Divider 2   Power

1.1 This part of the manual provides reference information to help specalist engineers dealing with the ICL PERQ power supply unit, power control and distribution. The information supplements that given in the ICL PERQ service manual TP10114.

1.2 **Processor power supply unit**

The assembly contained in the processor unit is a Boschert OL400-3033R two stage power supply. The description given in section 2 refers to the OL400 range of units in general, to which the OL400-3033R belongs. The component designations used are those of the OL400-3015 unit, a circuit diagram of this unit is also included in this manual.

2.1 General theory of operation

This outline description refers to the block diagram given in Figure 1 and is
applicable to the Baschart range of 400-watt power supply units.

Input circuit

The ac mains supply is passed through a radio frequency interference filter to
isolate the supply from switching noise generated by the power unit. Rectifiers
and a capacitor filter provide a raw dc input to the power switching circuit.
The capacitor filter also acts as an energy reservoir in the event of momentary
interruptions to the mains supply. A link may be fitted which converts the
input circuit into a voltage doubler for operation from a 115-volt mains
supply.

Power switching circuit

A transistor switch chops the raw dc power from the capacitor filter into a
train of pulses. One of the power unit dc output voltages is fed back through
an optical isolator to control the pulse width which regulates the output.

Primary inductor circuit

This circuit converts the train of pulses from the power switch into a smooth
dc input for the inverter circuit. The primary inductor is also the main energy
storage element in the power supply unit.

Inverter circuits

For manufacturing reasons, both push-pull and half-bridge inverter circuits are
used, but their purpose and operation are essentially the same. The inverter
circuit provides ac power to the output transformer primary winding. The
inverter operating frequency of about 20 kilohertz is determined by a saturable
reactor.

Output circuit

The outputs from the transformers multiple secondary windings are full-wave
rectified and filtered by inductor-capacitor networks to give the dc outputs.
Although only one output is regulated this simple arrangement is adequate for
virtually all digital circuit applications. The regulated output (normally +5
volts) is fed back to the power switch control circuit through the optical
isolator. This is necessary to separate the power supply regulated output from
the circuits feeding the outut transformer primary winding which are referenced
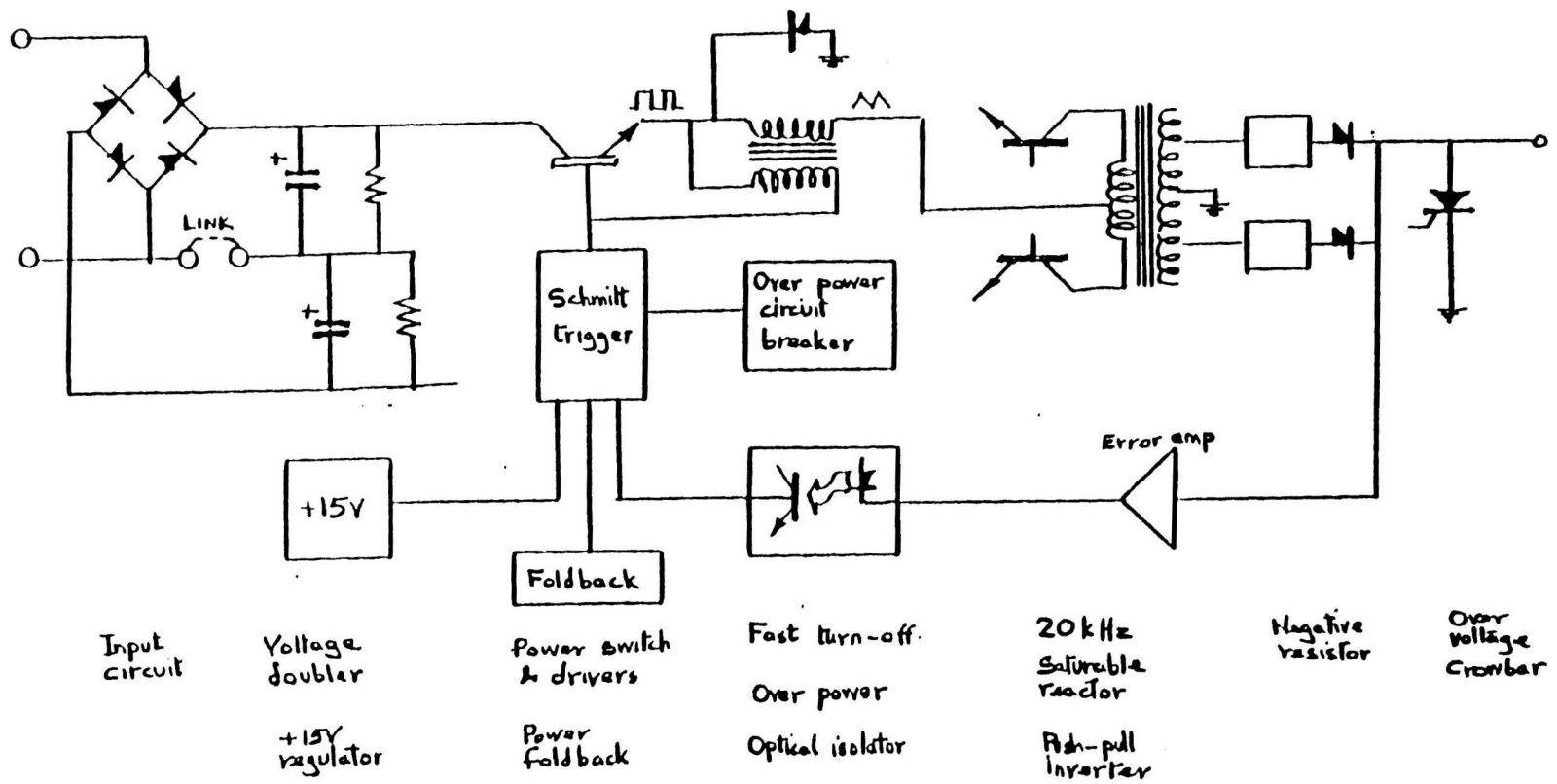to the mains supply voltage.

Input   Voltage   Power switch   Fast turn-off.   20 kHz   Negative   Over
circuit   doubler   & drivers   Over power   Saturable   resistor   voltage
                                                                      reactor   Crowbar
               +15V   Power   Optical isolator   Push-pull
               regulator   Foldback   Inverter

Figure 1   Block diagram

2.2 Detailed theory of operation

The following detailed description refers to the figures within the text and is applicable to the Boschart range of 400-watt power supply units.

2.2.1 The input circuit
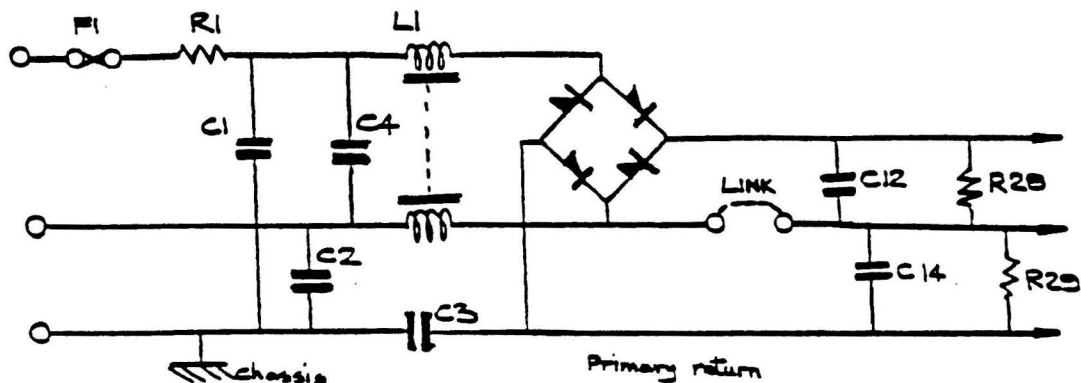
1. The RFI filter consists of components L1, C1, C2 and C4; it isolates the main supply from 20 kilohertz switching noise generated by the power unit

2. The fuse F1 is included to protect the printed circuit board tracks and reduce the risk of fire and electric shock in the event of supply failure.

   The fuse recommended for models OL400 is: Little fuse 3AG series 6-1/4A.

   An additional external mains fuse should always be used to provide further protection.

3. Provision of voltage doubler circuit selection allows the supply to operate from 115- or 220-volt ac sources. In the 115-volt ac mode (link fitted), capacitors C12 and C14 charge on alternate supply half cycles. The voltage which appears across each capacitor is approximately the peak input voltage (about 150 volts). The total voltage to the switching regulator is about 300 volts.

   In the 220VAC mode (link not fitted), the input rectifiers act as a full wave bridge rectifier, charging C12 and C14 to approximately the peak input voltage (about 300 volts). Resistors R28 and R29 force C12 and C14 to charge equally, and discharge the capacitors when the power is turned off.

4. Surge current limiting is accomplished with thermistor R1 whose resistance is high when cool. When the supply is switched on, the thermistor prevents a huge surge current from flowing into the initially uncharged C12 and C14. The normal input current quickly heats R1, decreasing its resistance by a factor of about 10 and, as C12 and C14 become fully charged, there is no further need for surge limiting. When the supply is turned off, R1 cools and C12 and C14 discharge. The circuit is designed so that the discharge time constant and cooling time constant are roughly equal. Thus, if the supply is turned back on before R1 has fully cooled, the surge current is limited by a combination of the charge remaining on C12 and C14, and the resistance of R1.

5. Energy stored by capacitors C12 and C14 ensures that the supply will continue to operate within the regulation limits for a minimum of 16 milliseconds after the input line has fallen below its lower limit. This allows time for information in, say, a volatile memory to be stored permanently before the system fails due to supply interruption or complete failure.
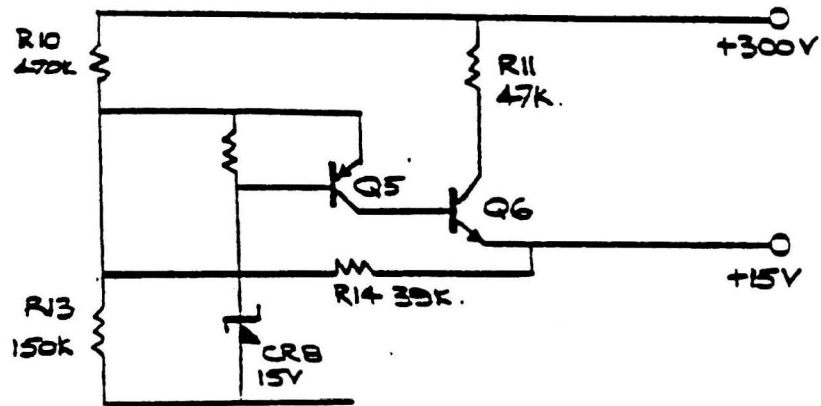
This circuit provides a stable reference for the switching regulator drive circuit and the 723 integrated circuit. The regulator operates as a Schmitt trigger; it switches on when the input voltage rises to about 75V, and switches off when the input voltage falls below about 60V. This means that the power to the 723 circuit and so, the entire supply, is either on or off; there is no "grey" area.

The circuit begins to operate when CR8 starts to conduct. This saturates Q5 which drives the emitter follower Q6. Positive feedback from R14 provides hysterisis allowing the regulator to switch on. Current through R14 tries to force the emitter of Q5 higher. Since the base of Q5 is at a fixed voltage, Q5 conducts harder, which in turn drives Q6. The circuit stabilises when the emitter of Q6 is at a potential of about +15 volts.

2.2.3 Power switch and drivers
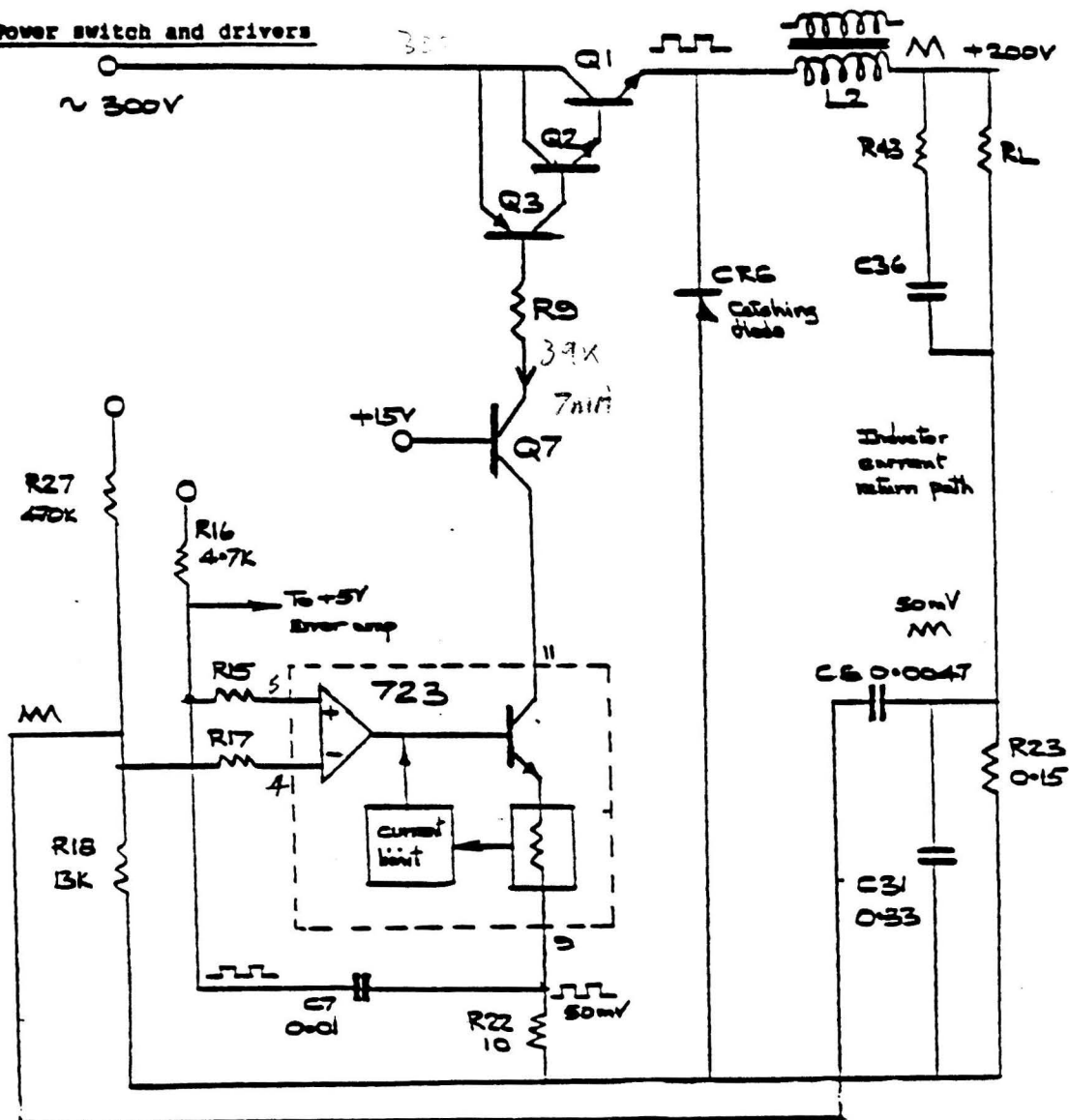
The modulated power switch Q1 provides a chopped DC output to the primary inductor L2. The circuit driving Q1 consists of a 723 integrated circuit, associated current buffers (Q2 and Q3) and isolator (Q7). Notice in Figure 4 that, for simplicity, the inverter and output loads have been represented by R_L. Also note that the 723, drivers, switch, and feedback loop form a free running multivibrator that will continue to run even if the main feedback loop is broken (this is shown in Figure 4 as "to 5V error amp").

The 723 is the basic switching control circuit. Although normally used in a linear mode, it is used here in a switching mode. The non-inverting input is referenced to about +5V. This voltage level is modulated by the +5V feedback circuit. In addition, a 50mV square wave hysterisis signal appears on this input.

The inverting input is also referenced to about +5V. In addition, a 50mV triangular waveform appears at this input. The triangular waveform is generated by the primary inductor current increasing and decreasing linearly in response to a step voltage change on its input. This current flowing through R23 + R43 generates the triangular waveform.

The signal is fed to the 723 circuit through capacitor C6 and is compared to the voltage on the non-inverting input. When the current (and hence voltage on the inverting input) reaches a predetermined value, the 723 switches, turning Q1 off, so removing source current from the primary inductor. The catching diode provides the necessary return path for the inductor current.

By now the 50mV hysteresis square wave on the non-inverting input has disappeared because no switch current is flowing through R22 and the triangular waveform on the inverting input is decreasing towards the new threshold on the non-inverting input. When it reaches this point, the 723 will switch, turning on switch Q1, the 50mV hysterisis signal will again appear on the non-inverting input, the current will increase and the cycle will be repeated.

2.2.4 Fast switch-off circuit
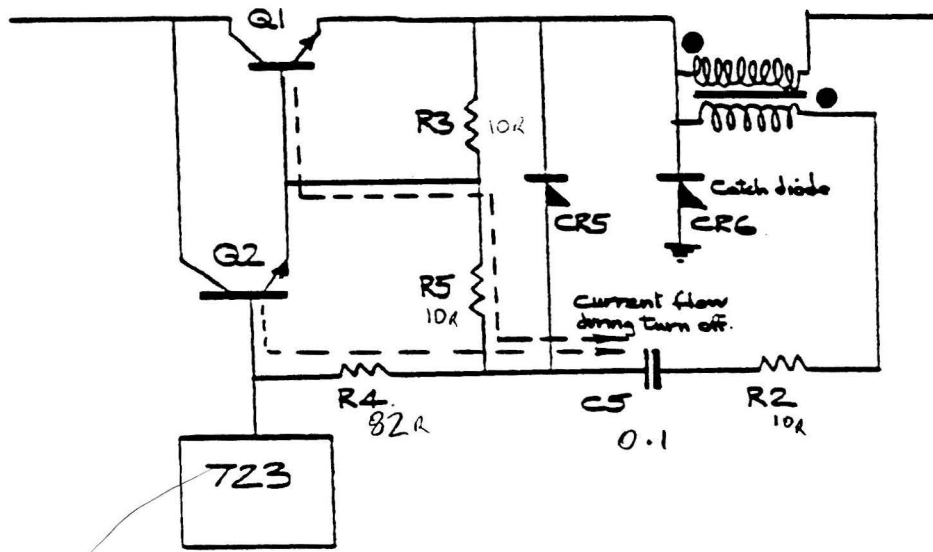
One way to minimise losses in the transistor switch is to switch it off
quickly. This circuit is designed to speed transistor switch-off by depleting
charge carriers from the base regions of Q1 and Q2.

When the 723 circuit turns Q1 off, the dotted end of the upper winding of L2
goes towards 0 volts, and the dotted end of the lower winding goes negative by
about 6 volts. This negative voltage applied to the bases of Q1 and Q2 helps
deplete charge carriers. The current flows through R5, R4, C5 and R2 during
this time. Capacitor C5 discharges through CR5 when Q1 switches on.

2.2.5 Saturable reactor inverter
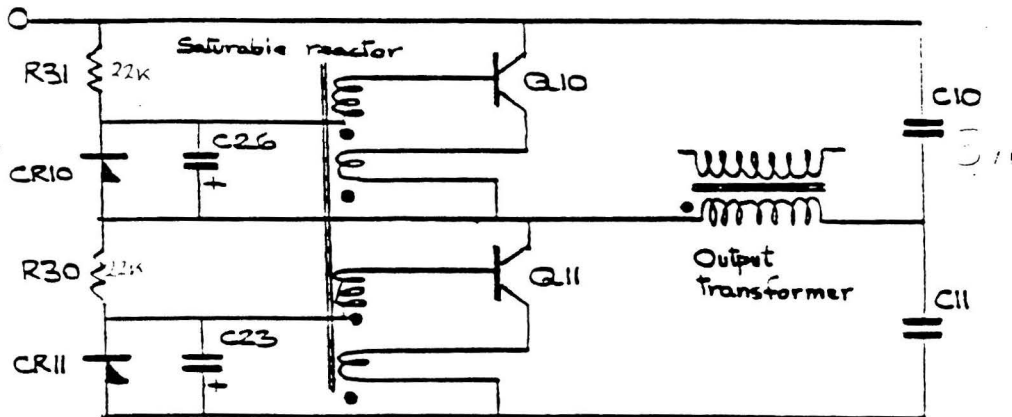
The saturable reactor inverter is a free-running square wave generator. Its
frequency is determined by the time taken to saturate a small ferrite toroid,
which also serves as a current feedback transformer to drive the bases of Q10
and Q11. A half-bridge inverter is shown; push-pull inverters work similarly.

When power is applied to the inverter, leakage current through R31 begins to turn Q10 on and the non-dotted end of the output transformer primary moves positive. Current through the emitter winding of Q10 forces Q10 into saturation and Q11 off. Current builds up in the emitter winding of Q10, and in the output transformer, until the toroid is saturated.

Because of the toroidal saturation coupling between its windings now decrease, so that drive to Q10 from the emitter winding virtually stops. Transistor Q10 come out of saturation and its collector current now decreases.

The rate of change of current in Q10 emitter winding is reversed so that transistor Q11 is driven on and Q10 is switched off. The transfer of current from one transistor to the other is cumulative and rapid.

Capacitors C10 and C11 define a voltage midway between the +200V supply and ground. This allows the dot end of the primary of the transformer to sw symmetrically between the supply voltage and ground. The capacitors als provide the return path for the transformer primary winding.

2.2.6 The main feedback loop
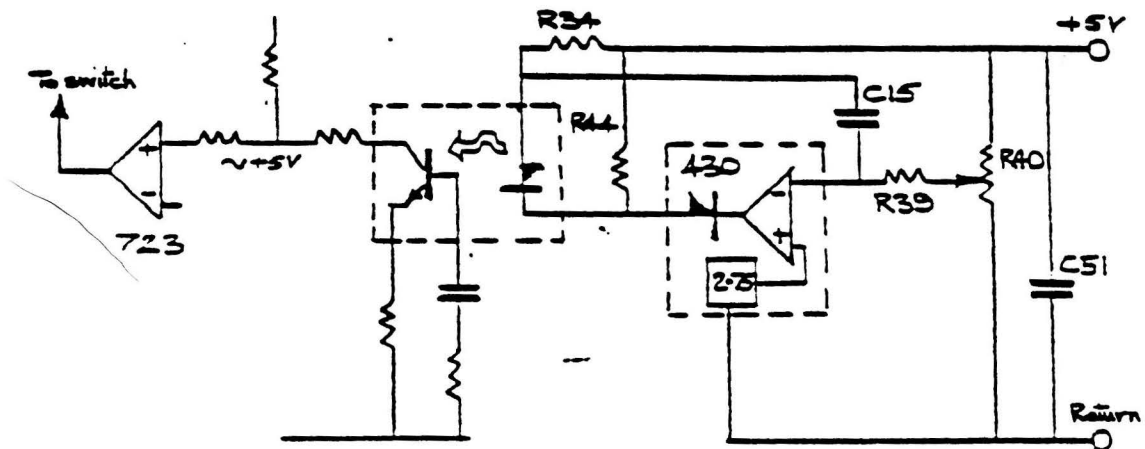
This circuit maintains the regulated output at a constant voltage (normally the +5-volt output). The other outputs are semi-regulated in that because of the tight magnetic coupling between the outputs, a change in load on any output affects the magnetic flux in the transformer and this tends to change the regulated output. The feedback loop compensates for any changes in the regulated output and so, partially compensates for the load change. Boschert call this semi-regulation.

The feedback loop circuit compares a portion of the regulated output supplied through R40 with a 2.75-volt reference within the 430 integrated circuit. This circuit controls the current through R34 and the optical isolator diode.

The optical isolator varies the voltage on the non-inverting input of the 723 switch control circuit. This controls the pulse width at the power switch and ultimately controls the output voltages by varying the voltage to the primary of the output transformer.

Capacitor C15 provides frequency compensation for the 430 circuit which has a bandwidth between one and two kilohertz.

The optical isolator is necessary to isolate the primary side of the supply (which floats at the mains input line potential), from the mains power unit outputs (which are normally referenced to 0 volts).
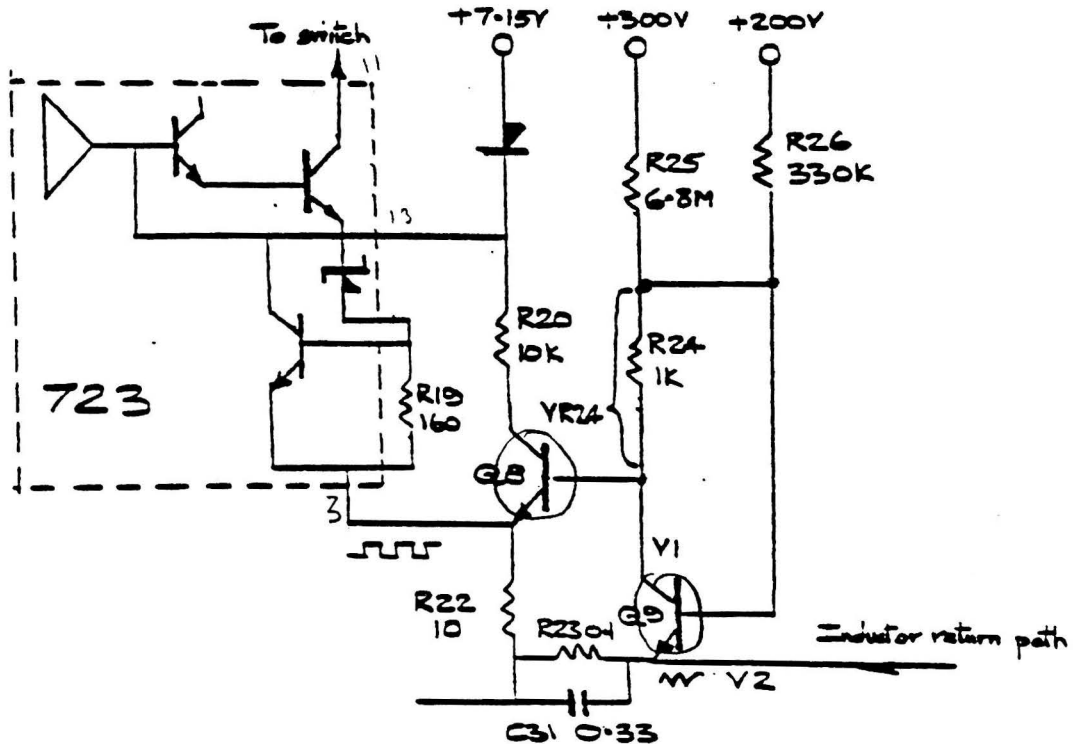
This circuit monitors the power in the primary circuit which, minus losses, is being delivered by the power units. If the secondary tries to deliver too much power (as would happen if a power unit output was short-circuited) the protection circuit causes all the outputs to be reduced to a very low voltage.

The circuit monitors both the regulated voltage to the inverter and a voltage proportional to the primary current through the inverter. The two voltages are added, and when their sum exceeds a specified value, the short circuit protection operates.

Transistor Q9 performs the combined functions of voltage and current sensing. It operates in an almost saturated state, and the output is the collector voltage V1. This voltage increases with <u>decreasing</u> regulated bus voltage (+200V nominal) and <u>increasing</u> primary inductor current. To understand why, it is helpful to consider the components of V1 as: $V2 + 650mV - V_{R24}$

Note that V2 increases with increasing primary current (the current from L2) and V_{R24} decreases with decreasing (+200V nominal) regulated bus voltage. Transistor Q8 controls the protection function. Under normal conditions, Q8 conducts very little during each cycle and so, does not affect the operation of the 723 integrated circuit. However, if V1 rises higher during each cycle, Q8 conducts more and absorbs more base drive from the output stage of the 723. Eventually, when V1 rises high enough during a cycle, Q8 absorbs all the base drive and shuts off the switch prematurely. The higher V1 rises, the more prematurely the switch goes off. This means the duty cycle of the switch (Q1) is changing, reducing the regulated bus voltage below the nominal 200 volts. As the bus voltage drops, V1 rises further and the switch is shut off even more prematurely.

2.2.8 Over-voltage protection
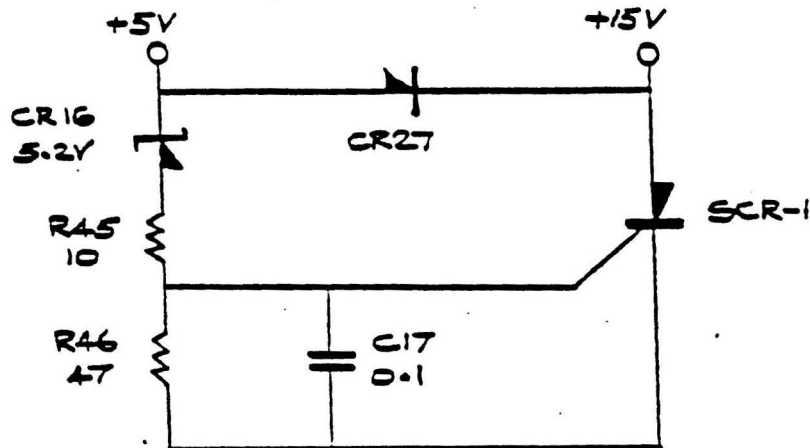
This circuit protects the supply output loads from an over-voltage condition
caused by power supply component failure. All standard Boschert supplies
incorporate this feature. As all the outputs have simple passive filtering, if
one output rises due to a supply component failure, they all rise. Because of
this, only one output needs to be monitored and the +5 volts output is used to
detect any over-voltage condition.

If the +5 volts output exceeds 6.25 volts plus or minus 0.75 volts the SCR
fires and pulls the +15 volts supply down to about 1.5 volts, activating the
short circuit protection. The +15 volts supply is used to ensure a clean decay.
Pulling the +5 volts down to 1.5 volts might not achieve this and might instead
deliver sufficient power to destroy the SCR.

Once the over-voltage protection is activated, the mains supply must be removed
from the unit for about one minute to reinitialise the circuit.

2.2.9 The negative resistance circuit
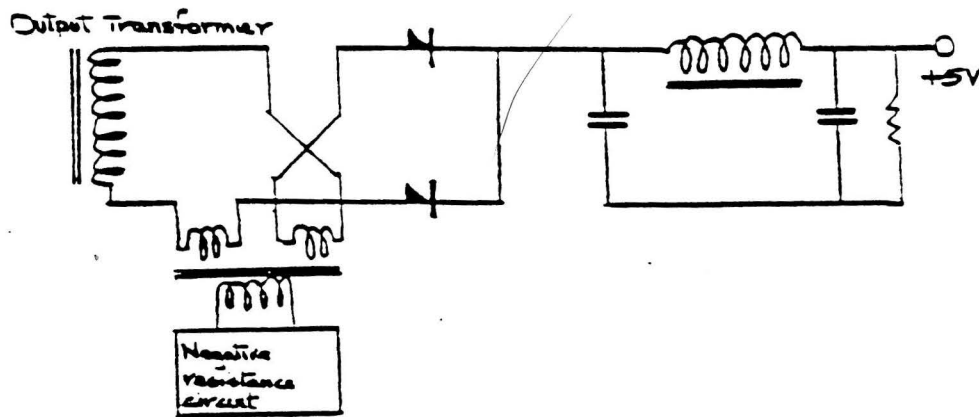
The negative resistance circuit is an active compensator for any voltage drop
in the +5 volts supply caused by high current drain. This magnetically coupled
circuit adds a few tenths of a volt drop to the output line at low output
current. At high currents the voltage drop is about zero.

The circuit compensates for load changes on the regulated +5 volts supply thus
minimising use of the main feedback loop for this purpose and so, reducing the
effect on the other supply outputs.
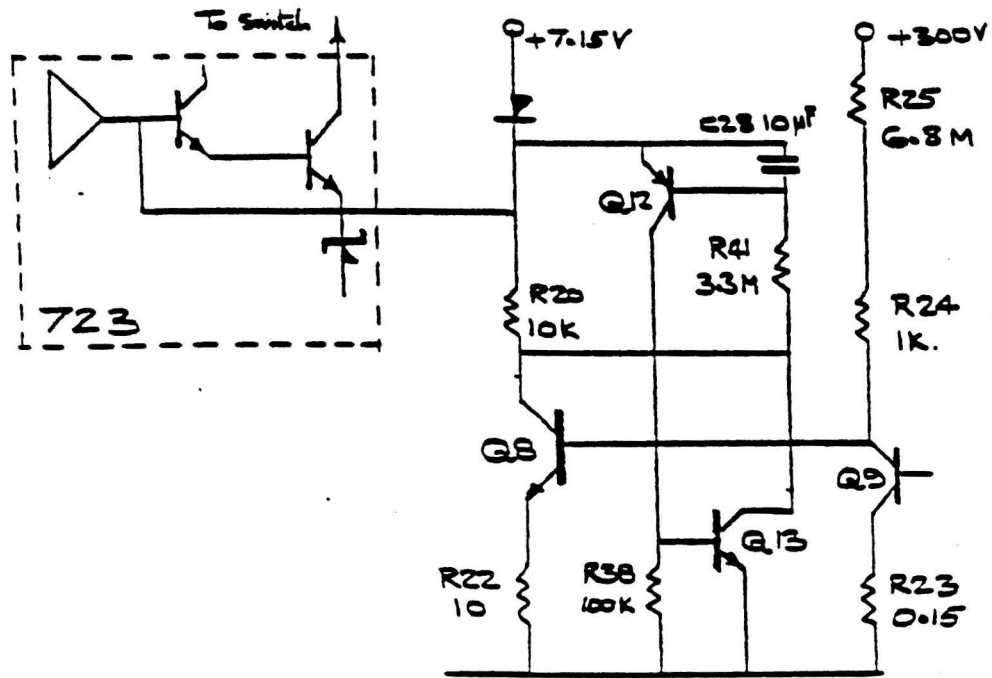
This circuit prevents the overheating of some power supplies if they are short circuited or crowbarred for a long time.

The circuit consists of Q12, Q13, C28, R41 and R38. Q12 and Q13 form a regenerative pair. If one transistor turns on and saturates, the other will also turn on, and sustain this mutually saturated condition.

During normal operation, C28 remains discharged by R41 and R20. When the short circuit protection operates, Q8 will remain saturated for a good portion of each cycle and then C28 is allowed to charge through R41. When the supply goes into foldback, Q8 remains saturated long enough during each cycle to charge C28 sufficient to forward bias Q12. When this happens Q13 also switches on and the supply completely stops. The time taken to turn Q12 on varies from about 5 to 30 seconds depending on the overload level.

Once the over-power protection is activated the mains supply must be removed from the unit for about one minute to reinitialise the circuit.
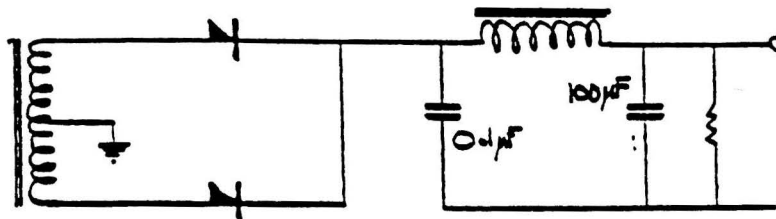
2.2.11 The output circuits

The outputs on most Boschert supplies are full-wave rectified and then filtered using passive L or PI-section filters. This provides quite good regulation at minimum cost. Almost all supply outputs share a common return and bleed resistors present minimum loading while giving a discharge path for output capacitors.

The outputs may be fused or may be able to accept a three terminal regulator.

Diodes are 1N414S unless otherwise specified.
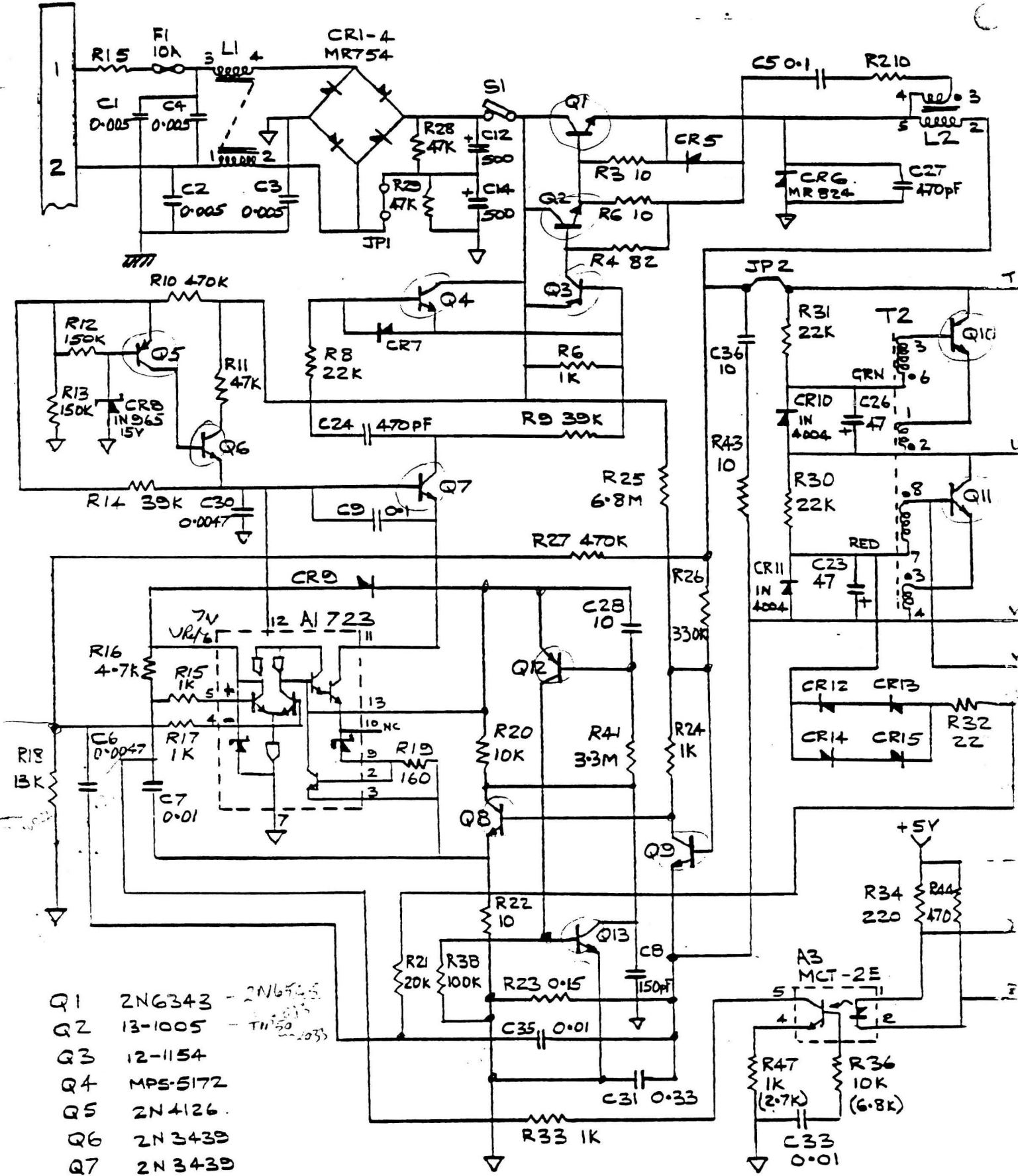
Q1 2N6343
Q2 13-1005
Q3 12-1154
Q4 MPS-5172
Q5 2N4126
Q6 2N3439
Q7 2N3439
Q8 MPS-5172
Q9 MPS-5172
Q10 13-11081
Q11 13-11081
Q12 2N4126
Q13 MPS-5172

Power supply unit OL400-3015
Circuit diagram part 1

5155427

Power supply unit OL400-3015
Circuit diagram part 2.

Nominal	outouts
+5V	35A
+12V	2.5A
-12V	0.75A
+24V	2.5A
+55V	1.8A

S2-12

5155437

ISS. | CHANGES
4 | M37777

R3 91K

ON CHASSIS

JB4

S1 S2

LINE HOT   LINE INTERLOCK

JB7

JB1   JB2

RIGID DISC

JA15

LINE

JA12 LINE
JA11 NEUTRAL
JA10 EARTH

LINE
GND
NEUTRAL

JA13

JA14

(ON CHASSIS)

V1

FLEXI DISC

ON

2   3

JB8

NO

JA9 LINE

OFF

5   6

JB5

JA8 NEUTRAL

JB3

NO

JA7 EARTH

R4
10K   RE1

CAGE

JA6 LINE

HOLD

NC

JB6

JA5 NEUTRAL

+5

JB12

JA4 EARTH

POWER DOWN :L

JB9

1N4148 D2   RE2

60HZ

JB11

D1
1N4148

R1
20K

FANS

JA3 LINE

60HZ GND

JB10

MCT274

R2
20K

JA2 NEUTRAL

U1

JA1 EARTH

5 | | 6
3 | | 4
1 | | 2 | .
SH | ISS. | SH | ISS.

ISSUE No. OF OTHER SHEETS AT TIME OF ISSUING THIS SHEET
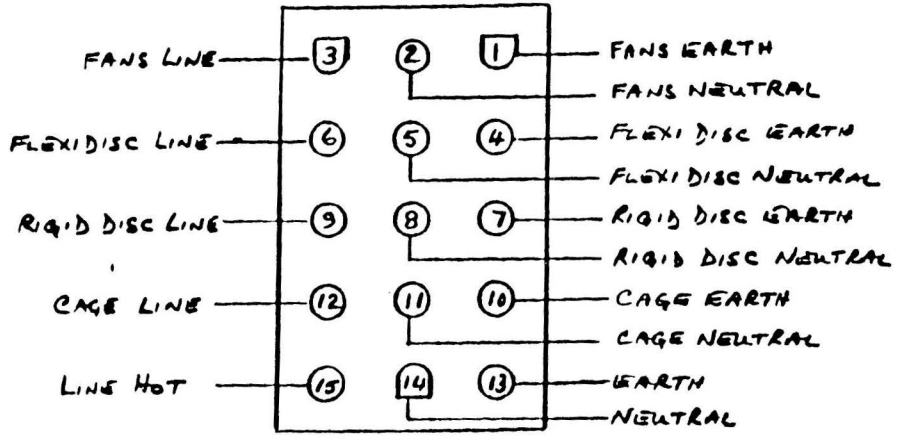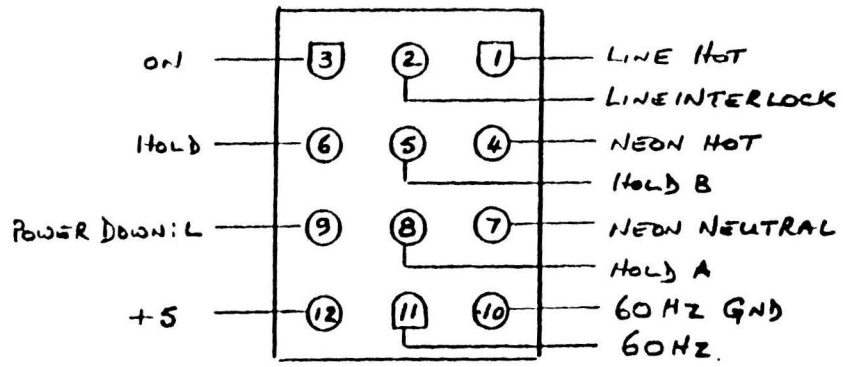
REDRAWN FROM
PRO-SC-0037-D

←— A.C. DISTRIBUTION BOARD MOUNTED —→

ICL
BRACKNELL

DATE 2-12-81   DES. AUTH   DEZ 81   CH'K'D   PROD/QA   ENG

DATE

JA

Connector JA pin assignments:
- FANS LINE — 3
- 2 — FANS EARTH
- 1 — FANS NEUTRAL
- FLEXI DISC LINE — 6
- 5 — 4 — FLEXI DISC EARTH
- FLEXI DISC NEUTRAL
- RIGID DISC LINE — 9
- 8 — 7 — RIGID DISC EARTH
- RIGID DISC NEUTRAL
- CAGE LINE — 12
- 11 — 10 — CAGE EARTH
- CAGE NEUTRAL
- LINE HOT — 15
- 14 — 13 — EARTH
- NEUTRAL

JB

Connector JB pin assignments:
- ON — 3
- 2 — 1 — LINE HOT
- LINE INTERLOCK
- HOLD — 6
- 5 — 4 — NEON HOT
- HOLD B
- POWER DOWN L — 9
- 8 — 7 — NEON NEUTRAL
- HOLD A
- +5 — 12
- 11 — 10 — 60 HZ GND
- 60 HZ

REDRAWN FROM:-
PRQ-SC-ØØ38-D

| MATERIAL | TITLE | SHEET 2 CONTINUED ON | DRG. No. |
| | LOGIC DIAGRAM/SCHEMAT- | | 5154459 |

ON CHASSIS

JB4

JB7

S1 S2

LINE HOT   LINE INTERLOCK

JB1   JB2

LINE   JA15

GND   JA13

NEUTRAL   JA14

ON
OFF

ON CHASSIS

2   3
B
5

JB8
JB5
JB3

JB6

V1

NO

NO

NO

RE1

RIGID DISC
LINE   JA12
NEUTRAL   JA11
EARTH   JA10

FLEXI DISC
LINE   JA9
NEUTRAL   JA8
EARTH   JA7

CAGE
LINE   JA6
NEUTRAL   JA5
EARTH   JA4

FANS
LINE   JA3
NEUTRAL   JA2
EARTH   JA1

+5   JB12

1N4118 D2   RE2

POWERDOWN L   JB9

60HZ   JB11

60HZ GND   JB10

5   2
1N4148 D1
4   1
6

NCT274   U1

R1 10K
R2 10K

JA
FANS LINE — 3 2 1 — FANS EARTH
— FANS NEUTRAL
FLEXIDISC LINE — 6 5 4 — FLEXIDISC EARTH
— FLEXIDISC NEUTRAL
RIGID DISC LINE — 9 8 7 — RIGID DISC EARTH
— RIGID DISC NEUTRAL
CAGE LINE — 12 11 10 — CAGE EARTH
— CAGE NEUTRAL
LINE HOT — 15 14 13 — EARTH
— NEUTRAL

JB
ON — 3 2 1 — LINE HOT
— LINE INTERLOCK
HOLD — 6 5 4 — NEON HOT
— HOLD B
POWERDOWN L — 9 8 7 — NEON NEUTRAL
— HOLD A
+5 — 12 11 10 — 60HZ GND
— 60HZ

ICL
BRACKNELL

LOGIC DIAGRAM BB10   SHEET 1