-001			

