XLS 3U SERIES
CIRCUIT DESCRIPTION AND SERVICE NOTES

INTRODUCTION

These notes are intended to assist maintenance and service of the XLS 3-rack-space family of amplifiers. Please refer to the relevant schematic diagrams and system diagram while reading this document.

The component references of the two amplifier channel electronics are appended "A" and "B" respectively. Shared circuitry (such as that of the protection system) has no suffix. This document will refer to channel A references only. Operation of channel B is identical except where explicitly noted. Voltage values in bold mentioned in the text are test voltages which may be used for diagnostic purposes. Please read the surrounding text which explains circuit operation and may qualify such measurements.

MECHANICAL CONSTRUCTION

The mechanical structure of the amplifier comprises three main components: chassis, front panel and cover.

The one-piece chassis incorporates rear panel, side panels, bottom cover and transformer mount.

The main PCB is fixed to the chassis using 4 M4x16 screws with insulating washers through the main heatsinks and 4 M4x8 screws for the edges of the board, one of which connects the chassis electrically to 0V on the PCB.

There are two heatsinks secured to the board with 3x No6 / 5/16" pozi pan 'B' point self tapping screws and 3x M3.5 shakeproof washers each. Output devices are bare mounted (with zinc oxide heatsink paste) to the heat-sinks with 2x No6 / 5/16" pozi pan 'B' point self tapping screws each. CAUTION: The heatsinks are LIVE at up to +95VDC on one AND -95VDC on the other.

The plugable input module and output module are secured using 4x No4 / 8 plastite screws and 4x M3 / 8 screws respectively.

The mechanical integrity of the amplifier is realised when the substantial frontpanel is fitted using 4x M4 /10 Flange Pozi Black screws at the sides and 2x M4 nuts behind the front. The cover is secured using 6x #8 / 3/8" Flange Pozi Black self tapping screws.

All internal wiring is plugable to allow quick removal of main PCB for repairs and servicing.

CIRCUIT DESCRIPTION

Input Stage

The input stage is built around one half of a TL072 dual operational amplifier, IC1A on the input board, configured as a unity-gain differential amplifier. Its correct operation depends on both of its input terminals being correctly terminated and, therefore, any gain errors around this stage may be a result of a faulty cable termination within the mating XLR connectors. There is no provision for trimming Common-Mode Rejection (CMR) but checking this can easily eliminate the input stage in the search for a fault.

CMR checkout procedure is as follows :

Inject a common-mode test signal at 1kHz and +4dBu to the channel under test. The common-mode test signal of the Audio Precision test system is suitable, otherwise connect the signal to both pins 2 & 3 via 56 Ohm or 47 Ohm resistors. Observe the amplifier output (with level control at maximum) which should be less than -9dBu.

Power for the input stage is derived from the main +HT and -HT supplies via 1W resistors R24 and R25 and shunt regulated to a nominal +18V, -18V by ZD3 and ZD4 respectively, all located on the main PCB. The output of the input differential amplifier is fed via DC blocking capacitor C7A and 100R "Build-out" resistor R10A to pin 5 of Header 2 (channel B - pin 2 of Header 3) and then exits the input board.

If LK1,2,3,4 are present and intact then the signal travels back onto the input board via pin 4 of Header 2 (channel B - pin 5 of Header 3).

Sub-Sonic filter and Clip Limiter

The Sub-Sonic filter is based around the other half of the TL072 dual operational amplifier, IC1A on the input board, configured as a Sallen & Key unity gain 2nd order Butterworth high pass filter. The two-pole three-position switch, SW1A, selects the following -3dB cutoff frequencies:
1) 30Hz: only C8A and C10A connected;
2) 15Hz: C11A and C12A connected in parallel with C8A and C10A respectively;
3) Off position: C14A bypassing C8A and C10A.

Limiter switch SW2 in its OFF position shorts R2A and disconnects LDR1A to turn the Clip Limiter off. In its ON position, SW2 connects R2A and LDR1A as a light-dependent voltage divider, controlling the level of the input signal. LDR1A faces LED2A, which is lit when the amplifier reaches about 1dB below clip (at the same time as the clip LED at the front). Because the resistance of LDR1A reduces as its cell area is illuminated, pushing the amplifier into clip will, therefore, cause the input signal to be reduced at the R2A -LDR1A divider. Thus the amplifier is Clip Limited.

The output of the filtering/limiting op-amp is AC coupled by C13A and built out by R11A, and continues to pin 3 of Header 2 (ch. B pin 4 of Header 3), at which point it re-enters the main board and makes its way to pin 1 of CN2A, a three-pin header making connection by wire to the level potentiometers: pin 1 is Top, pin 2 is Wiper, pin 3 is Bottom. The signal emerges from pin 2 and is fed to the input of the Power Amplifier.

POWER AMPLIFIER

The power amplifier consists of a fairly conventional Class A driver stage driving a Class AB bipolar output stage. Each stage will be dealt with individually.

Class A Driver

The input signal returned from the level control is fed via DC blocking capacitor C7A and R8A. DC bias current for the Class A input stage is supplied via R9A, while 33pF capacitor C54A prevents any extreme high frequency input signals from reaching the power amplifier and also provides a low source impedance at high frequencies to ensure frequency stability.

The first stage of the class A driver consists of Q1A and Q2A configured as a long-tailed pair differential amplifier. Emitter resistors R10A and R11A de-sensitise the performance of the input stage to parameter variations of the two input transistors. The quiescent current for the input stage is delivered by current source Q3A. Diodes D1A and D2A provide a reference voltage of approximately 1.2V, which is applied to the base of Q3A. Approximately half of this (0.6V) will then appear across R13A (220R), which then sets the current, sourced from Q3A collector at approximately 2.7mA. In the quiescent state half of this current is driven through Q1A and Q2A. Hence the voltage dropped across emitter resistors R10A and R11A will be approximately equal at 135mV.

Overall voltage feedback of the amplifier is derived through R18A and R17A. R57A and C20A provide local feedback around the Class A section only to define the dominant pole of the amplifier. C56A connected in series with R66A gives 100% DC feedback to minimize any DC offset at the output. The reulting feedback signal is applied to the base of TR53A.

The collector currents of Q1A and Q2A are fed via D3A and D4A to R15A and R16A respectively. Hence, in the quiescent state, R15A and R16A should each exhibit a voltage drop of 1.35V or so.

Under normal conditions, the signals at the bases of Q1A and Q2A will be identical. However, under fault conditions, such as a DC offset at the output, the base voltages will become offset also. For example, in the event of a large DC offset of +50V at the output, a positive DC voltage will appear at the feedback point and hence at the base of Q2A. Although this would, in theory, be the full +50V, owing to C11A being rated at only 25V, the voltage will, in practice, be somewhat lower. However, the important issue is that the voltage is positive. In the event the voltage is negative this indicates that the feedback network is faulty (most likely R18A itself).

The voltage at Q2A base being positive while the base of Q1A is close to 0V will then reverse bias Q2A base-emitter hence turning off the transistor. Hence, no voltage should appear across R11A and R16A while double the normal voltage will appear across R10A and R15A (270mV and 2.7V respectively). Should this not be the case, it indicates a fault in the input stage itself.

The output of the input long-tailed-pair (i.e. the voltages at the anodes of D3A and D4A) are fed to a second long-tailed pair Q4A and Q5A. The bias current for this stage is set by resistor R19A thus: D3A drops approximately the same voltage as the base-emitter junction of Q4A; the same can be said of D4A and the base-emitter junction of Q4A; therefore the voltage across R19A is approximately equal to the voltage across R15A and/or R16A, i.e. 1.35V. This sets a current of about 6.75mA split between Q4A and Q5A. C12A and C13A provide a little Miller Feedback around Q4A and Q5A respectively. These capacitors can be important to the stability of the amplifier but do not define the dominant pole. It should also be noted that either of these capacitors becoming "leaky" (difficult to measure in circuit) will result in a DC offset at the output.

The collector of Q5A drives the output stage in conjunction with the collector of Q7A while the collector of Q4A drives current mirror Q6A/Q7A via R20A. In the quiescent state R20A will show a voltage drop of around 67.5V, and the current mirror emitter resistors R23A R24A and will show equal voltage drops of 160mV. Hence, for the same +50V DC offset, described earlier, one would expect no voltage drop across any of R20A, R23A or R24A, indicating that the feedback is attempting to correct the fault. Likewise, for a negative DC offset one would expect these voltages to be twice their usual value. If this is not the case then the second stage (Q4A-Q7A) is at fault.

The collectors of Q5A and Q7A are joined to form the output of the class A driver by the Vbe multiplier: R22A, R21A and Q8A(mounted on the heatsink), bypassed at AC by C15A, which sets the output stage bias. The bias voltage across the Vbe multiplier should range between 2.4V (heatsink warm) and 2.5V (heatsink cold). Bias voltages outside this range indicate a fault with the Vbe multiplier and/or a fault in the second long-tailed pair (Q4A - Q5A, R19A, R20A, R23A, R24A). For example, too small a bias voltage could be caused by R19A being high, R24A being high, R21A being low, Q8A being faulty etc. Too high a bias voltage is rare, and would, most likely, be caused by a faulty transistor or resistor in the Vbe multiplier circuit.

C3A is is very important for ensuring HF Stability. A faulty capacitor in this position will usually cause excess distortion and in the case of anything less than 330pF can reveal a very spiky instability.

Power for the class A drivers is decoupled from +HT and -HT by D17, C19 and D18, C20 respectively.

Output Stage

The output stage consists of a symmetrical Siklai follower: Q9A-Q12A, R34A, R29A, R35A, R56A and C21A, generating the high current drive required for the parallel connected symmetrical follower output stage: Q13A-Q20A, R44A-R51A. V-I limiting is controlled by Q21A, Q22B, R36A-R43A, C1A, C2A, R20A, R25A-R28A, R30A, R33A, R55A, D7A-D9A, D11A, ZD3A-ZD6A.

As the output stage is symmetrical, the positive half only will be described (Q13A-Q16A, R44A-R47A, C2A, Q22A, R36A-R39A, R25A, R26A, R30A, R55A, D8A, D11A, ZD3A, ZD5A).

Output stage protection is accomplished by a three-slope V-I limiting circuit which has limiting characteristics chosen to emulate the Safe operating area of the output stage transistors at their maximum operating temperature.

The V-I limiting works by controlling Q22A: when the base-emitter voltage of Q22A exceeds about 0.65V then Q22A turns on and steals current, via D8A, from the input of the output stage and thereby limiting the output. So, V-I limiting is controlled by controlling the base-emitter voltage of Q22A.

Each output device has its own current sharing resistor -- R44A-R47A -- the voltage across which is proportional to the current flowing in the output device. These voltages are sampled and summed by R36A-R39A. C2A ensures stability when V-I limiting is activated.

The voltage across the output devices is sampled by R25A and R26A (R30A and ZD5A limit the voltage range to reduce off-load distortion) and this, summed with the output current derived signals from R36-AR39A, controls Q22A for output voltages less than about 3Vpk. Thus the amplifier is protected for short circuits because the base-emitter voltage of Q22A increases when output current increases and when voltage across the output devices increases.

For output voltages exceeding about 3Vpk, ZD3A conducts connecting R55A to sense the output voltage. In this case, as output voltage increases, the base-emitter voltage of Q22A reduces, thus the current limit is increased as the output voltage increases, defining the third slope of the limiting characteristic.

CLIP LED CIRCUIT

The clip LED (LED1A) is driven in series with the Limiter LED (LED2A) from the output of the amplifier via D13A with its threshold controlled by ZD7A and R58A. With no signal present, ZD7A and R58A generate a reference voltage at the anode of ZD7A which is 18V below the +HT supply rail. All the current flowing through R58A comes from ZD7A. To turn the LEDs on, the amplifier is required to produce an output voltage approximately 5V above the reference, at which point ZD7A is no longer in breakdown and the current flowing through R58A comes from the output stage via D13A, LED1A and LED2A. Thus the “peak” LED threshold and the “Clip Limiter” threshold vary with the +HT voltage and thus the output loading conditions.

FAULTS IN THE OUTPUT STAGE

Output device failure usually leaves you with two or more of the Collector, Emitter, Base shorted together. Deciding which of the output devices is at fault is relatively simple. Use a desoldering tool to remove the solder from the device pins (Base and Emitter) and move the pins so that they are clear of the pads. Do this for all suspects. You can now measure each output device separately with a multimeter set on the diode tester. Remember to test for all possibilities. A good output device will measure like this:

Probe connections:

For MJ15024 (npn): red (Volts/Ohms), black (COM).
For MJ15025 (pnp): reverse the red and black probes

	Correct reading
Base > Emitter	> 500mV
Emitter > Base	Open Loop or no reading
Base > Collector	> 500mV
Collector > Base	Open Loop or no reading
Collector > Emitter	Open Loop or no reading
Emitter > Collector	Open Loop or no reading

No special selection is required when replacing output devices.

If an output device has failed, it is very likely that other parts of the output stage will also have been damaged, especially Q9A - Q12A and associated resistors/capacitors and Q21A, Q22A and other parts of the V-I limiting circuitry.

Other Causes of Apparent Output Stage Faults

Output DC offsets can be caused by faults outside of the output stage itself. In the event that no dead output devices are found, check the driver stages for correct operation. The fault-finding routine should start at the feedback point: check that the DC fault is reflected at this point. Then progress through the driver stages: check that the relevant current sources are operating correctly, and that the feedback is attempting to correct the fault.

Premature clipping may also be caused by faults not connected with output device failure. Most often the fault lies within the V-I limiting circuit. This can easily be confirmed by removing D7A and D8A from the circuit board and observing if the fault clears. Note that, counter-intuitively, a faulty D8A will show as a problem on the negative half-cycle, and a faulty D7A will show as a fault on the positive half cycle. Faults within the V-I limiting circuitry can also cause some extremely strange and gross distortion, especially off load. Note that R44A-R51A, the 'current sharing' resistors are part of the V-I limiting circuitry.