Frigate®
Headphone Amplifier With Two 6922 & Two 6H30Pi Tubes

Augustica®
Technologies

www.augustica.com

DANGER

This amplifier kit has a high-voltage power supply, which provides high voltage and therefore may produce a lethal shock. Only persons who are competent at electronics assembly and understand the dangers of high voltages may attempt to assemble this kit! Safe assembly and operation of this kit is the users responsibility. The kit and this user manual are provided 'as is'. Augustica Technologies Inc. accepts no responsibility for any damage, injury or death as a result of assembling this kit or using the information herein. The assembled kit must be properly enclosed to prevent contact with high voltages and must be kept out of reach of children. Keep this kit away from water and other damp environs. As with any self-assembled electronics project improper assembly could cause damage to the kit, overloading of a circuit or an electrical fire. If you don't feel comfortable in assembling the kit or using the amplifier, please contact us to return it for a full refund.

Ideally, a variac should be used to slowly power up the power supply of the kit, as it is better to have a misoriented electrolytic capacitor or a mislocated resistor blow at low voltages, rather than at high voltages. Once the power supply is powered up, be cautious at all times. In fact, even when the power supply is disconnected or shut down, assume that capacitors of the power supply will have their high voltage charges retained and, therefore, still will be able to provide a lethal shock.

Wear safety eye goggles, which is not as bizarre as it may sound - a bursting power supply capacitor may spray hot caustic chemicals in your face. Make a habit of using only one hand, with the other hand behind your back, while attaching probes or handling high voltage gear, as a current flow across your chest can result in a lethal shock and death. In addition, wear rubber-soled shoes and work in dry environment. Remember, safety first, second, and last.

If you are not an experienced electrical practitioner, before attaching the transformer leads to the printed circuit board (PCB) of the amplifier, have someone who is well experienced in electronics review your work. Again, if you do not feel comfortable in assembling the kit or using the amplifier, please contact us to return it for a full refund.

INTRODUCTION

Tube circuit experts know that even power tubes that can deliver several hundred milliamperes of anode current can never drive a loudspeaker with an impedance of 8 Ω, since the internal impedance of a tube is several kiloohms. The two impedances are thus almost always matched using a transformer. In principle, there is no any objection to using this form of impedance matching, but every transformer tends to degrade the sound quality. Keeping this effect to a minimum requires very careful and complicated coil winding techniques, good-quality transformer iron and large core cross-sections. However, if the load impedance is not just a few ohms but instead several hundred ohms, as is the case with many types of headphones, and if in addition the required power level is not overly high, an amplifier with no output transformer - sometimes referred to as an 'output transformerless' (OTL) amplifier - can be a feasible option. In such a case, the load is driven directly by the tubes.

The headphone amplifier kit Frigate® allows building a headphone amplifier with outstanding sound. Frigate® omits the output transformer, avoids overall negative feedback and uses only high quality audiophile grade coupling capacitors, resistors and other components. The Electro Harmonix® 6922 and 6H30Pi tubes in left and right channels are closely matched, therefore, the amplifier guarantees a highly linear frequency characteristic and low crosstalk between the left and the right channels. The headphone amplifier Frigate® employs a two-stage design suitable for use with a single or dual headphone, with each headphone element having impedance between 15 and 300 Ω for the total impedance of 30 to 600 Ω.

AMPLIFIER - THEORY OF OPERATION

The circuit of the headphone amplifier Frigate® is shown in **Figure 1** (Frigate's schematic also appears on the website www.Augustica.com) uses the readily available Electro Harmonix® 6922 and 6H30Pi double triodes to provide amplification. For the purposes of this discussion, we will be considering left channel of the amplifier. Right channel of the amplifier Frigate® is identical in its construction and operation to the left channel and therefore its description will be omitted. A preamplifier stage is necessary to generate signal amplitudes sufficient to drive 6H30Pi which in turn will drive a headphone. The first section of 6922 with base pins 1, 2 and 3 and the second section of 6922 with base pins 6, 7, and 8 are used for this purpose. The input signal arrives to the circuit board via a 100-kilo Ω logarithmic potentiometer R1 that serves as a volume control and is directly coupled to the preamplifier stage via capacitor C1. Resistor R2 provides the necessary negative grid bias. Resistor R5 determines the gain, while resistor R4 determines the maximum input voltage. The value of the resistor R5 is selected to assure that the quiescent anode current is situated in the most linear possible portion of the characteristic curve for 6922.

The inverted and amplified input signal on the anode of the first section of 6922 is coupled to the grid of the second section of 6922 via capacitor C2. The cathode resistor of the second section is split into two resistors R7 and R8. The series resistance of R7 and R8 forms the load resistance, while the voltage division provided by the resistor pair allows the grid bias to be set to the proper level. The bias voltage is decoupled from the load and stabilized by resistor R9 and capacitor C3 before being applied to the grid of the second section of 6922. The anode current flowing through resistor R6 to the triode, which depends on the grid voltage and corresponding characteristic curve, generates a voltage across the combination of R7 and R8 that is exactly proportional to the current. This voltage is amplified by the second section of 6922 and is fed to the grids of the first and second sections of 6H30Pi via coupling capacitor C4.

Dual triode 6H30Pi is employed to provide amplification required to drive a headphone. The first and second sections of 6H30Pi are connected in parallel to increase the output power provided by the tube. Diodes D1, D2, and D3, along with resistors R12 and R13 provide the necessary negative grid bias. Resistor R15 determines the gain, while diodes D1, D2, and D3, along with resistor R14 determine the maximum input voltage. The value of the resistor R15 is selected to assure that the quiescent anode current is situated in the most linear possible portion of the characteristic curve for 6H30Pi. The signal amplified by both sections of 6H30Pi is fed to the headphone via coupling capacitor C6. Resistor R17 holds the output at ground potential for DC signals in order to avoid crackling noises when the headphone is plugged into stereo jack.

POWER SUPPLY - THEORY OF OPERATION

The power supply for the headphone amplifier Frigate® is shown in **Figure 2**. The power supply uses two transformers (not shown on the schematic). The first transformer is employed to provide high AC that is rectified to B-plus DC voltage and applied to anodes of 6922 and 6H30Pi tubes in the left and right channels. This transformer is connected to the terminal block K1 of the power supply. The second (filament) transformer has two secondary windings. Each secondary winding of the second (filament) transformer is employed to provide a separate low voltage applied to filaments of 6922 and 6H30Pi tubes in the left and right channels. In other words, each channel of the amplifier Frigate® has its own filament power supply. The transformer windings that supply voltage to the filaments of the left channel are connected to the terminal block K3. The transformer windings that supply voltage to the filaments of the right channel are connected to the terminal block K5.

The high AC voltage produced by the first transformer is rectified by the rectifying bridge D1-D4 and then is smoothened by capacitors C5, C6, C7, and C8. The capacitors C1, C2, C3, and C4 connected in parallel with the diodes of the rectifying bridge D1-D4 suppress high-frequency noise generated by the diodes of the rectifying bridge D1-D4. The high DC voltage then is applied to a MOSFET transistor IC1 that serves as a voltage regulator and AC filter. Resistors R1 and R2 of the power supply are responsible for a 15 second delay during which the high B-plus DC voltage reaches its maximum level of 300

Volts (without any load). This delay is significantly increases longevity of the 6922 and 6H30Pi lifespan. Finally, additional smoothening of the high B-plus DC voltage is provided by capacitors C9 and C10. Red LED D7 serves not only as high B-plus DC voltage pilot light, but also, together with resistors R3 and R4, provides a minimum load and ensures that the high capacitance capacitors C5, C6, C7, C8, C9, and C10 are discharged once the power supply is switched off, even if no load is connected to the power supply. Diodes D5 and D6 are protecting the MOSFET transistor IC1 from surges of current that may develop after the power supply is switched off.

For the purposes of this description we will be dealing with the stage of the power supply that supplies filament voltage to the tubes of the left channel of the amplifier Frigate®. The stage of the power supply that supplies filament voltage to the tubes of the right channel is identical to the one that supplies filament voltage to the tubes in the left channel and its description therefore will be omitted. The low AC voltage produced by the second (filament) transformer is rectified by the rectifying bridge D8–D11 and then is smoothed by capacitors C15, C16, C17, and C18 of the power supply. The capacitors C11, C12, C13, and C14 connected in parallel with the diodes of the rectifying bridge suppress high-frequency noise generated by the diodes of the rectifying bridge D8–D11. High stability filament voltage of 6.3 Volt is produced in a simple manner using a low drop voltage regulator IC2 LD1084V. Finally, additional smoothening of the filament DC voltage is provided by capacitors C19 and C20 of the power supply. Green LED D14 serves not only as a pilot light, but also, together with resistor R7, provides a minimum load and ensures that the high capacitance capacitors C15, C16, C17, C18, C19, and C20 are discharged once the power supply is switched off, even if no load is connected to the power supply. Diodes D12 and D13 are protecting the low drop voltage regulator IC2 from surges of current that may develop after the power supply is switched off.

ASSEMBLY OF THE POWER SUPPLY PCB

Cleanliness is essential. Before soldering, be sure to clean both sides the PCB with 70% to 90% isopropyl alcohol. Do not use dull looking solder. Solder should shine. If it does not shine, first clean away the outer oxidation with some steel wool or a copper-scouring pad. If the resistor leads look in the least gray, clean away the oxidation with either steel wool or a wire sniper’s sharp edges. Admittedly, with new resistors and a fresh PCB, such metal dulling is rare, but if the parts have sat in your closet for a year or two, then expect a good amount of oxidation to have developed.

Be consistent in orienting the resistors, capacitors and diodes. Keep nominal information on a resistor's, capacitor's, or diode's body flowing from the left side to the right side as you face the resistor, the capacitor, or the diode straight on. This will pay dividends later, if you need to locate and de-solder a resistor, a capacitor, or a diode placed in a wrong location. Because the board is double sided, with traces and pads on each side, it is easier to solder the resistors from their topside. As the PCB is overbuilt, it is difficult to remove an incorrectly placed part. Be sure to confirm all the electrolytic capacitor orientations, as

a reversed polarized capacitor can easily vent (or even explode) when presented with high-voltage. Confirm trice, solder once.

The headphone amplifier kit Frigate® has two printed circuit boards (PCB). One PCB houses the power supply and the other houses the amplifier. Start assembly of Frigate® with assembly of the power supply PCB. Start the assembly of the power supply PCB with assembly of the high B-plus DC voltage bus of the power supply and first attach the MOSFET transistor IC1 to its heatsink. This transistor is extremely sensitive to electric static, therefore, you must use ESD safe soldering station and you also must ware an ESD bracelet. Once you attached the MOSFET transistor to its heatsink, you can insert heatsink leads and the MOSFET transistor leads into the power supply's PCB. Solder the leads of the MOSFET transistor to the PCB of the power supply. At this point do not solder the heatsink's leads to the PCB - you will do it later.

Second, solder the rectifying bridge D1-D4 and capacitors C1, C2, C3, and C4 of the power supply. Pay attention to the polarity of the rectifying bridge D1-D4. Now solder terminal block K1. Connect a transformer or variac to the terminal block K1 and slowly bring voltage to 220 Volt AC. Measure the high B-plus DC voltage produced by the rectifying bridge D1-D4. If you applied 220 Volt AC to the rectifying bridge, after rectification, you should obtain about 320 Volts DC without any load.

Third, solder diodes D5 and D6 and then solder resistors R1 and R2 of the power supply followed by capacitors C5, C6, C7, C8, C9 and C10. Solder red LED D7 and resistors R3 and R4 followed by terminal block K2. Connect a transformer or variac to the terminal block K1 again and slowly bring voltage to 220 Volt AC. Measure the high B-plus DC voltage (at the terminal block K2) produced by the high voltage bus of the power supply as a whole. If you applied 220 Volt AC to the terminal block K1, the power supply should deliver about 320 Volts DC to the terminal block K2 without any load. Measure AC component that is present in the DC voltage after it is regulated and filtered by the MOSFET transistor IC1. The AC component of the high B-plus DC voltage should fluctuate between 2 millivolts and 20 millivolts AC. If your measurements show substantially higher values of the AC component present in the high B-plus DC voltage, your MOSFET transistor is probably burned out and it has to be replaced. Otherwise, the MOSFET transistor IC1 is regulating and filtering the high B-plus DC voltage properly and now you can solder to the power supply PCB the heatsink on which the MOSFET transistor IC1 is situated.

Fourth, assemble the left channel of the low DC voltage (filament) bus of the power supply and start with attaching IC2 low drop voltage regulator LD1084V to its heatsink. Once you attached the LD1084V to its heatsink, you can insert heatsink leads and LD1084V leads into the power supply PCB. Solder the IC2 regulator's leads to the PCB. At this point do not solder the heatsink's leads to the PCB - you will do it later.

Fifth, solder the rectifying bridge D8-D11 and capacitors C11, C12, C13, and C14. Pay attention to the polarity of the rectifying bridge D8-D11. Solder terminal block K3.

Connect a transformer or variac to the terminal block K3 and slowly bring AC voltage to 12 Volt AC. Measure the DC voltage produced by the rectifying bridge D8-D11. If you applied 12 Volt AC to the rectifying bridge, you should obtain about 17 Volts DC after rectification.

Sixth, solder diodes D12 and D13 and then solder resistors R5 and R6 followed by capacitors C15, C16, C17, C18, C19, and C20. Now solder green LED D14 and resistor R7 followed by terminal block K4. Connect a transformer or variac to the terminal block K3 again and measure the voltage produced by the left channel of the power supply (at the terminal block K4) as a whole. If you applied 12 Volt AC to the terminal block K3, the power supply should deliver about 7 Volt DC at the terminal block K4. Measure AC component that is present in the filament DC voltage after it is regulated and filtered by the IC2 LD1084V. The AC component of the filament DC voltage should be about 0.6 millivolts AC. If your measurements show substantially higher value of the AC component present in the DC voltage, your IC2 LD1084V is probably burned out and it has to be replaced. Otherwise, the IC2 LD1084V is stabilizing and filtering the filament DC voltage properly and now you can solder the to the PCB the heatsink on which the IC2 LD1084V is situated.

Seventh, assemble the right channel of the low DC voltage (filament) bus of the power supply and start with attaching IC3 low drop voltage regulator LD1084V to its heatsink. Once you attached the LD1084V to its heatsink, you can insert heatsink leads and LD1084V leads into the power supply PCB. Solder the IC3 regulator's leads to the PCB. At this point do not solder the heatsink's leads to the PCB - you will do it later.

Eighth, solder the rectifying bridge D15-D18 and capacitors C21, C22, C23, and C24. Pay attention to the polarity of the rectifying bridge D15-D18. Solder terminal block K5. Connect a transformer or variac to the terminal block K5 and slowly bring AC voltage to 12 Volt AC. Measure the DC voltage produced by the rectifying bridge D15-D18. If you applied 12 Volt AC to the rectifying bridge, you should obtain about 17 Volts DC after rectification.

Ninth, solder diodes D19 and D20 and then solder resistors R8 and R9 followed by capacitors C25, C26, C27, C28, C29, and C30. Now solder green LED D21 and resistor R10 followed by terminal block K6. Connect a transformer or variac to the terminal block K5 again and measure the voltage produced by the right channel of the power supply (at the terminal block K6) as a whole. If you applied 12 Volt AC to the terminal block K5, the power supply should deliver about 7 Volt DC. Measure AC component that is present in the filament DC voltage after it is regulated and filtered by the IC3 LD1084V. The AC component of the filament DC voltage should be about 0.6 millivolts AC. If your measurements show substantially higher value of the AC component present in the DC voltage, your IC3 LD1084V is probably burned out and it has to be replaced. Otherwise, the LD1084V is stabilizing and filtering the filament DC voltage properly and now you can solder the to the power supply PCB the heatsink on which the IC3 LD1084V is situated.

Now, set aside the power supply's PCB and start soldering the headphone amplifier's PCB.

ASSEMBLY OF THE AMPLIFIER PCB

Tenth, solder resistors, capacitors, diodes and tube sockets of the left channel of the headphone amplifier Frigate®. Start with the tube sockets, followed by the resistors, capacitors, and diodes. Finally, solder volume control potentiometer R1, headphone stereo jack, and terminal block K1 of the amplifier.

Grounding of the volume control potentiometer R1 is required as without it, the amplifier Frigate® may be subject to static noise or radio frequency interference. Cut out a wire having length of at least 15 centimetres. Strip out isolation from the wire. Wrap the wire around the threaded portion of the potentiometer's neck making two loops and after that twist together the two ends of the wire. Put on washer and nut included in the kit together with the potentiometer R1. Solder the wire to the ground pad on the bottom side of the amplifier's PCB.

Eleventh, solder resistors, capacitors, diodes and tube sockets of the right channel of the headphone amplifier Frigate®. Start with the tube sockets, followed by the resistors, capacitors, and diodes.

Before testing the headphone amplifier Frigate®, visually inspect the amplifier's PCB for breaks in symmetry between the left and right channels.

TESTING

First, attach only low voltage (filament) power supply’s transformer leads to the terminal block K3 of the power supply's PCB, leaving the other set of the filament transformer leads, and the high voltage transformer leads unattached and electrical tape shrouded. Do not install 6922 and 6H30Pi tubes in their sockets.

Second, apply the low AC voltage to the terminal block K3 in the left filament bus of the power supply, while looking for smoke or part discoloration or bulging.

Third, attach the second set of the filament transformer leads to the terminal block K5, while looking for smoke or part discoloration or bulging.

Fourth, using wire, connect the terminal block K4 on the power supply's PCB with the terminal block K3 on the amplifier's PCB. Measure the filament voltage regulator IC2 LM1084V output voltage with the load provided by the left channel filament bus of the amplifier Frigate®. If the filament voltage regulator IC2 LD1084V fails to regulate, try either lowering the filament voltage a tad, or increasing it a tad, for example try 16 Volt

instead of 17 Volt, as the 1 Volt difference might be enough to bring the regulator back into regulation.

Fifth, using wire, connect the terminal block K6 on the power supply's PCB with the terminal block K4 on the amplifier's PCB. Measure the filament voltage regulator IC3 LM1084V output voltage with the load provided by the right channel filament bus of the amplifier Frigate®. If the filament voltage regulator IC3 LD1084V fails to regulate, try either lowering the filament voltage a tad, or increasing it a tad, for example try 16 Volt instead of 17 Volt, as the 1 Volt difference might be enough to bring the regulator back into regulation. Power down the filament buses of the power supply by disconnecting low voltage filament transformer or variac from the power supply of the amplifier Frigate®.

Sixth, attach the high B-plus voltage transformer leads to the terminal block K1 of the power supply's PCB and insert the 6922 and 6H30Pi tubes in their sockets on the amplifier's PCB. Using wire, connect the terminal block K2 on the power supply's PCB with the terminal block K2 on the amplifier's PCB.

Seventh, bring up the AC voltage.

Eighth, measure the voltage across ground and B-plus pads of the amplifier's PCB in the left and right channels. If the B-plus voltages of two channels differ by more than 10 VDC, try switching 6922 and 6H30Pi tubes from one channel to the other. If the voltage imbalance does not follow the tubes, there is a problem, probably a misplaced part. Only after you are sure that both filament and B-plus power buses are working properly should you attach the amplifier Frigate® to a headphone.

LET US KNOW WHAT YOU THINK

If you would like to see some new audio PCB or kit or recommend a change to an existing product, drop us a line by e-mail on the website www.Augustica.com (begin the subject line with “Frigate” or the SPAM filters are sure to eat your message).