5 Technical Description

5.1 Start-up Sequence (S-Band)

The start-up sequence described below, should be read in conjunction with Figure 1.33 'S-Band Turning Unit Schematic'.

5.1.1 Start-up

Important Notice *- Once mains is applied to the PSU board the Power Factor Correction (PFC) circuitry starts and generates 390V. It should be noted that whilst mains is applied the PFC is active and cannot be manually switched off. The start circuitry only controls the flyback converter so High Voltage DC is present on primary power components whenever mains is present on the board. This* ***fact should be noted when servicing the Transceiver.***

The Power Supply in the Transceiver is only active during normal operation when there is a Display (or Compatibility Unit) connected to it. The RS422 serial data stream from the Display is used to drive an opto-coupler in the PSU which detects the presence of either polarity voltage and enables the flyback converter in the PSU.

The RS422 serial data stream from the Display enters the Input Board on connector TSB 1, 2 as "DU DATA+ and DU DATA-". It is then passed to the Trigger Board via PLYB 16, 17, and then on to the PSU via PLTH 11, 12 (as PSU START and PSU START RTN). For test purposes the PSU can be turned on in the absence of a serial data stream by linking pins 1-2 on LKA (PSU).

5.1.2 Transmit Enable

When the operator selects Transmit, the TU Enable signal is activated LOW on the Trigger PCB (PLYH 10). On the S-Band Scanner Unit, this signal is fed via the Power Supply Unit to the Input PCB and (via TSB10) to the Scanner Control Unit to start the antenna rotating. Once the antenna has done one complete revolution transmission is started. When standby is selected, transmission is immediately halted and, after one complete revolution of the antenna, TU Enable is disabled.

The Modulator starts to generate radar pulses when the Trigger PCB sends it MOD TRIGGER pulses (to PLVC 9). Note that the CHARGE TRIGGER pulses (on PLVC 8) are present even in Standby mode.

A signal indicating that the Magnetron has fired is fed via MAG SAMPLE from PLVC 7 on the Modulator PCB to the Trigger PCB. This signal is processed on the Trigger PCB and outputted as TX TRIG (PLYB 20 & 21) to the Input PCB (PLZB 20 & 21) and then to the Display Unit via TSB 5 & 6.

Note *- TX DATA is sent from the Transceiver to the Display Unit.*
DU DATA is sent from the Display Unit to the Transceiver Unit.

The Trigger PCB processes the serial data input from the display, and generates the required control signals for the Transceiver.The data is transmitted each time a bearing pulse is received from the Turning Unit. The various timing signals required by the Transceiver including the Pulse Repetition Frequency (PRF), are generated by the Trigger pcb.

5.1.3 Transmitter Operation

The high-voltage negative pulses required to drive the magnetron are generated by the Modulator PCB. The modulator pulse widths are selected by the Trigger pcb but are defined by the Modulator pcb.Timing signals are controlled from the Trigger pcb. A spark gap on the Modulator is fired if the magnetron fails to operate. Continual operation of the spark gap is detected and a signal is fed back to the Trigger pcb, as the spark gap detect signal.

When the spark gap detect signal reaches approximately 2.5v, the microcontroller inhibits transmission for approximately one second. On detection of this signal, the Trigger pcb switches the radar to Standby, and generates an error signal which is transmitted to the Display Unit via the serial data link.

When Standby is selected, rotation of the Antenna is inhibited. Unless in Test Mode, transmission from the radar is inhibited if the Antenna is not rotating.

On the Trigger PCB, there is a timer circuit which is basically a capacitor that slowly discharges (between 4s and 18s) when power is removed from the PCB. On power-up the microcontroller measures the charge remaining on the capacitor to determine whether the transceiver has been switched off for long enough to warrant inhibiting transmit for three minutes until the magnetron heaters have had time to warm up again.

The other analogue signals into the Trigger PCB come from the Modulator. The Modulator supply voltage and the magnetron current (only when transmitting) are measured and sent to the Display as an aid to fault finding.

5.2 Trigger PCB (S-Band)

5.2.1 General Description

The Trigger PCB controls the operation of the Transceiver under instruction from the Display. There are two serial links, which are used to transfer control messages from the Display to the Trigger PCB and Transceiver information back to the Display. The Trigger PCB generates the control and tuning signals required by the Modulator, Receiver, Performance Monitor and Biased Limiter. The PSU is enabled with a signal from the Trigger PCB.

5.2.2 Signals To/From the Trigger PCB

To/From Display

Serial Data to Display
Serial Data from Display
Trigger to Display

To/From Modulator

Pulse Length select lines
Charge and Modulator Triggers
Magnetron Heater Turndown signal (only used for S-Band, Long Pulse operation)
Voltage/Current Monitor signals

To/From Receiver

Tuning Voltage signal
Bandwidth Control signal
AFC/Manual control
AFC Trigger
Tune Indicator signal

To Biased Limiter

Trigger signal

To Performance Monitor

On/Off signal
Mode Control signal
Tuning Voltage signals

To/From Power Supply PCB

+30V, +12V, +5V, 0V & -12V Supply lines
Turning Unit Enable
Power Supply Start and Return

5.2.3 Functional Description (S-Band Trigger PCB)

The 80C51 family microcontroller provides overall control of the Trigger PCB functions. Program memory and RAM are included within the microcontroller IC. Serial I/O is handled by the microcontrollers internal UART and an external RS422A driver and receiver. Baud rate is fixed at 76800 baud for operational use but is link selectable to 19200 or 38400 baud for test purposes. The serial data format is 8-bit data, 1 stop bit and even parity.

The Display sends serial messages comprising four or five characters depending on message content. Control messages are four bytes long and tuning messages are five. The tuning voltage levels are sent as 12-bit values which are converted on the Trigger PCB using a four-channel DAC before amplification/buffering and distribution to the Receiver and Performance Monitor.

The Bearing signal from the Turning Unit is used to initiate serial transmission from the Trigger PCB such that each time one of the 4096 azimuth pulses per rev is generated and fed into one of the microcontrollers interrupt pins, a character (one byte) is sent to the Display. One bit in each of the characters sent is dedicated to the heading marker, on every new heading marker pulse from the Turning Unit, the bit is toggled.

The Power Supply in the Transceiver is only active during normal operation when there is a Display (or Compatibility Unit) connected to it. The RS422 serial input from the Display is used to drive an opto-isolator which detects the presence of either polarity voltage and enables the PSU.

Trigger Ouputs
There are a number of trigger signals generated by the Trigger PCB:

Pre-Trigger (optional)
Charge Trigger
Modulator Trigger
Display Trigger
Performance Monitor Trigger
AFC Trigger
Swept Attenuation Initiate

The Charge Trigger is the timing signal used to recharge the Modulator PFN. This is generated by the microcontroller using an internal timer routine set to the appropriate PRF for the pulse length selected. A wobbulation factor is added to the basic timing to ensure that no two radar transmissions are locked together. The wobbulation is calculated according to the number of serial messages received before going to transmit and the position of the antenna between each trigger pulse.

An optional Pre-trigger will be produced approximately 11μs before the modulator trigger. This is not a normally fitted option and is intended for use in Special Options applications.

The Modulator Trigger is used to discharge out the PFN into the magnetron and is the trigger that initiates the modulator firing. The PFN is recharged by the Charge Trigger pulse which follows100μs after each Modulator Trigger pulse. In standby mode, the Charge Trigger pulse is still generated, but the Modulator Trigger pulse is gated off.

In standby, the Display and Performance Monitor Triggers are generated from the Mod Trigger pulse. When the transceiver is in transmit mode the triggers begin on the leading edge of the magnetron sample pulse and end after a preset time, adjustable using RV1.

The AFC Trigger is used by the receiver when in AFC mode and is only generated when the transceiver is in transmit mode. The pulse is started on the front edge of the Modulator Trigger and terminates on the back edge of the magnetron sample pulse.

The Swept Attenuation Initiate pulse is the timing signal fed to the Limiter Drive PCB which generates the control for the biased limiter. It is initiated by the front edge of the Pre-trigger (approximately 2μs prior to magnetron firing) and terminated 2.5μs after the leading edge of the magnetron sample pulse.

The Display and PM Triggers are essentially the same trigger and are present at all times when the radar is powered up. They are initiated by the Modulator Pulse and last for approximately 2.5μs.

Analogue Outputs

The Trigger PCB generates four variable DC signals; LO.Tune, PM Tune, Xr Adjust and Xt Adjust. These signals are coded as 12-bit digital values and incorporated into the serial messages from the Display. A 12-bit, four channel DAC is used to generate the signals from the message data. Additional buffering is added to the LO and PM Tune outputs of the DAC and x3.5 amplification to the Xr and Xt Adjust signals.

LO Tune is the 0V to +5V receiver tuning signal, and PM Tune the 0V to +5V Performance Monitor tuning signal. Xr and Xt Adjust are 0V to +15V signals used to control the receive and transmit attenuators in the Performance Monitor.

Analogue Inputs

There are various analogue inputs to the Trigger PCB from other PCBs in the transceiver and some on-board signals that are fed into an eight channel 8-bit ADC, and converted to digital values either for further processing by the microcontroller or to be passed to the Display via the serial message link.

The signals on the Trigger PCB that are measured are the dropout timer and +12V and +30V supplies. The timer circuit is basically a capacitor that slowly discharges (between 4s and 18s) when power is removed from the PCB. On power-up the microcontroller measures the charge remaining on the capacitor to determine whether the transceiver has been switched off for long enough to warrant inhibiting transmit for three minutes until the magnetron heaters have had time to warm up again. The power supply levels are measured and the results sent to the Display as an aid to fault diagnosis.

One channel of the ADC is used to detect whether a Performance Monitor has been fitted to the system. The voltage on this channel will be lower than a preset value if a Performance Monitor is present otherwise it will be pulled to the +5V supply rail. This information is encoded and sent as part of the configuration message to the Display.

The Receiver sends a tune indicator signal to the Trigger PCB which indicates how close it is to being on tune. This signal is coded as part of the serial message and sent to the Display.

The other analogue signals into the Trigger PCB come from the Modulator. The Modulator supply voltage and the magnetron current (only when transmitting) are measured and sent to the Display as an aid to fault finding. The spark gap detect signal is generated by the modulator when the spark gap arcs over, if it reaches a predetermined level the microcontroller inhibits transmission for approximately one second and sends an error message to the Display.

Digital Outputs

The digital outputs from the Trigger PCB are all straight forward on/off control signals to various parts of the transceiver.

Signals to the Receiver select wide or narrow bandwidth (Wideband) and AFC or manual tuning mode (AFC On). Narrowband is selected when the modulator is transmitting in long pulse and briefly during pulse length changing. AFC or manual mode is selected by the radar operator and is part of the control message sent from the Display.

Modulator signals MP and SP are used to set the pulse length as requested by the radar operator, SP set to 0V indicates short pulse operation, MP set to 0V indicates medium pulse operation and both SP and MP set to +5V indicates long pulse operation. SP and MP both set to 0V is an illegal state and will not happen in normal operation. Turndown enable is used to reduce the heater current in the magnetron and is only set when an S-Band magnetron is fitted and is transmitting in long pulse.

The control signals PM On/Off and PM Tx/Rx are used to switch the Performance Monitor on and to switch it between system test mode and receiver test mode.

TU Enable is the control signal fed to the Motor Drive PCB to initiate rotation of the antenna. When the operator selects transmit the TU Enable signal is activated to start the antenna rotating.

Once the antenna has done one complete revolution transmission is started. When standby is selected, transmission is immediately halted and, after one complete revolution of the antenna, TU Enable is disabled.

Optional I/O

There are several optional I/O signals for use with Special Options variants of the PCB; Pre-trigger (as described in the section on triggers), External Trigger Input and Radar Inhibit. The External Trigger input is used when the modulator needs to be triggered from an external source rather than the Trigger PCB. Trigger signals fed to this input are prf limited to prevent damage to the modulator. Radar Inhibit is a method of inhibiting transmission without using the appropriate command in the serial message. An active signal at this input will cause the microcontroller to inhibit transmission within one trigger pulse at either of the internal prfs.

Built In Self Test (BIST)

The microcontroller performs a number of self test operations and reports the results to the Display as part of the serial message link. Error situations that are monitored in the transceiver are; serial message corruption, loss of Display messages, loss of Heading Marker signal, loss of either Charge or Modulator Trigger and spark gap arcing. Error situations will in all cases cause the microcontroller to inhibit transmission until the error has been cleared. The other signals that are monitored and sent directly to the Display without further action by the microcontroller are the power supply lines and magnetron current as described in the section on analogue inputs.

Test Modes

There are two test modes for the Trigger PCB. The production test mode is used solely during production testing of the PCB and is initiated by fitting the test link LK4. This must only be done on the production test bed as connecting this link when incorporated into a transceiver could lead to unpredictable and possibly dangerous operation.

The second test mode, of use to service engineers can be initiated by fitting the two links LK5 and LK6 to position 2-3. When in this mode the transceiver can be operated without the antenna rotating, and may be removed from the turning unit, reconnected to the Display below decks (with suitable test cables) and run as per normal operation. Fitting the links causes the Trigger PCB to generate bearing and heading marker data internally, allowing the transmitter to operate without the antenna rotating. A dummy load MUST be connected to the RF output. Since the Transceiver has been removed from the Turning Unit and the Pulse Bearing PCB outputs, the bearing and heading marker information normally required for Trigger PCB operation is simulated on a section of test circuitry on the Trigger PCB.

5.3 Transceiver Power Supply (S-Band)

5.3.1 General Information

The power supply is an AC to DC inverter that generates the supplies for the Transceiver. The inverter is housed on a single board and is powered by an AC supply of nominal 115V or 230V in the frequency range 47-64Hz.

The power unit uses a boost converter front end to provide a regulated high voltage d.c. to a flyback converter providing the output supplies. Some of these supplies use additional switch mode converters to provide regulated outputs.

The outputs supplied by this power supply are:-
Variable -600V, +30V, +20V, magnetron heaters (via further regulator, +12V, -12V and +5V) and for the X-Band Turning Unit variant, +50V for the Motor Drive pcb.

The power unit has the following features:

- -600V adjustable over the range -550V to -650V for control of magnetron current via modulator.
- Output short circuit protection.
- Universal input from 95V to 276V without tap changing. Power factor corrected providing a PF of better than 0.9.

5.3.2 Functional Description (S-Band Transceiver Power Supply)

The following functional description is based on the block diagram given at Figure 1.30.

Principles of Operation

This power supply utilises a boost converter to provide approximately 390V d.c. to the main flyback converter which drives the power transformer T2. The principles of operation are as follows:

The incoming AC supply is filtered mainly to suppress noise emitted from the p.s.u. but also to attenuate incoming noise. Mains is then passed to the power factor controller which converts mains between 95V to 276V RMS to a stable high voltage d.c. (390V). The p.f.c. takes the form of a boost regulator which forces the input current to follow the waveshape of the input voltage as if a resistor were connected across the rectified AC supply. The p.f.c. also aims to regulate the output voltage to a level greater than the peak supply voltage. These factors are achieved by the control circuit (U3) which senses the input and output voltage as well as the input current. The control circuit sends a stream of constant frequency but varying width pulses, to the switching FET (Q1) such as to control the input current and output voltage.

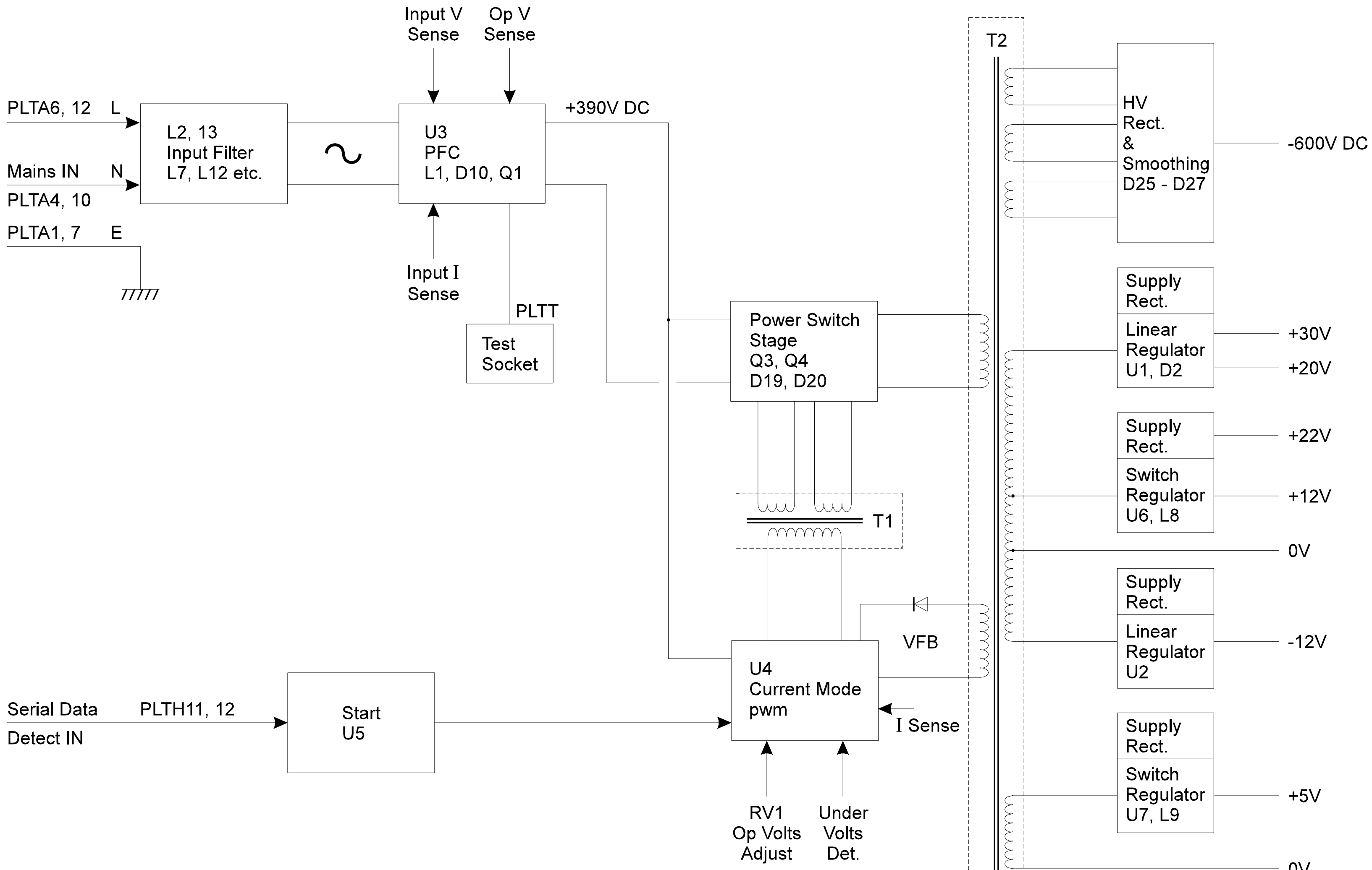

Figure 1.30 Block Diagram - Power Supply Board

The choke (L1) current increases during the FET on period and falls during the FET off period when the boost diode D10 conducts. This produces a triangular current waveform at 100kHz superimposed on the sinusoidal current in the choke. At full load this triangular current may be 10% of the actual peak current. The High Voltage DC (390V) is applied to the main Current Mode power converter comprising U4, Q3, Q4 and T2.

The high voltage DC line is switched to the primary of transformer T2 by the two FETs Q3, and Q4, These FETs are driven by the control circuitry (U4) such that they will both be either 'on' or 'off' together. Flyback action takes place during the off state. A small drive transformer T1 is used to provide the simultaneous but isolated drives to the two FET switches. The cross-connected diodes D19, D20 return excess flyback energy to the supply lines and provide hard voltage clamping of the FETs at a value of a diode drop above and below the supply line voltages. Switching devices with a 500V rating can be used. Energy recovery action of D19, D20 eliminates the need for an energy recovery winding or even snubbing components. Output current is fed back to U4 via sense resistor R47 which stabilised the control circuit and provides overcurrent protection under fault conditions. A further control winding provides a voltage feedback path via D32 which is used to supply power to U4 and regulate the voltage output.

DC Outputs

All output voltages are taken from the secondary winding of T2. A series of rectifiers, reservoir capacitors, linear and switch mode regulators are connected to the secondary windings of T2 to provide the following DC voltage outputs.

1. -600V	120mA max.	Modulator HT
2. +30V	20mA max	Tuning Range
3. +20V	15mA max.	Drive to IGBTs
4. 20V(approx:)	0.7A	to magnetron heaters via a switch mode step down regulator.
5. +12v	1.5A	Rx, trigger board modulator
6. -12V	0.6A	Rx, trigger board modulator
7. +5V 0	5A	Rx, trigger and pulse bearing board

As the modulator requires HT voltage that can be varied over 550V to 650V to set up the correct magnetron current, all outputs have to be further regulated to ensure stability. Adjustment of RV1 sets the required modulator HT voltage and thus the required magnetron anode current.

To produce the 600V d.c. HT, three windings on the secondary of T2 each produce 200V and are added together at the output of the rectifier circuits. The 30V and -12V rails are fed via three terminal linear regulators whilst the 20V is Zener stabilised. The +12V and +5V rails are fed via 'simple switches' five terminal regulators and chokes with flywheel diodes.

The flyback current mode converter formed by U4, Q3, Q4 and T2 is started by detection of a serial data stream applied to U5 from the display at PLTH 11, 12. On detection of the data stream the photo transistor within U5 is turned on pulling down the gate of Q2 below its threshold voltage.

Q2 turns off allowing the compensation pin 1 U4 to rise enabling output of the IC U4. In the PSU off state Q2 is held on by current in R37 from Vcc.

In the absence of a serial data link from the display, for test purposes, LKA 1-2 can be made and the p.s.u. will output the required d.c. voltages.

The operating frequency of the PFC section is approximately 100kHz. That of the p.w.m. flyback converter is approximately 40kHz whilst the 'simple-switchers' run at approximately 52kHz.

Once the mains supply is applied to the PSU board, the PFC (Power Factor Correction) circuit starts and generates 390V. Whilst mains is applied, the PFC is active and cannot be manually switched off. The start circuitry only controls the flyback converter and so High Voltage DC is present on primary power components whenever mains is present on the board. **This fact should be noted when servicing the Transceiver**.

5.3.3 Circuit Description (S-Band Transceiver Power Supply)

The following circuit description is based on Circuit Diagram65801909 at Figure 1.31.

Mains Input

The AC supply enters the power supply from the external input filter via plug PLTA pins 6, 12 live, PLTA pins 4, 10 neutral and PLTA pins 1, 7 earth, to the comprehensive EMC suppression circuitry. Although the filtering provides some rejection of mains born interference its main task is to suppress pfc and main switcher interference generated from within the PSU. Due to the 100kHz triangular choke current and capacitive switching currents in the pfc power stage, common mode and differential mode interference pulses are present either side of C16. The multi-element filter formed by common mode chokes L2, L3. and differential mode chokes L7 and L12 together with the adjacent capacitors C18-C21 effectively minimise conducted 100kHz and harmonics from being superimposed on the incoming mains. VDR1 suppresses transient voltages on the AC supply whilst RT1 limits inrush currents to the smoothing capacitors C4, C5.

Power Factor Correction Circuit (PFC)

The PFC takes the form of a continuous mode fixed frequency, average current mode boost regulator. It produces a stable 390V DC rail from the incoming mains whilst ensuring the input current remains sinusoidal. The drive pulses for the main switching FET Q1 are generated by the PFC controller U3 pin 16. The ground pin 1 is referenced to HVRTN which is Q1 source and via the current sense resistors R20, 21 the bridge rectifier -ve output.

The Vcc supply for U3 pin 15 is derived from:-

1. Winding pins 7, 8 on the main choke L1.
2. Resistors R2, 3 and D31 from +HV DC
3. An external 17V dc PSU for test purposes.

All the following pins refer to U3. The V sense pin 11 senses the +HV DC (390V) line and causes Q1 drive pulses to adjust in width to keep the d.c. output voltage constant for load changes. The 0VP pin 11 senses the +HV DC line and cuts off Q1 drive if the output voltage exceeds 390V by approximately 5%. The IAC pin 6 receives a current proportional to the rectified AC voltage from the bridge rectifier D1. V ref pin 9 outputs a 7.5V reference voltage. PK lim pin 2 receives a -ve voltage from current sense resistors R20, 21 via R1. When this is large enough to take pin 2 voltage below 0V, against the current flowing through R41, Q1 drive is cut off.

The EN/SYNC pin 10 is permanently held in the enable state by resistor R19 connected to Vcc. The C set and R set pins 14 and 12 are connected to C7 and R18. These components set the frequency of the internal oscillator to 100kHz. The SS pin 13 is for slow startup which is not used in this application.

The Va out pin 7 in conjunction with components C13, C8, R14 and R13 stabilise the +HV DC feedback control circuit in U3. The M out pin 5 receives the current sense voltage via resistors R22 and R59. The I sense pin 4 senses the voltage on the HV RTN end of the current sense resistors.

Inputs on pins 4, 5 and 6 are used in U3 to control Q1 drive pulse width such as to make the average current waveform in the choke L1 follow the rectified AC output voltage from bridge rectifier D1. The CA out pin 1 in conjunction with components R23, 8, C14 and C15 stabilise the current sensing feedback control circuit in U3.

Overcurrent Limit Operation of PFC

There are two separate circuits to protect the power switching components.

a) A controlled and stable current limit circuit is built into the average current feedback control loop. The current limit value is determined by resistors R20, 21. Increasing the PFC load current above the maximum level will cause the pfc input current to progressively have a flat top to the full wave rectified waveform.

b) A second current limit path is provided by the level of voltage appearing at PKLIM pin 2 of U3. The level of this current limit point is set slightly higher than the previous one in a) above.

Start Sequence of the PFC

(with the application of mains from the ship's supply contactor)

Initially C4, C5 charge up to the peak value of the AC supply via D24, L1 and D1. Vcc line capacitor C3 starts charging via R2, R3 and D31. When C3 voltage reaches about 16V the pfc IC U3 starts operating and delivers pulses to Q1. The +HV DC starts to increase towards 390V whilst Vcc falls due to U3 current drain. The +HVDC line reaches 390V before C3 voltage drops to 10.5V where U3 would switch off. With the HVDC line at 390V, Vcc is then maintained from winding 7, 8 of L1 via D14, D15, C29 and C30.

All the time the +HVDC line is building up the current limit circuits are operating allowing the 390V line to build up in the shortest time. As the HVDC line builds up the flyback converter drive IC U4 Vcc rises. Upon reaching approximately 16V (pin 7 VCC) the IC becomes active and the power output FETs are driven. The output voltage from the power supply starts approximately 2-3 seconds from initial mains application.

Capacitors C23 and C24 serve to provide a return path for the capacitive currents resulting from stray capacities of Q1, D10 and D11 thermal insulating material on the heatsink. Prior to Q1 switching on, L1 current is passing through D10. When Q1 switches on D10 takes a finite time to switch off. At this time Q1 sees the full +HVDC voltage present on C4, C5.

A very high current pulse results causing significant power dissipation in Q1. With inductor L4 in circuit Q1 current is allowed to build up slowly until L4 saturates. At this time Q1 is switched on and its drain current has risen sufficiently to reverse D10 current. D10 turns off. This L4 circuit significantly reduces the switching losses in Q1. Diode D11 and resistors R25-R27 serve to absorb the stored energy in L4 when Q1 switches off. In particular it prevents Q1 drain voltage rising significantly above 390V.

The PFC circuit can be tested separately from the rest of the PSU by utilising the test plug PLTT. Testing the pfc is achieved by removing LKB, fitting a variac to the AC supply and applying a floating DC supply of 16 to 20V across Vcc and HVRTN (pins 4 and 5 of PLTT). The floating external PSU provides power to U3. With the low voltage supply on, the variac can be turned up whilst monitoring +HVDC. The pfc circuit should produce an output of 390V d.c. with about 4V AC input. The +HVDC line should remain stable at 390V for all IP voltages up to 276V RMS. If it rises above 390V do not increase variac input as there is a feedback fault. An external resistive load may also be connected to the pfc via PLTT pins 1, 5.

Main PWM Power Supply Stage

The pfc provides stable +390V d.c. for the current mode flyback converter over the full mains input specification. In spite of the converters dual power FETs the converter is of single ended flyback design. The high voltage DC line is switched to the primary of transformer T2 by two power FETs Q3 and Q4. These switches are driven via T1 from the control IC U4. They are both either on or off together. Drive transformer T1 provides simultaneous but isolated drive to the two FETs.

The cross coupled diodes D19, D20 return excess flyback energy to the supply line and provide hard clamping of the two FETs at a value of only one diode drop above or below the supply line voltages. In addition, energy recovery action of D19, 20 eliminates the need for an energy recovery winding or even snubbing components. This reduces the waste heat in the psu.

When both power FETs are ‘on’ the supply voltage appears across the transformer primary and series leakage inductance. All secondary rectifiers will be reverse biased and no secondary current flows. The primary current increases linearly and energy will be stored in the coupled magnetic field of the transformer and also energy will be stored in the leakage inductance. At the end of the 'on' period both FETs Q3, Q4 turn off simultaneously and the primary supply current in the FETs falls to zero. By flyback action all voltages on the transformer reverse. Initially clamp diodes D19, D20 conduct clamping the flyback voltage to the supply line. All output rectifiers become forward biased and secondary current flows. When the secondary current has built up (to nxIp) and the energy stored in the primary leakage inductance has been transferred back to the supply line the energy recovery clamps D19, D20 cease conduction and the primary voltage falls back to the reflected secondary voltage. Thus all surplus stored energy is recovered to the supply line and dissipation is minimised.

On application of HVDC (390V) when the mains input is first connected C55 charges up via R48. When C55 attains 16V the under voltage lockout within U4 is released and V ref is enabled and outputs 5V. Output pin 6 delivers 15V pulses to the primary of T1 and Q3, Q4 receiver in phase drive pulses which in turn causes primary current to build up. Primary current is sensed across R47 and fed back to pin 3 U4 for feedback stability and overcurrent detection. Voltage feedback is generated from windings 10, 50 from T2 via resistor network formed by R31, R32, R33 and RV1 into pin 2 U4. frequency compensation for the error amps within U4 is accomplished by network formed by C53, R30. In addition to providing voltage feedback the feedback winding (10, 50) supplies power to U4 via D32 and C55 once the psu has started operating and supplying output power. The feedback voltage as applied to pin 2 U4 is adjustable via RV1 which sets the raw output voltage levels of all secondary windings.

Overcurrent trip operation occurs should the primary current exceed 4.5A approximately. Once I sense pin 3 (U4) exceeds 1V then the gate drive output ceases and the feedback voltage falls. Once the feedback voltage on pin 7 (U4) falls to less than 10V the V ref shuts down and C55 discharges. The only charge path for C55 now is R48 and after approximately 1-2 seconds C55 exceeds 16V and output pulses are initiated and the PSU operates.

Should a permanent short circuit be applied to one of the power output lines the psu will 'hiccup' continuously with an approximately 3 sec off time. Thus the mean power dissipated within the psu under fault conditions should be low. Gate drive is clamped by D21, 22, 17 and 18 so as not to exceed the FET gate voltage specification. R49, 50 serve, together with the FET gate capacitance, to slow the switching edges of the power drain waveform thus minimising conducted and radiated interference without causing excessive power dissipation within the FETs.

To switch the flyback converter on the opto-coupler detects the presence of a serial data stream from the display at PLTH 11, 12. On detection of the data stream the photo transistor within U5 is turned on pulling down the gate of Q2 below its threshold voltage. Q2 turns off allowing the compensation pin 1 U4 to rise enabling output of the IC U4. In the PSU off state Q2 is held on by current in R37 from Vcc. For test purposes the psu can be turned on in the absence of a serial data stream by linking 1-2 on LKA.

T2 Secondary Circuits

Modulator -600
The three isolated windings of T2 (1-20, 2-19, 3-18) are individual 200V windings each having a rectifier and reservoir capacitor. The supplies are connected in series to give the required -600V supply for the modulator.

Receiver Tuning Supply +30V
Rectifier D9 and capacitor C41 provide d.c. input to the three terminal linear regulator U1 which produces a fixed 30V output. L5 and C10 provide additional noise filtering.

Modulator IGBT Drive Supply +20V
Zener stabilisation formed by D2 and R15 converts +30V input to a stable 20V supply using L6 and C39 as additional noise filters.

Magnetron Heater Supply
D28 together with C31, 32 provide approximately 20V d.c. for the magnetron heater switch mode regulator on the modulator pcb.

Rx/Trigger Board +12V
With approximately 20V input from D28, C31, and C32 the five terminal 'simple switcher' U6 output is set to +12V by R52, R53 and R54. The switcher operates at approximately 50kHz using L8 as the step down regulator inductor and D3 as the flywheel diode. Whilst the power device within U6 is off energy is transferred to the load via L8 and D3.

Rx/Trigger Board -12V
D12, C33 provides approximately 20V d.c. into the three terminal linear regulator U2. R16, R17 set the output of U2 to -12V.

Rx/Trigger Board +5V
D29, C44 provide approximately 15V d.c. to the input of U7 a 5 terminal 'simple switcher' power IC. R55, R56 sets the output of U7 to 5V. L9 supplies power to the load, during the off period of U7, via D7. This simple switcher operates at approximately 50kHz.

All output linear regulators are protected against input short circuits by reverse diodes connected from output to input (D8, D6). Both linear regulators and simple switchers are current limited for short circuit protection.

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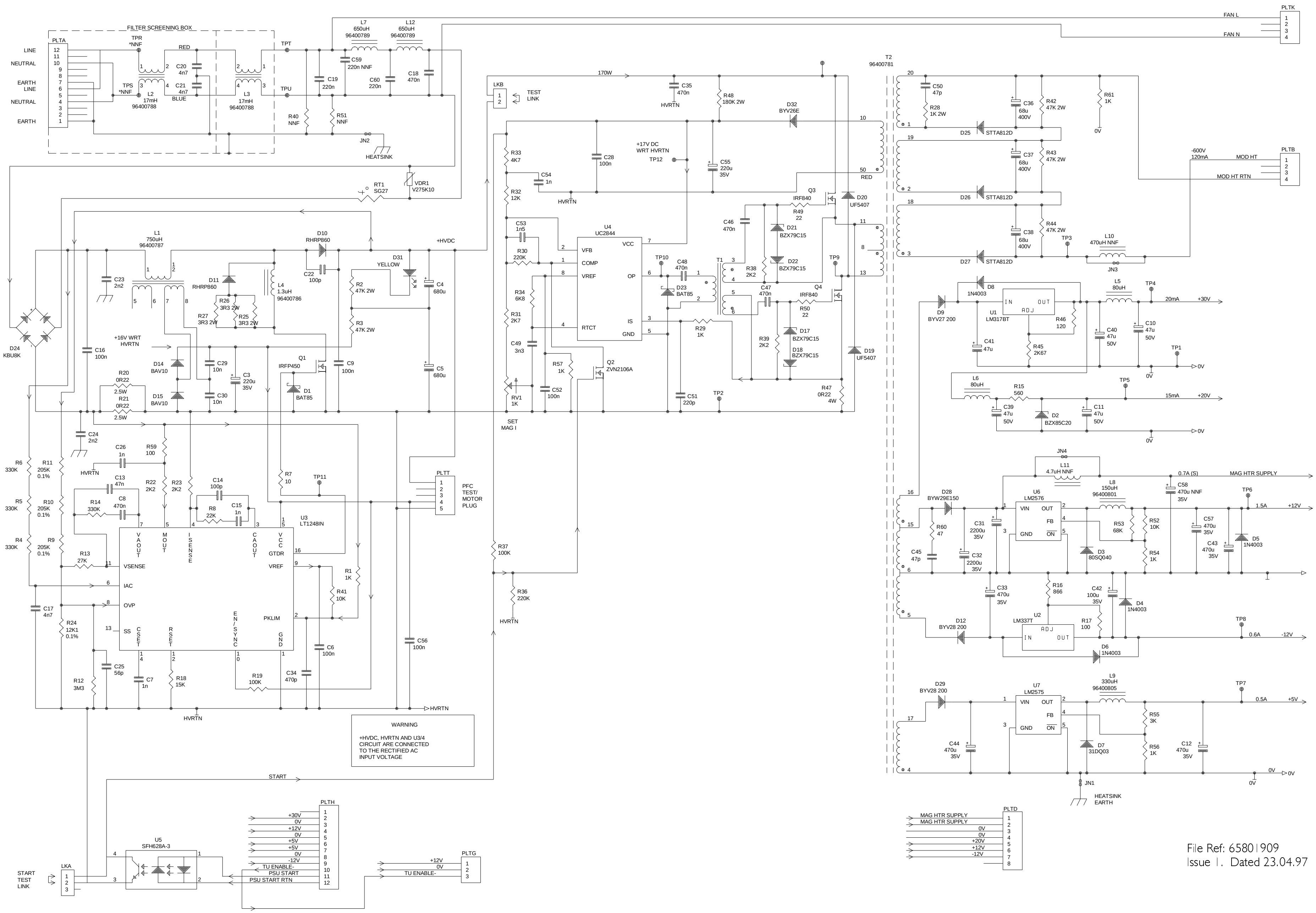

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Figure 1.31 Circuit Diagram 65830909 - S-Band Transceiver Power Supply

A3 page 1-61/62 Figure 1.31, discard this A4 sheet.

5.4 Modulator PCB (S-Band)

5.4.1 Functional Description

The principal function of the Modulator PCB is to generate an 8kV, 8A negative pulse to drive the cathode of the magnetron. An SCR is used to resonantly charge a Pulse Forming Network (PFN) to -1200V from the -600V Modulator HT supply. The charging cycle is initiated by the Charge Trigger. The number of sections of the PFN is selectable by the relays controlled by the Pulse Length Control Lines. The number of sections of the PFN used defines the length of the output pulse.

At a defined time after the PFN is fully charged it is discharged by three series connected Insulated Gate Bipolar Transistors through a pulse transformer. The discharge is initiated by the Modulator Trigger. The Pulse Transformer, which has step up ratio of 12:1, transforms the resulting pulse to 8kV. The back edges of the medium and short pulses are speeded up by a saturable reactor connected across the primary of the pulse transformer.

Other functions include regulating the magnetron heater supply, monitoring a spark gap to ensure correct operation of the magnetron, and generation of a timing reference for the Radar Trigger.

5.4.2 Inputs to the Modulator PCB

-600V Modulator HT Supply
+20V Modulator Trigger Supply
+16V - +27V Magnetron Heater Bulk Supply
+12V
-12V

Short Pulse Control Line	when 0V selects short pulse.
Medium Pulse Control Line	when 0V selects medium pulse.
Charge Trigger	initiates charging of Pulse Forming Network. Typically 1Amp current pulse.
Modulator Trigger	initiates discharge of Pulse Forming Network. Typically 4us, 3.5V positive pulse.
Turn Down Enable	dc voltage controls the magnetron heater voltage. 0V on long pulse, 3.5V Standby Medium and Short Pulse

5.4.3 Outputs from the Modulator PCB

Primary sample	positive pulse sample from pulse transformer used to initiate Radar Trigger. Typically 40V amplitude.
Magnetron current sample	a dc voltage proportional to the magnetron current derived from the secondary of the pulse transformer. Typically +2.5V (on long pulse).

TX Active	a signal that is normally 0V that rises to >2.5V if the spark gap operates continuously for 2 seconds. This signal is used by the Trigger PCB to indicate a transmitter fault to the display.
HT Sense	sample of Modulator HT Supply fed to Trigger PCB for inclusion in BITE message sent to display.
TX Define	Link settings used to define modulator type to Trigger PCB. 0V or 3.5V dependant on link settings.

5.4.4 Circuit Description (S-Band Modulator PCB)

The following circuit description is based on Circuit Diagram 65830912 given at Figure 1.32.

Magnetron Heater Supply

The magnetron heaters are derived from the Magnetron Heater Supply at PLVD1 and PLVD2. This supply may vary between 16V and 27V.

The Modulator PCB is configured for the intended magnetron by the setting of link LK1 fitted on the PCB. Refer to Figure 6.18 'Link Settings - Modulator PCB' in Chapter 6.

WARNING - On no account should the heater voltage be measured whilst the Transceiver is transmitting.

In a 30KW S-Band system, the magnetron requires a heater voltage (measured between TSJ1 and TSJ2) of 6.1V on Standby, Short Pulse, and Medium Pulse. On Long Pulse, this may be turned down to 5.1V depending on the type of magnetron fitted.

The Mag Heater Supply is connected to the input of the switching regulator U1. U1 is configured as a buck regulator running at a constant frequency of approximately 52kHz. During the time that the regulator is switched on, power is supplied to the load from the Mag Heater Supply via L106. When the regulator switches off, energy stored in L106 is transferred to the load via commutation diode D112. C112 provides output smoothing. The output voltage is sampled by the feedback network R132, R133, R145, R136, and Q102. The sample voltage is fed back to pin 4 of U1 where it is compared with an internal voltage reference. If the sample voltage fed back is greater than the internal reference voltage the time that the regulator is switched on for is reduced until the sampled voltage equals the reference voltage. Similarly if the sample voltage is less than the internal reference voltage the time that the regulator is switched on for is increased until the two voltages are equal. In this way a constant output voltage can be set by selecting values in the feedback network.

When long pulse is selected, the Turn Down Enable signal at the gate of Q102 is 0V biassing Q102 off. In this condition R136 is connected in series with the feedback network, increasing the voltage at U1 pin 4. The regulator 'on' time is therefore reduced and the output voltage is reduced to the level required for 5.0V magnetron heaters.

When Standby, Short Pulse, or Medium Pulse is selected the Turn Down Enable signal at the gate of Q102 is set by the Trigger PCB to 3.5V turning Q102 on. When Q102 is turned on, R136 is short circuited and the voltage at pin 4 of U1 is reduced.

The regulator 'on' time is therefore increased and the output voltage is increased to the level required to set the magnetron heaters to 6.3V. The inductor L103 and capacitor C115 isolate the regulator from the high voltage pulse that appears at the bias winding of T107. The voltage at the output of the regulator measured at TP106 is typically 1.5V greater than the 6.3V or 5.0V to allow for the voltage drop across L103 and the secondary of the Pulse Transformer.

Charging the PFN

With -600V supplied from the Power Supply PCB via L101, the PFN charging is initiated by the positive edge of the Charge Trigger signal on PLVC8. This trigger signal passes via the isolating transformer T101 to the gate of input SCR Q101. The positive pulse turns the SCR on to start the resonant charge. Because L101 and the capacity of the PFN form a resonant circuit, the input current to the PFN is sinusoidal in character and the line charges to about 1.8 times the Modulator HT supply voltage.

The PFN charges through Q101, the isolating diode D101, and the delay reactor L105. The charge current reaches a peak and decays to zero, and at this point D101 becomes reverse biassed and Q101 turns off. This occurs when the voltage on the PFN is at its maximum value. R106, R107, and R108 provide a discharge path for any voltage on the anode of Q101. R126, R129, R130, and R131 form a potential divider across the Modulator HT Supply to feed a sample voltage to the Trigger PCB for incorporation into the BITE message sent to the display.

Discharging the PFN

The modulator is triggered by the Modulator Trigger pulse from the Trigger PCB. This positive pulse of typically +3.5V amplitude is amplified to 20V by U3, . The output of U3 is fed to the primary of the isolating transformer T105. The transformer has three identical secondary outputs, each of which drives one of the gates of the series connected IGBT's Q103, Q104, and Q105. The transformer turns ratio is 1:1 so each gate emitter of the IGBT's is driven by a 20V positive pulse.

By clamping any signals fed back from the transformer to a safe level, D111 and D110 protect the output of U3. R121, R122, and R123 control the peak current spike into the capacity of each gate to ensure the IGBT's turn on together. Initially the delay reactor L105 is high impedance and momentarily delays the discharge of the PFN until the IGBT's are fully turned on. This ensures that high current does not flow through the IGBT's until the voltage across them has fallen to a low level. Approximately 250nS after the trigger pulse the delay reactor saturates, and the PFN is discharged through the primary of the Pulse Transformer T107. The resulting 650V primary pulse is transformed up to 8kV to drive the magnetron.

D107 in the charging circuit clamps any positive spike fed back through the capacity of D101 to protect Q101. R125, R126, R127, VDR1, VDR2, and VDR3 ensure that the voltage is shared equally across each IGBT.

Defining the Pulse Length

The PFN defines the transmitted pulse shape. It is only when long pulse is selected that all the energy stored in the PFN is transferred to the magnetron. On medium and short pulse the transmitted pulse length is controlled in two places, using RL1 and RL2.

a) The PFN
The relays are used to select the number of sections of the PFN that are used for a given pulse length. The more sections used, the longer the pulse.

b) The Tailbiter.
On short and medium pulse the PFN is used to define the start of the pulse but the width of the pulse is determined by a saturable reactor L104 (tailbiter) connected directly across the primary of the pulse transformer. The number of turns on L104 is varied to suit the pulse length required. The number of turns is selected by RL1 and RL2 dependant on the pulse length selected.

The tailbiter acts by changing from a high impedance to a low impedance to short circuit the primary of T107, terminating the drive pulse to the magnetron. The time that L104 remains in the high impedance state is dependant on the number of turns and the voltage impressed across it. Any charge remaining in the PFN when L104 changes state, is dumped into the circuit consisting of D102 and R115. The PFN is then in a fully discharged state ready for the next charging cycle.

Pulse Length	Relay Energised	PFN Capacitors in Circuit	L104 Tailbiter Winding Used
Long	None	All	None
Medium	RL2	C105, C107, C108 C109	1 - 3
Short	RL1	C105, C107	2 - 3

Relay 1 and Relay 2 Operation

Pulse Transformer

The purpose of the Pulse Transformer T107 is to match the impedance of the PFN to the impedance of the magnetron. In doing this, it also steps up the voltage pulse to the correct level to drive the magnetron. The output of the PFN is directly connected to the primary of the Pulse Transformer, and the secondary is connected directly to the magnetron cathode. A bifilar wound secondary is used to allow the heater supply to be connected to the magnetron. An additional secondary winding carrying the heater current is used to bias the core of the transformer magnetically, so that the number of secondary turns required to support the long pulse voltage pulse can be kept to minimum.

R137 and current transformer T108 in series with the primary of T107 provide a 40V positive pulse (Mag Sample) to the Trigger PCB as a timing reference for the Radar Trigger, and AFC Trigger.

R119, D104, C118, R118, and current transformer T106 in series with the Pulse Transformer secondary provide a rectified output (Mag Current Sense) proportional to the magnetron current. This voltage is passed to the Trigger PCB where it is incorporated into the BITE message sent to the display.

Zener diode D127 restricts the maximum output voltage below the level that would damage the circuit on the trigger PCB. The voltage can be monitored at TP100, and is used to set the magnetron current in service.

The EHT PCB

The two leads from the bifilar secondary of the Pulse Transformer are routed through the EHT PCB. D106, D113, and R120 clamp any positive overswing at the end of the magnetron pulse and absorb any surplus energy from the secondary of the Pulse Transformer. The spark gap (Gap 1) operates at approximately 12kV and provides protection for the Pulse Transformer if the magnetron mistriggers, or if the magnetron heaters become disconnected.

Spark Gap Detection Circuit

The earth return for the Spark Gap is routed through current transformer T104. When the Spark Gap operates the current through T104 generates a positive pulse across R138. This pulse is used to trigger monostable U4A. D124 and D125 clamp the input voltage to the monostable to a safe level. The resulting positive pulse at the "Q" of U4A charges capacitor C125 positively. The voltage at C125 +ve rises from its normal value of 0V towards +12V. This voltage is sampled by the Trigger PCB, and when the voltage rises to +2.5V the Transceiver is switched to standby and an error message is sent to the display.

On long pulse the spark gap has to be triggered for approximately two seconds for the voltage on C125 +ve to reach 2.5V. R143 provides a discharge path for C125, which discharges between monostable pulses such that the voltage on C125 returns to its normal level in approximately four seconds if there is no spark gap activity.

R139 and zener diode D122 provide a 3V bias for the electrolytic capacitor. Zener diode D126 together with D122 restrict the maximum voltage at C125 +ve to 4.5V. R147, R148 and D120 ensure that the voltage at C125 +ve is always positive. These limits are required to protect the circuitry on the Trigger PCB. Low leakage diode D121 prevents C125 discharging through the output of U4A.

5.5 Input Board (S-Band)

The following circuit diagram is also included.

Circuit Diagram 65830904 - S-Band Input Board - Figure 1.33

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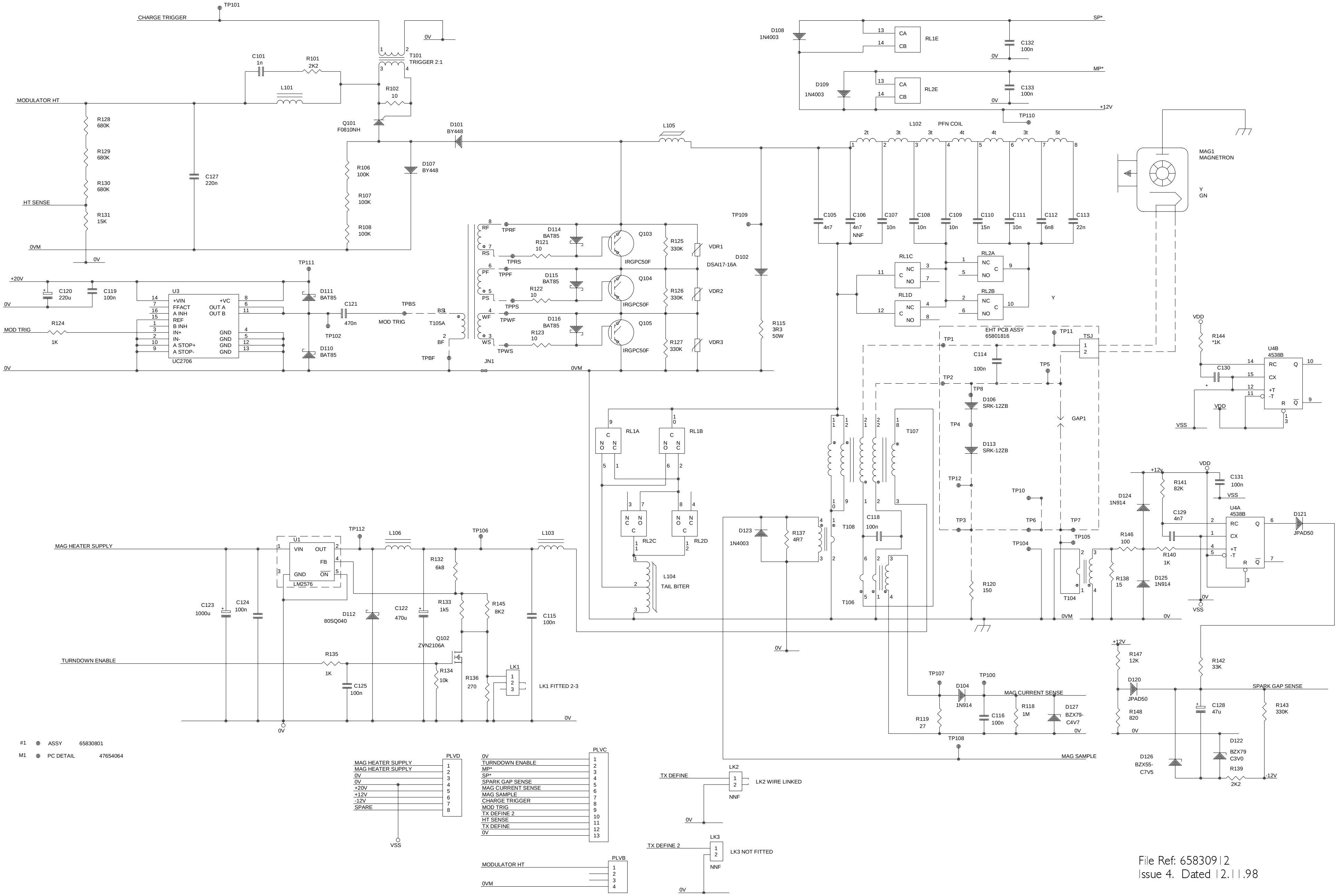

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Figure 1.32 Circuit Diagram 65830912 - S-Band Modulator Board (30kW)

A3 page 1-69/70 Figure 1.32, discard this A4 sheet

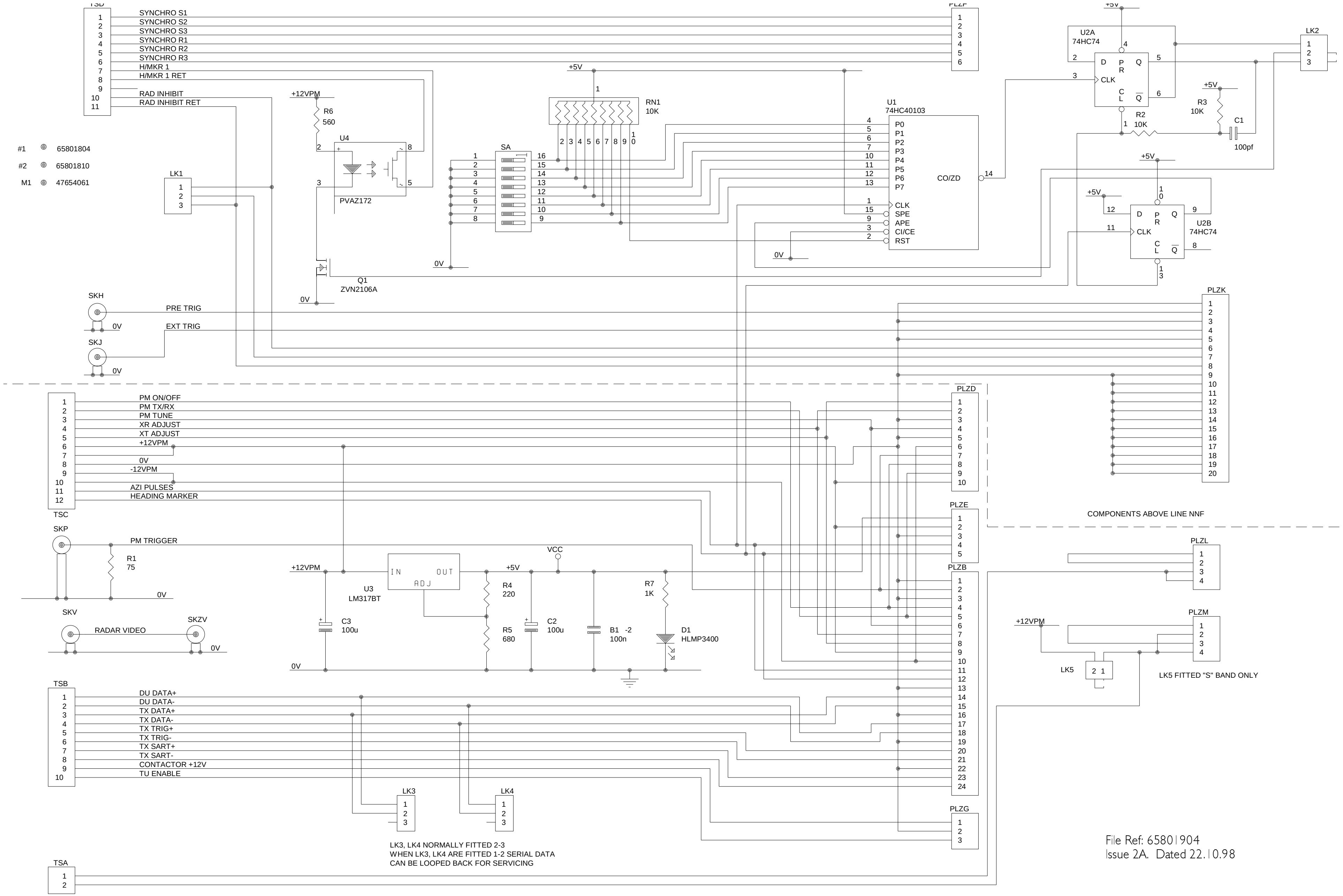

Figure 1.33 Circuit Diagram 65801904 - S-Band Input Board

A3 page 1-71/72 Figure 1.33, discard this A4 sheet.