Guitar Amplifier - Technical Description - Preliminary

A fully featured guitar amplifier using cascaded progressive distortion and attenuation stages in the preamplifier, and either a Class-AB push-pull or a Class-A single ended output stage.

Contents

Build details are shown in the Construction Manual supplied with the kitset.

Difficulty Level (1-5) 3.5

Revision date 20-9-22

Why Valves?

3-500Z transmitting valves undergoing stress testing. If you ever see anodes this colour there is something very wrong! Photo: James Hawkins (Amateur Radio Callsign WA2WHV).

Despite the incredible technological development since the valve era, and the exceptional performance of modern solid-state devices, many musicians and audiophiles still prefer the sound of an old-fashioned clunky valve amplifier. How could valves possibly survive when they are clearly technically inferior? How could a state-of-the-art audio amplifier with impeccable specifications, vanishingly low distortion, and oodles more power, ever be considered inferior to something developed about a century ago?

Almost 40 years ago, (together with Ron Keeley, a noted Australian musician), I designed and described a 140 Watt DIY valve guitar amplifier in the Australian edition of Electronics Today International magazine (Eti) - a popular electronics magazine still published in some countries.

The words Ron and I penned on our Remington typewriters in 1980 are just as relevant today; “the valve vrs. transistor argument will probably never be settled conclusively. Despite all the obvious advantages of solid state musicians prefer valves because, they say, valve amps simply sound ‘better’, subjectively – like the preference some people have for an old Harley-Davidson or Triumph motorbike, rather than a modern high-revving performance machine. On the other hand there are definite technical reasons why a valve amp will sound ‘different’.

It’s All About The Sound …..

“The reason most often advanced is that valves produce predominantly second harmonic distortion, whereas transistor amp distortion is mainly third harmonic. While this is true, it is not the whole truth; the distinctive sound of valves is caused by the synergy of many factors, and the spectral balance of the distortion factors is just one of them. Other important factors are the shape of the distortion-power curve, the fact that valve amps are transformer coupled to the load (which affects the overall response of the amp), the higher output impedance of valve amps (resulting in reduced damping of the loudspeaker and a more ‘colourful’ sound), and the higher ‘dynamic output’ of valve amps (the ability to deliver relatively constant power output to a varying load; i.e. a speaker). If all these factors could be built into a transistor amp, then possibly it would sound, subjectively, like a valve amp. Many have tried to do this – most have failed”.

I do hope this quality guitar amplifier brings you lots of satisfaction, both in its construction and its use. I also really do appreciate feedback on any issues you may have and any suggestions about how we can improve this project. Send us an email at www.redrookits.com.au   Have fun!

Phil Wait, RedRoo Kits, Sydney.

Safety Precautions - Read Me!

Valve amplifiers can be dangerous if they are physically damaged, misused, poorly located, or are being worked-on without taking appropriate safety precautions. Valve equipment contains hazardous voltages, (several hundred volts or more), and it can hold a high-voltage charge for a very long time even after the power is switched-off.

Valve circuitry can be very hazardous, even after the power is switched-off. Make sure the internal high voltage power supply is fully discharged before working on any part of the circuit.

- ***Only work on valve circuitry if you are experienced in working with high voltages.***
- ***Make sure somebody is with you, and have an emergency resuscitation chart on the wall of your work area.***
- ***Switch off the equipment at the power point and remove the power-plug.***
- ***Wait several minutes and then check the HV power supply with a DC voltmeter. Do not touch any part of the circuitry unless the DC voltmeter is reading less than 30V.***
- ***Even if the voltmeter reading indicates that the power supply is safe, never trust the meter alone - always double-check. Use a thick insulated wire (bared at the ends), or a screwdriver with a plastic handle, to short out the power supply to the chassis-ground.***
- ***If you need to take measurements or trace signals in valve circuitry while it is switched-on, always keep your free hand in your pocket. Never hold the chassis.***

Never work on hazardous voltage equipment if you are alone.

Valves run very hot and can cause a nasty burn. They can also ignite materials that come into contact with them such as a curtain flapping in the wind.

- ***Position valve equipment carefully so it is away from combustible materials.***
- ***Leave at least 200mm clearance on all sides and the top for adequate ventilation.***
- ***Do not locate valve equipment near curtains or any flammable material.***
- ***Never leave a valve amplifier switched on when unattended.***
- ***Keep out of reach of children***

Never leave valve equipment unattended. Always switch it off after use.

Overview

The preamplifier section is a multi-stage progressive overdrive/distortion design, with cascaded 12AX7 amplifier stages, each followed by a resistive attenuator. Progressive overdriven stages are biased hot and cold, to give a particular mix of distortion characteristics.

An effects loop can be connected between the preamplifier and power amplifier sections, with an effects by-pass switch if that function is not required.

The power amplifier section uses a 12AT7 effects recovery and voltage amplifier, and an NPN transistor phase splitter driving the output stage. The output stage is push-pull using either EL34 or 6L6 tubes giving about 18 Watts RMS into 4, 8, or 16 Ohm speakers. Using a different type of output transformer, it can also be configured as a paralleled-tube single-ended output stage giving about 8 Watts of pure Class-A sound. Presence and Depth controls tailor the feedback response around the output section.

The front panel has high and low sensitivity guitar inputs, and controls for Gain, Bass, Midrange ,Treble, Volume, Presence and Depth. This combination gives you a great ability to tailor the sound to your taste. The separate gain and volume controls allow you to adjust the amount of overdrive at any volume level. There is a power on-off switch, and a mute switch, each with their own indicator lights.

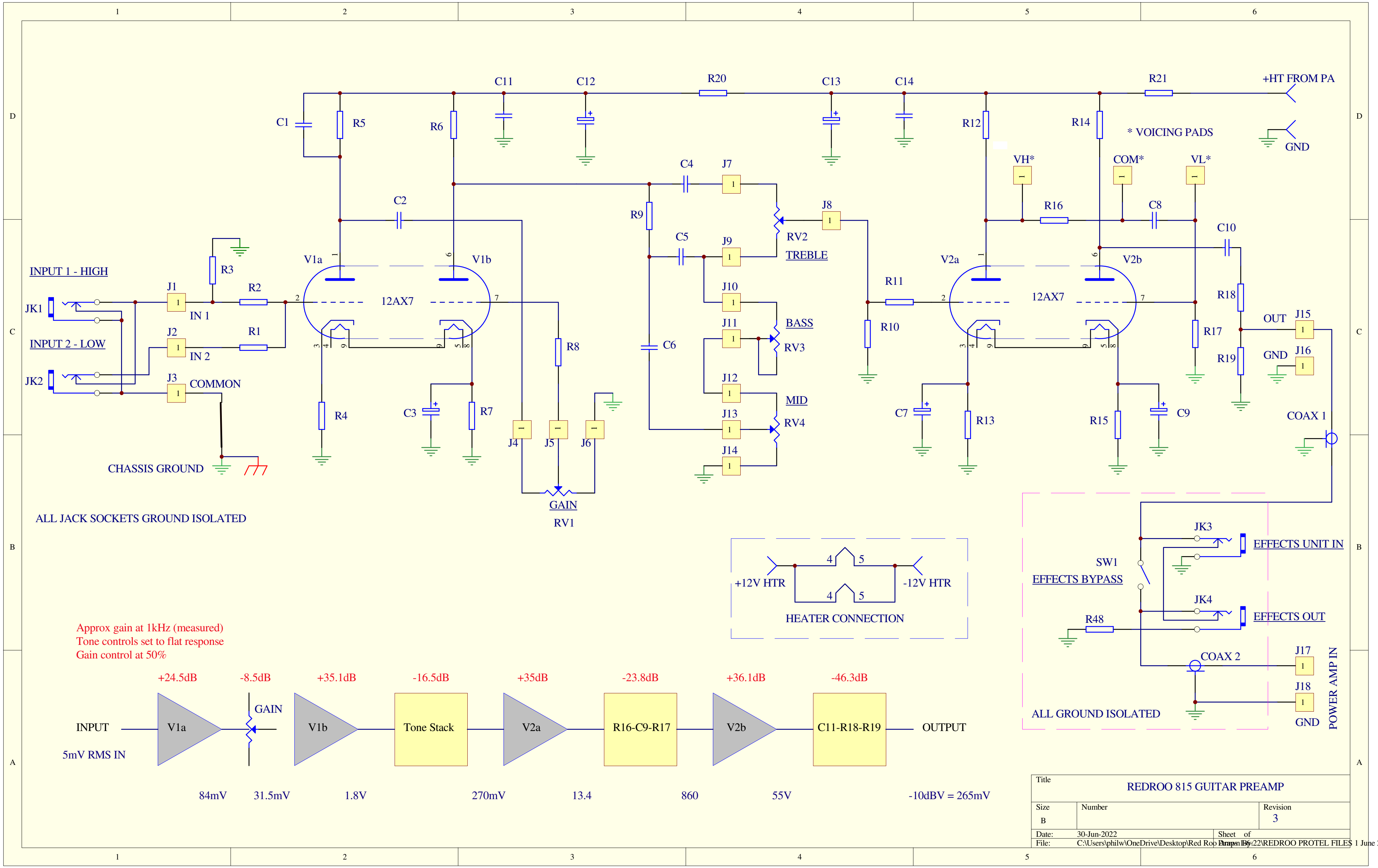
The rear panel has 6.5mm jack connections for the effects loop input and the the speaker connections, and an effects bypass switch. Like other RedRoo amplifier designs, all components are mounted on a PC Board, so tricky point-to-point wiring is minimised. The front panel components (potentiometers etc.) can either be soldered-in, or plugged-in for ease of assembly and replacement. Valve technology is used exclusively in the audio signal path apart from the phase splitter/buffer which uses a high-voltage NPN transistor.

The amplifier is powered from a 12Volt 10Amp in-line computer type power module, ort any 12VDC source capable of at least 7.5 Amps.

An internal voltage-boost inverter module converts the nominal 12V DC input to the high voltage (280V) required by the valves. Using a boost-inverter power supply has several advantages over traditional mains transformer-based power supplies, including: much smaller lighter and less expensive than transformer based circuitry; no power supply induced mains hum in the speaker output; 12V DC is available for the valve heaters; and most importantly, no need for DIYérs to work with mains-power wiring.

There are two options that can be fitted later: a foot-operated overdrive function which it’s own gain control on the amplifier; and a sag function switch for those who like the compressed sound of vintage amplifiers, with three sag settings.

This technical description is in two sections: Preamplifier and Power amplifier. Hi-Fi buffs beware; you are entering a completely different world where amplifiers spend most of their time being overdriven, distortion is king, and you need a loudspeaker intended for Guitar use.



C11
C12
R20
C13
C14
R21
+HT FROM PA
GND
C1
R5
R6
R12
R14
* VOICING PADS
VH*
COM*
VL*
C4
J7
J8
R9
C2
C5
J9
RV2
TREBLE
R16
C8
C10
V1a
V1b
V2a
V2b
12AX7
12AX7
INPUT 1 - HIGH
R3
J1
R2
IN 1
JK1
INPUT 2 - LOW
J2
R1
IN 2
JK2
J3
COMMON
R11
R10
J10
J11
BASS
RV3
J12
MID
RV4
J13
J14
C6
R8
R4
C3
R7
J4
J5
J6
GAIN
RV1
CHASSIS GROUND
ALL JACK SOCKETS GROUND ISOLATED
C7
R13
R15
C9
R18
R17
R19
OUT
J15
GND
J16
COAX 1
JK3
EFFECTS UNIT IN
SW1
EFFECTS BYPASS
JK4
EFFECTS OUT
R48
COAX 2
J17
J18
GND
POWER AMP IN
ALL GROUND ISOLATED
+12V HTR
-12V HTR
HEATER CONNECTION
Approx gain at 1kHz (measured)
Tone controls set to flat response
Gain control at 50%
+24.5dB
-8.5dB
+35.1dB
-16.5dB
+35dB
-23.8dB
+36.1dB
-46.3dB
INPUT
5mV RMS IN
V1a
GAIN
V1b
Tone Stack
V2a
R16-C9-R17
V2b
C11-R18-R19
OUTPUT
84mV
31.5mV
1.8V
270mV
13.4
860
55V
-10dBV = 265mV
Title
REDROO 815 GUITAR PREAMP
Size
B
Number
Revision
3
Date:
30-Jun-2022
Sheet of
File:
C:\Users\philw\OneDrive\Desktop\Red Roo Amps\July 22\REDROO PROTEL FILES 1 June 22\REDROO GUITAR A
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How it Works - Preamplifier Section

Please refer to the circuit diagram on the previous page. The gain budget block diagram below the circuit diagram shows the gain, or loss, of each stage at 1kHz.

This preamplifier is a high-gain cascading distortion design, where V2b will break into distortion first, followed by V2a as the signal level increases further, and then V1b at very high gain settings. This gives a progressive onset of distortion, rather than the sudden lurch into distortion found in simpler low-gain circuits with fewer tubes.

As the guitar signal from the input progress through the preamplifier, it is alternatively amplified and attenuated. The first two amplifier stages V1a and V1b operate cleanly (unless at full gain) and almost all the overdrive occurs in V2a and V2b, after the tone controls. This gives distorted filtered audio, rather than filtered distortion if the tone controlls were placed later in the circuit.

To compensate for the extremely high gain, attenuators are used between each amplifier to reduce the total system gain back to a usable level, and to set the correct signal level for the desired onset of overdrive in the next amplifier stage. Attenuation is provided by the gain control, the tone stack, R16-R17, and R18-R19.

To obtain a particular distortion characteristic with a good deal of 2nd harmonic distortion, V1a and V2a are biased cold and V1b and V2b are biased hot, set by the value of their cathode resistors. The amount of overdrive/distortion in the preamplifier is set by the gain control, RV1. Let's now look at each stage in detail.

The Input Stage (V1a)

The input to the preamplifier uses a pretty common guitar jack socket circuit providing both high and low sensitivity inputs. When a guitar is plugged into the high sensitivity input, R1 and R2 are placed in parallel and in series with the grid of V1a. When a guitar is plugged into the low sensitivity input, R1 and R2 form a 6dB (half-voltage) voltage divider, and a lower voltage signal is sent to the grid of V1a.

V1a is a voltage amplifier which provides about 24db (x16) gain prior to the gain control. The high frequency response is determined by the input miller capacitance of V1a and the value of C4. The low frequency response is determined by the value of C2.

2nd Amplifier Stage (V1b)

V1b provides additional gain (about 36dB) prior to the tone stack. This is necessary to overcome the loss in the passive tone stack, and to allow some overdrive in V1b at maximum gain setting. The low frequency response of this stage is determined by the value of C3.

Tone Stack

The tone stack comprises the components R9, C4-C6, and the treble, midrange and bass controls RV2-RV4. The component values used give a classic Fender tone response. The circuit has a loss of about 10dB @1kHz when RV2-RV4 are set to midrange.

3rd Amplifier Stage (V2a)

After the tone controlls, the filtered audio is fed to the grid of V2a. This stage is cold-biased with a larger than normal value cathode resistor, giving a higher than normal grid bias voltage. This stage provides about 35dB of gain and will easily overdrive as the gain control is advanged. The cathode bypass capacitor C7 sets the low frequency response.

1st Resistive Attenuator (R16, R17) and Coupling Capacitor C8

The attenuator formed by R16 and R17 reduces the signal level by about 24dB. This attenuation is chosen to produce the desired cascaded overload characteristics, where V2b is the first stage to overload as signal is increased, followed then by V2a.

The coupling capacitor C8, working together with the output impedance of V1a and R16, provides about 5.5dB attenuation at 82Hz. This capacitor provides a the majority of fixed bass cut to the preamplifier circuit.

Large PC Board pads, VH-Com-VL, are provided to allow shunting of R16 and C8 to change the frequency response of this attenuator circuit to suit your taste.

4th Amplifier Stage (V2b)

V2b is the final amplifier stage in the preamplifier. It is biased hot, with a low value cathode resistor and a low grid bias voltage, so it will almost always produce compression on each positive half-cycle of signal voltage, giving predominantly 2nd harmonic distortion during overdrive. It is also the first stage in the preamplifier to overdrive as signal levels increase or the GAIN control is advanced.

2nd Resistive Attenuator (R18, R19) and Coupling Capacitor C10

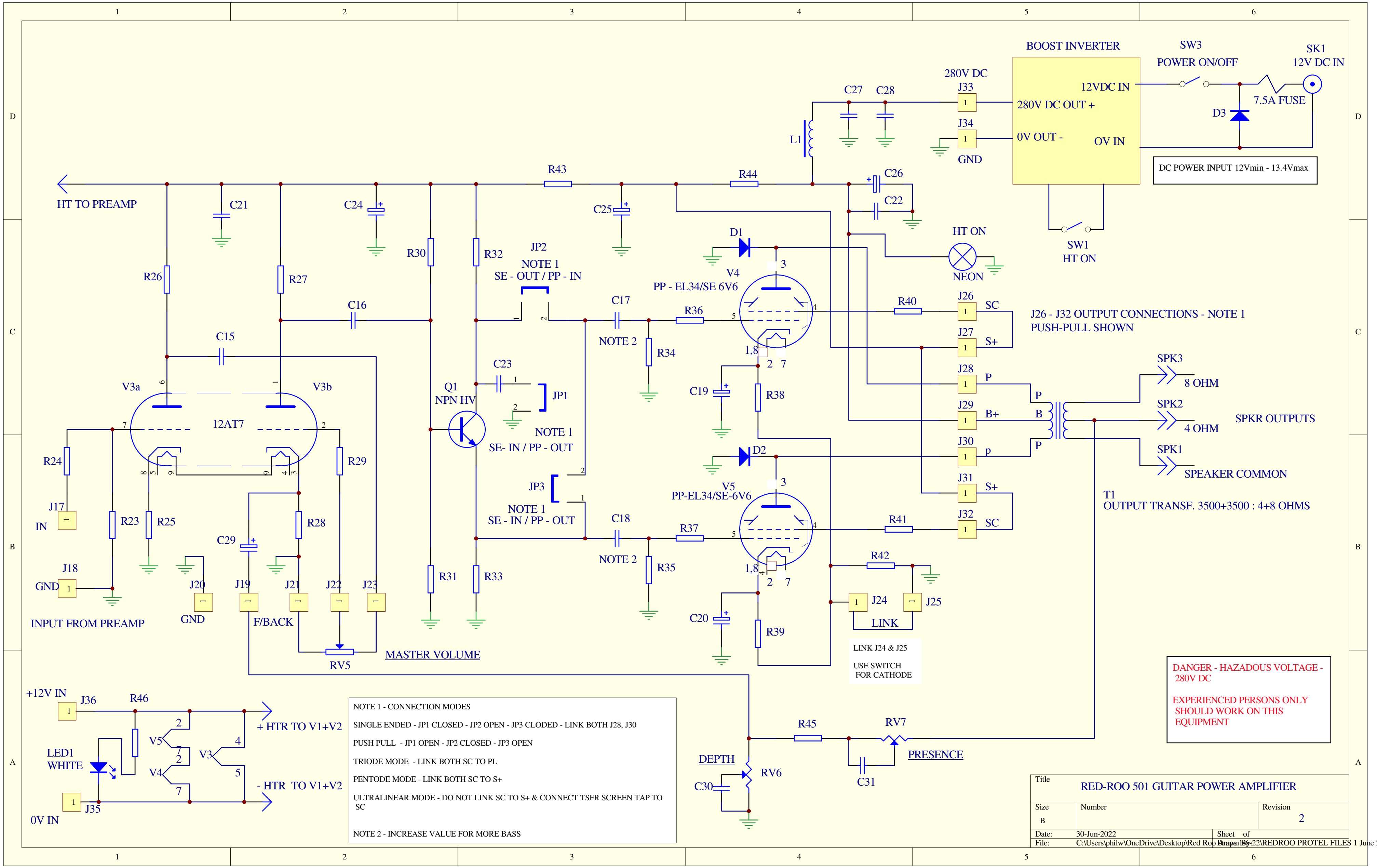
The signal level on the anode of V2 is likely to be around 50V - far too high to feed an effects unit or a power amplifier. R18 and R19 form a resistive attenuator with a loss of about 46dB. This will provide a signal level at the output of the preamplifier of about 265mV (-10dBV). The values of R18 and R19 are chosen to give an output impedance of about 4.7K, which is suitable to drive an effects unit and the capacitance of its connecting cable. The value of R19 can be increaded if a larger output voltage is required, but the preamplifier’s output impedance will also increase.

C9, and C10 together with R18 and R19, determine the low frequency response of this stage.

Effects Loop

An effects loop can be connected to JK3 and JK3. When the effects jacks are not inserted the effects loop is bypassed. Switching on SW1 will also bypass the effects loop.

The circuit is designed to drive an effects unit with a -10dBV (low level) input. A higher voltage output up to +4dBV can be obtained by increasing the value of R19, though this will also increase the preamplifier output impedance requiring the following effects unit to have a higher impedance.


BOOST INVERTER
SW3
POWER ON/OFF
SK1
12V DC IN
280V DC
J33
C27
C28
12VDC IN
280V DC OUT +
7.5A FUSE
D3
J34
0V OUT -
OV IN
GND
L1
DC POWER INPUT 12Vmin - 13.4Vmax
R43
R44
C26
C22
HT TO PREAMP
C21
C24
C25
SW1
HT ON
D1
HT ON
NEON
R30
R32
JP2
NOTE 1
SE - OUT / PP - IN
V4
PP - EL34/SE 6V6
R26
R27
C16
C17
R36
R40
J26
SC
J26 - J32 OUTPUT CONNECTIONS - NOTE 1
PUSH-PULL SHOWN
C15
NOTE 2
R34
J27
S+
SPK3
8 OHM
C23
J28
P
V3a
V3b
Q1
NPN HV
JP1
C19
R38
12AT7
NOTE 1
SE- IN / PP - OUT
J29
B+
B
SPK2
4 OHM
SPKR OUTPUTS
R24
R29
D2
J30
p
SPK1
SPEAKER COMMON
J17
IN
JP3
V5
PP-EL34/SE-6V6
J31
T1
OUTPUT TRANSF. 3500+3500 : 4+8 OHMS
R23
R25
R28
NOTE 1
SE - IN / PP - OUT
C18
R37
R41
J32
C29
J18
GND
J20
J19
J21
J22
J23
R31
R33
NOTE 2
R35
R42
J24
J25
LINK
INPUT FROM PREAMP
GND
F/BACK
C20
R39
LINK J24 & J25
USE SWITCH
FOR CATHODE
MASTER VOLUME
RV5
DANGER - HAZADOUS VOLTAGE - 280V DC
EXPERIENCED PERSONS ONLY SHOULD WORK ON THIS EQUIPMENT
+12V IN
J36
R46
+ HTR TO V1+V2
LED1
WHITE
V5
V3
V4
- HTR TO V1+V2
J35
0V IN
NOTE 1 - CONNECTION MODES
SINGLE ENDED - JP1 CLOSED - JP2 OPEN - JP3 CLODED - LINK BOTH J28, J30
PUSH PULL - JP1 OPEN - JP2 CLOSED - JP3 OPEN
TRIODE MODE - LINK BOTH SC TO PL
PENTODE MODE - LINK BOTH SC TO S+
ULTRALINEAR MODE - DO NOT LINK SC TO S+ & CONNECT TSFR SCREEN TAP TO SC
NOTE 2 - INCREASE VALUE FOR MORE BASS
R45
RV7
DEPTH
PRESENCE
RV6
C30
C31
Title
RED-ROO 501 GUITAR POWER AMPLIFIER
Size
B
Number
Revision
2
Date: 30-Jun-2022
Sheet of
File: C:\Users\philw\OneDrive\Desktop\Red Roo Amps 1 June 22\REDROO PROTEL FILES
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How it Works - Power Amplifier Section

Refer to the circuit diagram on page 8

Effects Recovery Amplifier (V3a)

The output signal from the preamplifier, possibly via an effects unit, is fed to the input of V3a. This stage amplifies the signal back to line-level (about +4dBV) before being sent to the MASTER VOLUME control, RV5. The MASTER VOLUME control sets the loudness of the sound through the speaker; it does not affect the level of overdrive which is set by the GAIN control.

Voltage Amplifier (V3b)

V3b provides additional gain so the signal voltage is sufficient to drive the output stage. Negative feedback is applied to the cathode of this stage after it has been frequency-tailored by the DEPTH and PRESENCE controls RV6 and RV7.

Power Buffer/Phase splitter (Q1)

The output stage can be configured as either a single ended amplifier or a push-pull amplifier, depending on the type of output transformer used and the settings of the three links, JP1 - JP3.

Q1 is a high-voltage NPN transistor biased by R30 - R33 so its cathode is at about 1/3 supply voltage and its anode is about 2/3 supply voltage. When the output stage is wired in Single Ended Class-A, Q1 is configured as an emitter follower and the signal is taken from the emitter of Q1 to both grids of the output tubes, Q4 and Q5, via C17 and C18. The anode is AC grounded via capacitor C23.

When the output stage is wired in push-pull Class-AB, Q1 is configured as a phase splitter with opposite phases appearing at its collector and emitter. The anode is connected to the grid of V4 via coupling capacitor C17, and the emitter is connected to the grid of V5 via coupling capacitor C18.

The low frequency response of the power amplifier section is mostly determined by the values of C17 and C18 which are chosen to give about a 3dB attenuation at 70Hz. The bass response can be changed by changing the value of these capacitors. A lower value decreases the bass response.

Output Stage (V4, V5)

As stated previously, the power output stage can be configured as a single-ended Class-A amplifier giving about 8 Watts, or a push-pull Class-AB amplifier giving about 18 Watts. In single ended mode the two output tubes are operating in parallel. The output stage mode selection is by the type of output transformer and the links JP1 - JP3.

A wide variety of tubes can be used depending on the output transformer used. In Single ended mode, using a 3.5k primary single-ended output transformer, two 6V6 tubes are a good choice. In push-pull mode EL34 or 6L6 tubes are a good choice.

Push-Pull Mode (as shown on the circuit diagram):

In push-pull mode the anodes are connected to each primary anode connection of a push-pull output transformer. The grids of V4 and V5 are fed with out-of-phase signals from the emitter and collector of Q1 via coupling capacitors C17 and C18. Each tube has its own cathode bias resistors R38 and R39, and cathode bypass capacitors, C19 and C20, in case they age diferently.

The choice of tube depends largely on the primary impedance of the push-pull output transformer used. A common 3.5k aside primary impedance transformer will be a good match for a pair of EL34 or 6L6 tubes. A primary impedance of about 5K aside would be a good match for a pair of 6V6 tubes.

Push-Pull mode will give a higher 3rd harmonic content and should sound somewhat 'harsher' than single-ended mode when pushed. Power output will be about 18 Watts.

Single-Ended Mode (not shown on circuit diagram):

In single ended mode the anodes of V4 and V5 are connected together by strapping together the screw terminals J28 and J30, and connecting them to the anode connection of a single-ended output transformer. The signal from the emitter of Q1 is fed to the grids of V4 and V5 in-phase via C17 and C18. Each tube has its own cathode bias resistors R38 and R39, and cathode bypass capacitors, C19 and C20, so they also have independent DC is conditions.

The choice of tube depends largely on the primary impedance of the single-ended output transformer used. A common 3.5k primary impedance transformer will be a good match for a pair of 6V6 tubes, or a primary impedance of about 1.8K would be a good match for two EL34 or 6L6 tubes. The output transformer should have a DC primary current rating of about 100mA, preferably more. Expect about 8 Watts output power. (Two smaller identical output transformers couple be used with their speaker outputs paralleled).

Alternatively, a single output tube could be used. In this case a 5K primary transformer should be used for a 6V6 tube and a 3.5k primary transformer used for an EL34 or 6V6 tube. The output transformer should have a DC primary current rating of at least 50mA. Expect less than 5 Watts output power.

Single ended mode will give a higher 2nd harmonic content and should sound somewhat 'creamier' than push-pull mode, especially when the preamplifier GAIN control is low giving a clean preamplifier output, and the VOLUME control is high overdriving the output stage into distortion. Power output will be limited to well under 10Watts with two tubes.

Protection Diodes (D1, D2)

During gross overload conditions, where guitar amplifiers spend most of their time, or if the loudspeaker is accidently disconnected, a high reverse voltage can appear on the anodes of the output tubes. This reverse voltage can be large enough to damage the output tubes or, worse, the output transformer. Diodes D1 and D2 are reverse connected onto the anodes of the output tubes and short-out any reverse voltage to ground.

Optional Mute Connection (J24,J25)

The output stage can be muted by opening the link between J24 and J25. This is normally left shorted, but it may be used with alternative power supplies that do not have a mute facility.

The Power Supply: Power supplies in valve amplifies are large, heavy, and very expensive compared to modern solid-state amplifiers. Because mains power transformers operate at very low mains frequencies (50Hz or 60Hz) they have high inductance windings (lots of turns), and large heavy cores in order to avoid magnetic core saturation. Toroidal transformers (those with a closed-loop steel or ferromagnetic core in the shape of a doughnut) offer a significant improvement, but they are still comparatively large and are even more expensive.

The output of a full-wave rectifier is 100Hz or 120Hz (depending on country) pulsating DC. Turning this into smooth DC suitable for an audio amplifier requires a multi-stage low-pass filter consisting of large value filter capacitors and often one or two large and expensive iron cored inductors (chokes).

Additionally, the stray pulsating low frequency electromagnetic field emanating from such large transformers and chokes is often difficult to contain, and it can easily interfere with sensitive electronic circuitry. The power supply in this valve amplifier is different and, we believe a highly worthwhile concession to the 21st century. This amplifier requires 12V DC at approx. 7.5 Amps, and the 12V DC is up-converted to about 280V DC using a small and efficient switch-mode voltage-boost inverter module.

There are significant advantages to this approach:

1. The inverter converts 12V DC from a commonly available in-line or bench power supply to a high frequency AC waveform, which is then transformed up to the high voltage using a very small, lightweight, and inexpensive ferrite-cored transformer. (This is possible because of the high switching frequency, about 37kHz).
2. As the switching frequency is well above the human hearing range, there is no audible power supply noise (hum) in the loudspeakers.
3. The filter components following the rectifier in the inverter (C27-C28, L1) are small and inexpensive. (Again, due to the high switching frequency).
4. The inverter is supplied as a pre-assembled module. The resulting amplifier is smaller and lighter. (The 150 Watt inverter used is loafing along).
5. And, possibly most important of all - there is no need to work on mains power wiring. The external 12V DC power supply is commonly available in most countries and, if purchased locally, should carry all the necessary regulatory approvals and the correct power plug for the country of purchase.

There are some excellent resources for those who wish to learn more about valve audio technology. For those starting out www.valvewizard.co.uk is excellent, or for those up for a challenge John Broskie's TubeCad Journal at www.tubecad.com is our favourite. Morgan Jones' Valve Amplifiers, Third Edition ISBN: 978-0-7506-5694-8 is required reading.

Specifications

The following measurements are of the prototype. All measurements taken with and HP8903B Audio Analyser and reverse RIAA equalisation network

Circuit Configuration:
Preamplifier stage - Cascaded high-gain progressive overdrive design using 2x 12AX7 amplifiers, Fender tone stack and effects loop.

Output stage - 12AT7 effects recovery amplifier and voltage amplifier, followed by NPN transistor phase inverter/buffer driving a pair of output tubes.
Circuit can be configured for push-pull or single-ended operation.

Controls: GAIN, BASS, MIDRANGE, TREBLE, VOLUME, PRESENCE, DEPTH, POWER ON-OFF, POWER-ON INDICATOR, MUTE, MUTE INDICATOR, EFFECTS BYPASS.

Signal Inputs: High and Low level 6.5mm mono jack guitar inputs. Sensitivity TBA

Speaker outputs: 4-8-16 Ohm 6.5mm mono speaker jacks.

Power Output: push pull mode - 20 watts rms @ 10% distortion / single ended mode (two tubes) - 8 watts rms depending on tube selection (one tube less than 5 Watts)

Tone Controls: Treble, Midrange, Bass. Classic Fender response. Presence and Depth Controls.

Effects loop: -10dBV output and input voltages. Can be changed to +4dBV by changing resistor values. Effects by-pass switch on rear panel.

Hum and Noise: TBA 20Hz - 30kHz   (be careful comparing this to largely meaningless weighted measurements which will appear much better).

Mute control: Instantly switched HT voltage. No clicks or pops. Mute light.

Power supply: External 12V @ 9A benchtop power pack. Internal boost inverter 12V - 280V DC. Fuse protected.

Dimentions: Width - 305mm Depth - 240mm Height - 190mm without cover, 225mm with cover.

Weight: TBA

Specifications are typical specifications and may change without notice.