The Class-A Amplifier Site
This page was last updated on 17 August 2003

[Back to Index]

JLH Class-A Update

I had originally intended that this page would be a step-by-step record of the modifications carried out during the past year by one constructor – Tim Andrew. However, recent ill health has meant that I have been unable to spend much time sitting at my pc so, rather than incur yet more delay in publishing the results, I have decided to write a short summary instead. I am very pleased that Tim has taken the time to supplement this with his own comments. At the end of the page is a brief update on the higher power ‘JLH for ESL’ circuit.

Tim is a professional musician (a classical concert pianist) and so I trust his subjective judgement when it comes to assessing the accuracy and realism of sound reproduction. Before Tim first contacted me, he had built a kit version of the 1996 design, which he had subsequently upgraded with higher quality components. Though Tim was happy with the results, he was keen to see if further improvements could be made to the sound quality and I was pleased to be able to suggest various circuit modifications, the majority of which subsequently proved to be very worthwhile. Each of the modifications was carried out separately so that the results could be evaluated on an individual basis.

Rather than show schematics for each stage, I will start off with the penultimate circuit and include some appropriate comments.

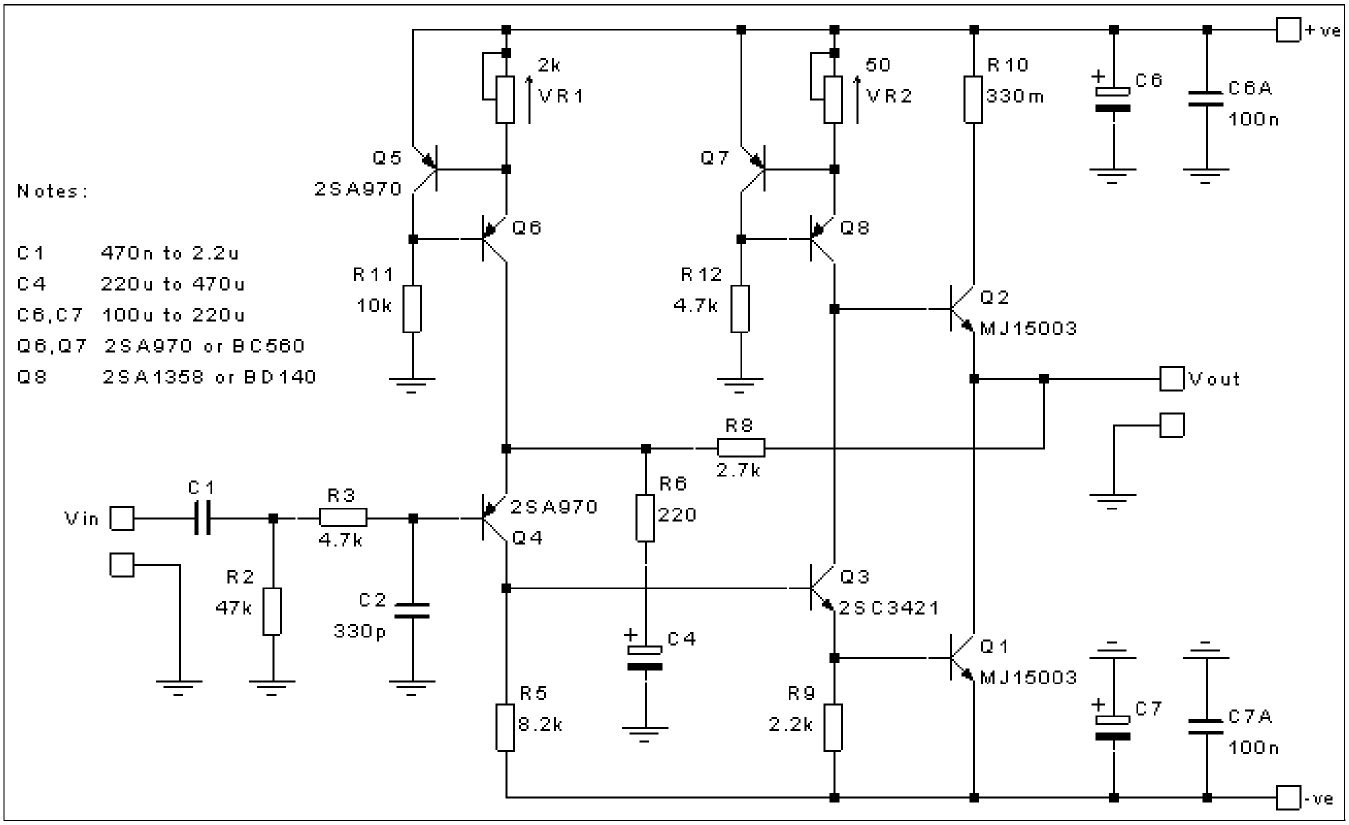


Fig 1 – The Penultimate Circuit

Transistor substitutions

One of the first modifications was to try alternative output transistors. The MJL3281A gave an audible indication of oscillation and was quickly rejected. The MJ21194 sounded significantly better than the 2N3055 but, in Tim's layout, introduced a low-level hum. The MJ15003 gave a similar improvement to the MJ21194, but without the hum, and so was retained for future use. At a later stage, the BC212 and 2N1711 (Q4 and Q3) were replaced with the 2SA970 and 2SC3421.

Output dc offset control

The standard dc offset control circuitry (7815 and associated components) was replaced with a two transistor constant current source (Q5/Q6). I had various reasons for suggesting this change. Firstly, three terminal regulators are not renown for their quietness and so it did not seem like a good idea to inject the noisy output from one directly into the feedback loop. Also, I had received reports that certain 7815s oscillated due to the low current conditions under which they were being operated.

However, one of the main benefits of the ccs is that the output dc offset variation as the amp warms up is greatly reduced. This is because the temperature coefficient of the ccs acts in the opposite direction to that of the input transistor (Q4) and negates the effect of temperature changes in Q4 (assuming that the temperature of Q5 follows that of Q4). This cancellation of temperature coefficient effects can be put to further good use as will be seen later.

Quiescent current control

I first suggested that Tim try the 1969 bootstrap Iq control circuit, partly because the simulated distortion figures were half those for the 1996 version but mainly because I wanted to know how the two methods of Iq control compared in the same amplifier. I had received reports that the 1969 circuit (modified to dual supply rails) sounded better than the 1996 version, but I could not be sure that there were no other variables involved. As it turned out, the bootstrap circuit was a retrograde step and Tim immediately reverted to the original 1996 arrangement.

I still had some nagging doubts about the 1996 Iq control circuit and so I suggested introducing another constant current source (Q7/Q8). As with the bootstrap circuit, the simulated distortion figures were still half those for the 1996 version but with the added advantage that the distortion did not increase at low frequencies due to a reduction in capacitor effectiveness. A further advantage was an increase in amplifier efficiency (or maximum output). The maximum output voltage swing with the ccs is greater than that for the standard 1996 circuit and the maximum output current increases from around 1.35 to about 1.5 times the quiescent current.

When carrying out this modification, Tim reused the existing MJE371 for Q8. R10 has been retained to provide an easy means of measuring the quiescent current. To my relief, Tim found the second ccs to be worthwhile improvement.

Power supply

Whilst making the other alterations, Tim also took the opportunity to upgrade his power supply, initially by fitting larger bridge rectifiers and snubber capacitors and then by replacing the LM338s with 'follower' type discrete regulators, in line with my desire to remove unnecessary feedback loops from the overall circuit. The 'follower' regulators, basically a capacitance multiplier circuit with a fixed voltage reference (derived from a resistor fed by a ccs), gave a small improvement. A much greater improvement was obtained when separate regulators were provided for each amplifier, whilst retaining a common transformer, rectifier bridges and reservoir capacitors.

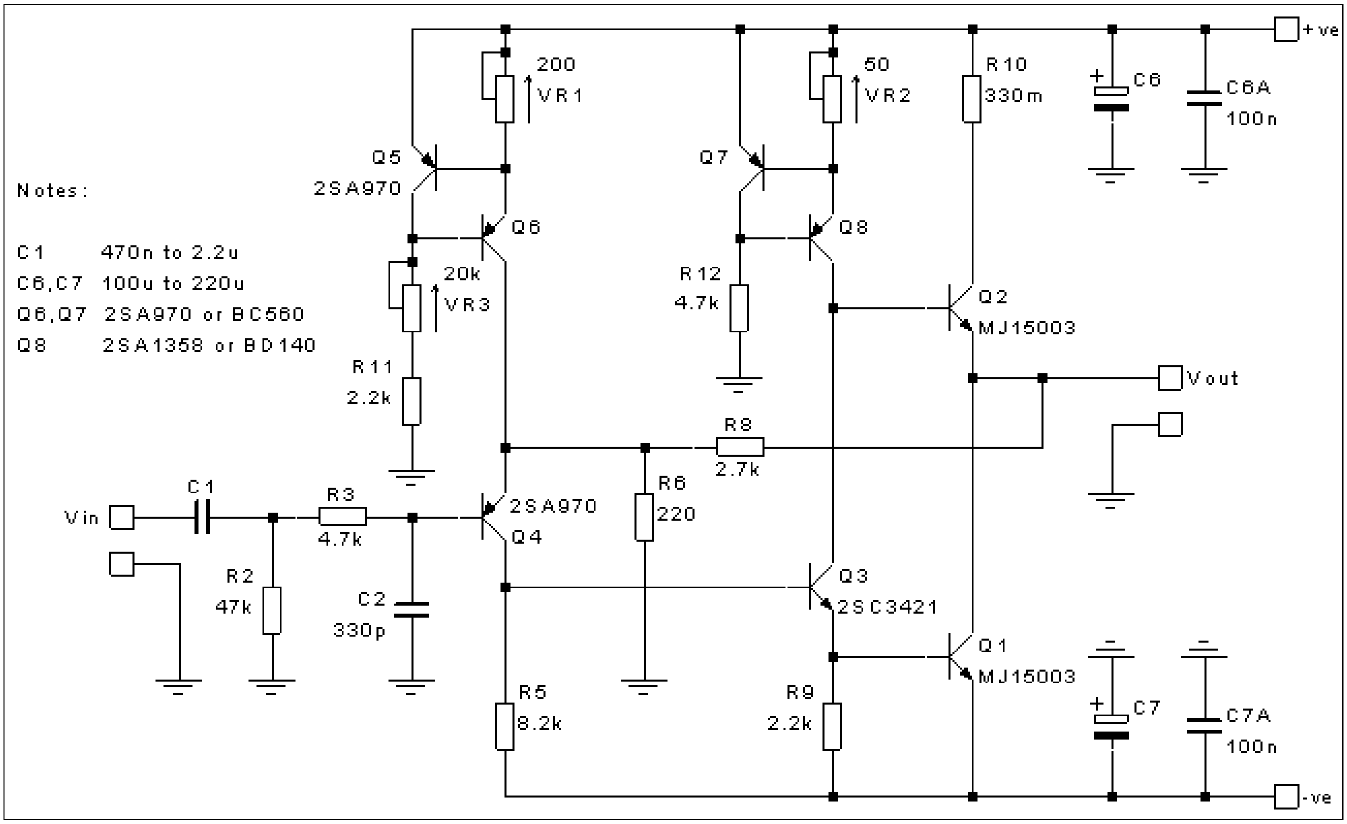


Fig 2 – The Final Circuit

Removal of the feedback capacitor

I had received emails from a couple of constructors reporting on the beneficial effects of removing the feedback capacitor (C4). I passed these comments on to Tim and he decided to try this modification for himself.

This modification should be treated with caution. I would not recommend trying it unless the dc offset ccs (Q5/Q6) modification has been done first because otherwise the output dc offset variation during the warm-up period is likely to be in the order of several hundred millivolts. In Tim's case, with the dc offset ccs fitted, the output dc offset variation with the feedback capacitor removed was only slightly higher than that which he had previously with the standard 1996 circuit.

I believed that the offset variation could be reduced further by utilising the temperature coefficient of the Q5/Q6 ccs. I therefore suggested that R11 be made adjustable so that the temperature rise of Q5 could be varied. In this way, the output dc offset variation due to temperature changes in all stages of the amplifier could be compensated for, though this requires a lengthy, iterative process. With the amp at its normal operating temperature, the offset is adjusted to near zero using VR1. The offset when the amp is cold is then measured. VR3 is adjusted slightly, the amp is allowed to warm up and the offset is re-zeroed using VR1. The offset is then rechecked when the amp is cold and the process repeated until the minimum offset variation has been obtained. Tim has been able to achieve an output dc offset variation between switch-on and normal operating temperature of less than 50mV.

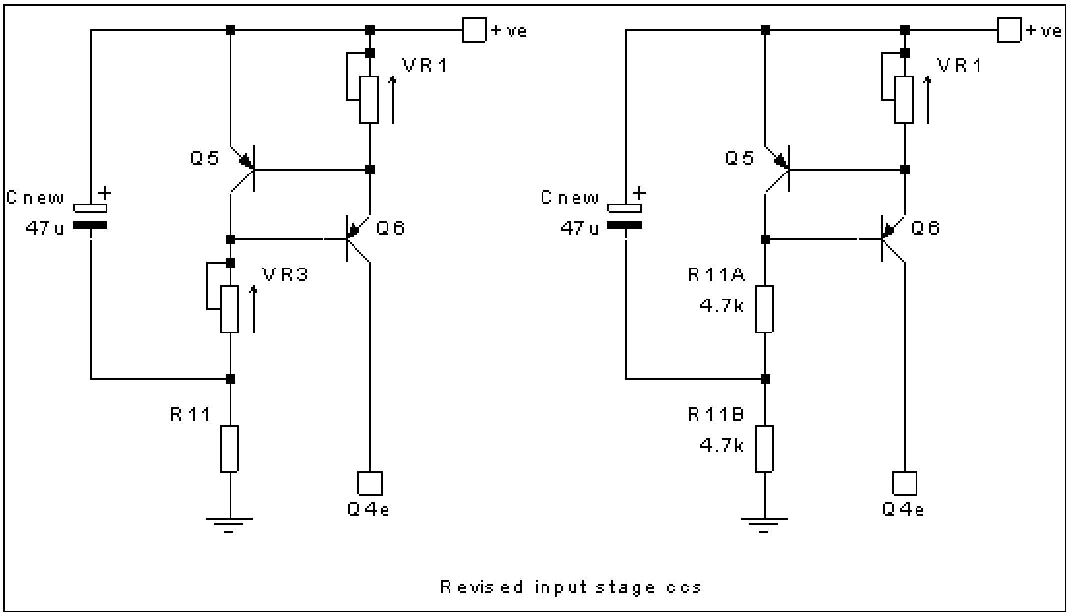
15/03/2003 Addendum

It has been brought to my attention (thanks Mietek and Rudy) that removing the feedback capacitor increases the hum level at the amplifier output, which is particularly noticeable with high sensitivity speakers and if a simple rectifier/capacitor power supply is used. I had not anticipated this, but some quick simulations soon indicated that removal of the feedback capacitor reduces the PSRR of the amp by a factor of about 3, causing any supply rail ripple to become more audible.

Fortunately, the cure for this problem is relatively simple. The PSRR of the input stage ccs can be improved by the addition of a single capacitor, connected between the junction of VR3/R11 (Fig 2) and the +ve supply rail. Doug Self's 'Audio Power Amplifier Design Handbook' indicates that this modification will improve the PSRR of the ccs by about 10dB. A capacitor value of 47uF will suffice, but higher values (within reason) can be used.

The higher power ('JLH for ESL') circuit can be similarly modified by splitting R11 (Fig 3) into two 4k7 resistors in series and connecting the capacitor from the mid-point of these resistors to the +ve supply rail.

This modification can also be carried out even if the feedback capacitor is not removed, and will give an improvement in PSRR with the corresponding reduction in hum.



17/08/2003 Addendum

Several constructors have found that adding the 47uF capacitor to the input stage ccs after having removed the dc blocking capacitor from the feedback network has caused the ccs to become unstable. This has manifest itself by relatively large output dc offset variations when taking voltage readings around the input circuit or when a hand is moved near to the ccs components.

In Tim's case, a successful solution to this problem has been to replace Q5 and Q6 with 'slower' transistors. The MPSA56 appears to work well in the ccs. Alternatively, the 47uF capacitor could be removed and the PSRR of the ccs improved by omitting VR3 and replacing R11 with a 1mA constant current diode (or an FET wired as a ccs to give a similar current).

Adding base resistors (100R to 1k) to Q5 and Q6 and/or a 1k resistor between Q6c and Q4e should also help to improve stability.

Tim's comments on the modifications (Updated 17/08/2003)

A few years ago I built the 1996 version JLH Class-A amplifier. Constructors of this amplifier have commented about its smooth sound, with many favourable comments and comparisons against valve designs and a few not so favourable comments with regard to its limited power output. In its standard 1996 form, which I built from a kit using cheap components, my first impressions of its sound were of smoothness coupled with a relaxed liquid musical flow which I found far preferable to anything else which I had previously heard. In the context of my system with speaker efficiency somewhere around 87dB/W and with volume set correctly such as is appropriate for the perspective as recorded, or in other words "at a realistic level", its limited power output has never been a problem. The amplifier and its power supply have since been subject to extensive component substitutions and substantial circuit modifications.

As this section is about my impressions of the modifications that have been made to the circuit, a brief word on what I consider to be an "improvement" might be in order. I want to hear, with ease, the ambient signature of the recording venue, with a distinct impression of the space between its walls. Also, I want to notice, for example, the sound of the felt hammer of a piano hit the string, followed not only by the sound of the string vibrating but also the more subtle reflected and attenuated sounds of the hammer and its mechanism as these reverberate between the walls of the recording venue. This is sometimes more noticeable in larger venues where the reflected sound arrives later, albeit weaker. Those delicate piano harmonics must be reproduced with the greatest accuracy, enabling subtle shadings of timbre to be noticed, again with ease. As a pianist, I want to hear the "pitch" of the note as it decays through to its quietest moment as acutely as possible, but I want no hint of hardness or roughness. With orchestral strings for example, where there are many instruments playing together, I don't want to hear one homogeneous group, and I want transparency, not brightness.

Professionally, I have a very close affinity with the piano. A difficult instrument to reproduce, it is perhaps more revealing of faults in the reproduction chain than can be the case with other instruments although the human voice is also very useful, for obvious reasons. It is my view that any modification that produces a more realistic rendition of the complex sound of this instrument, and the very subtle structure of its over-tones, will also represent an improvement in the accuracy of the amplifier overall. This has been the case during all my listening trials. It is worth mentioning that any modification which leads to an apparent decrease, for example in the level of the treble, will not necessarily be deemed to be an improvement, even if the new treble level is a welcome one, unless it is accompanied by an improvement elsewhere, improved detail or portrayal of nuance for example. From this, you will gather that I am not in the habit of 'voicing' the system, adjusting one thing to correct for another, but that I prefer to address the transparency of the system as a whole, with the aim of neutrality. Only then will I look at altering the balance, perhaps with a slight adjustment to the treble. It is through this approach (transparency first, followed by tonal balance) that I am now able to enjoy the vast majority of recordings in my collection, previously I had found many of these to be deficient in one way or another. Almost without exception, each modification has improved "difficult" recordings, whilst further improving others, often revealing a warmth and atmosphere, the previous lack of which had been wrongly attributed to the recording.

Though considerable time has been expended on both the amplifier and its power supply, I find it sobering to say the least that improvements made to power supply, specifically to the method of its delivery into various parts of the amplifier circuit have been so rewarding. The following is a list of the modifications that, with considerable help from Geoff, I have been able to carry out on the 1996 version of the JLH. Also included are my opinions of the results of these. Each substitution has been carried out individually, this has enabled subsequent and hopefully accurate (but not always positive!) evaluation. !

The Amplifier

<u>Input capacitor.</u>
The cheap polycarbonate(?) 1uF input capacitor was replaced with a 470nF Mcap "Audiophile" polypropylene type. This led to an improvement in both bass firmness and in detail, treble sounded less bright. Later, I replaced the Mcap 470nF with Audio Note paper-in-oil 470nF. This sounds very different, smooth, warm and open with much more textural detail and firmness in the bass. There is some loss of focus when compared with the better plastic types and the positioning of instruments within the stage is not as precise as it could be, however none of the plastic types I have tried has approached the naturalness and openness of the paper-in-oil, particularly in the treble, and any shortcomings are easily forgiven in light of considerable improvements elsewhere. This simple modification has since proved to be one of the most effective. I have also tried a polystyrene type (333nF) which sounds more detailed and focussed than anything else tried previously, though there is a tendency to sound a little "squeaky" on occasions (placing a small paper-in-oil capacitor across it improves this considerably), nevertheless I prefer this to most polypropylene types, many of which sound hard and slightly blurred to me.

<u>Resistors.</u>
All standard grade metal film resistors in both critical and semi-critical parts of the circuit were replaced with tantalum film types.
Improved smoothness and texture, with a more fluid sound. A slight "mumbling" quality has been removed.

<u>Output transistors.</u>
The 2N3055s were replaced with MJ21194. In comparison with these the 2N3055s sound grey and rather diffused with less sense of authority, less detail and a more prominent treble quality. In contrast, the MJ21194s have a noticeably firmer sound with more ambience in the treble and greater detail. More natural generally. Reluctantly, they were removed from the circuit due to a faint hum which was not present with the 2N3055s.
Wanting to try something else, and now with the strong impression that the 2N3055s were less than ideal, I tried some MJ15003s.
This time, a substantial improvement over the 2N3055s. The MJ15003's bass is both tauter and more authoritative, with cleaner treble and greater textural detail.

<u>DC offset control.</u>
Replace 7815 with constant current source.
Result...Cleaner, smoother and weightier, with what can only be described as an organic flow. It was obviously all there before, but I suppose it was masked somewhat by the noise of the regulator. The volume can be increased further without sounding "loud". A substantial improvement in all respects.

Iq control circuit.

The Iq control circuit was replaced with a bootstrap circuit (using an Elna "Silmic"). Less clarity was the result, with less tonal variety and focus, sounding more shut-in. The bootstrap simply doesn't sound as detailed. I assume this is due to the presence of the bootstrap capacitor connected to the signal path. Perhaps a Black Gate might improve things, but I suspect not enough to equal the MJE371 circuit which is more transparent, open, dynamic and uncoloured, the female voice sounds less "female" with the bootstrap circuit. It strengthens my theory that those who prefer the earlier version of the JLH do so because of the absence of the 7815 in the earlier circuit. I would go further and say that due to the absence of both a bootstrap capacitor, and an output capacitor, and with the ccs in place of the 7815, they might well prefer the 1996 version, all other things being equal. My original Iq control circuit was very quickly re-instated!

It was not long until the original Iq control circuit was removed again, this time replaced with a constant current source and with better results this time. The initial reaction is to think that the treble detail and "air" have been diminished with a reduction of transparency. On prolonged listening things are rather different. There is actually more detail coming across, coupled with a growing sense of "rightness". Sounds are presented in a more natural light, gone is the spotlight effect with its admittedly pleasant but artificial treble detail. String harmonics are more balanced and proportioned with a sense that they now belong to the fundamental, part of the whole. The gaps between rapid piano notes are often missed by amplifiers, the JLH reproduces these well and they are even clearer now than before. Familiar recordings of woodwind and brass instruments sound remarkably smooth and natural. Differences in scale between smaller chamber music recordings and larger scale works are now more clearly conveyed. It is interesting to compare the sound of the Iq ccs circuit with that of the bootstrap which shared many of the attributes of the ccs but had a lumpy and coloured, slightly congested characteristic which I found unpleasant. Returning to the standard 1996 Iq circuit the next day was quite a relief, this time I have no plans return. I would miss the qualities that the Iq ccs circuit has brought to the amplifier. Final thought........Recommended for those who want to sit down for an evening of good music and a fine wine.

Feedback capacitor.

The 470uF Oscon (previously a very similar sounding 220uF Silmic) feedback capacitor was replaced with link (needing a small change in value to the DC offset ccs preset). The result of this change was a more open and natural treble with an increased sense of fluidity, depth and ease. Hot/cold offset variation are much greater without the feedback capacitor, in my circuit a variation of 150mV was observed (with the feedback capacitor it was around 65mV), this was reduced by controlling the current through the ccs in an effort to adjust the temperature compensation, but on a recent re-build of the circuit this arrangement proved ineffective and was subsequently removed.

Driver transistor (2N1711).

This was replaced with a 2SC3421. As with the other transistor substitutions I have made in the JLH, the actual pitch of a note is more easily heard with the 2SC3421s. The same characteristics introduced by the Iq ccs circuit are still there but each single note now conveys more "meaning", more clearly defined in time. Timing, of course, is a musician’s greatest asset! The Iq ccs circuit introduced a smoother, rounder sound with a somewhat darker hue, the extra transparency and openness brought about by the 2SC3421s has lifted that slight darkness away whilst apparently retaining the smoothness and naturalness of the Iq ccs.

Input transistor.

The BC212 was replaced with 2SA970 with similar improvements to those noticed with the 2SC3421.

The Power supply.

Rectifier diodes.
Having tried snubber capacitors across the original "standard" diodes with no noticeable improvement, the originals (and snubbers) were replaced with schottky types. This seemed to be beneficial with more smoothness and an improved "woody" quality with woodwind.

Regulators.
The LM338K regulator circuit was replaced with a capacitance multiplier. The bass now conveys more authority and the amplifier sounds a little warmer, also with more detail.

Dual regulators.
The single capacitance multiplier was replaced with a new (adapted) dual version allowing separate regulation for each channel. This warrants a detailed write-up so I shall list my observations in the order in which I noticed them and in descending order of their magnitude.

It is only now that I have heard the new dual power supply, that I can identify the sonic effects of the single supply. For the first, and most important observation, I shall use a single piano note as an illustration. With the single supply, when the note is struck there is an initial transient 'bump' as the hammer hits the string, followed by the decay, which starts after the initial 'bump' has subsided. With the dual supply, this initial transient is less 'loud' (better controlled?) and it carries more weight and meaning, this is followed by the decay which not only conveys better pitch, leading to more emotion and tunefulness, but the decay starts sooner, its first moments not masked by the apparently exaggerated impact of the hammer blow introduced by the single supply. Also, due to the increased definition, the note seems to decay more slowly, incidentally this is one of the more significant differences between a small grand piano, and a large 'concert' grand where, due to the increased string length of the larger instrument, its sustaining power is much greater. A single note can therefore be followed more easily from start to finish. The tonal signature and real colour of all instruments are now better conveyed.

There is also a significant improvement in the quality of the treble where there is greater transparency. For most of the time, it is less obvious than before, and smoother, but little details previously almost un-noticed are conveyed more clearly and with improved texture. This treble improvement was unexpected and is a constant pleasure!

The third improvement I have noticed is an improvement in the positioning of individual instruments. The perceived stage width is not obviously any wider than before, although I couldn't fault it before, on a good recording the stage width was almost limitless, on a bad recording it had definite limits. This hasn't changed, what has improved is the positioning of instruments within the limitations of the stage width imposed by the recording, with instruments on the edge of the stage more clearly conveyed in space with a better "floating" feel to the acoustic coupled with a more acute sense of the venue.

Filter capacitors.
Having previously bypassed the standard grade electrolytics with Elna "Silmic" 100uF with little, if any improvement, this time the original capacitors (30,000uF per rail) were replaced entirely with "Silmics" (18,000uF per rail). A superb improvement in definition. The scale of which came as quite a surprise.

Conclusion.
I consider the JLH in its present form, to be a very special amplifier. Its ability to portray the acute sense of emotion and excitement contained in a fine performance, through its accuracy

and with such grace, coupled with its ability to scale music's dynamic heights so convincingly, is rare. My most sincere thanks to Geoff who, through spending so much time helping others like me, has so far not had time to carry out these modifications for himself *.

* *Unfortunately not the only reason - Geoff*

Higher power circuit

The ‘JLH for ESL’ circuit, which can be used with conventional speakers as well as electrostatics, already has a ccs for dc offset adjustment but it would benefit from the other modifications outlined above. In particular, the use of a ccs for quiescent current adjustment obviates the need for a high power preset, which can sometimes be hard to find.

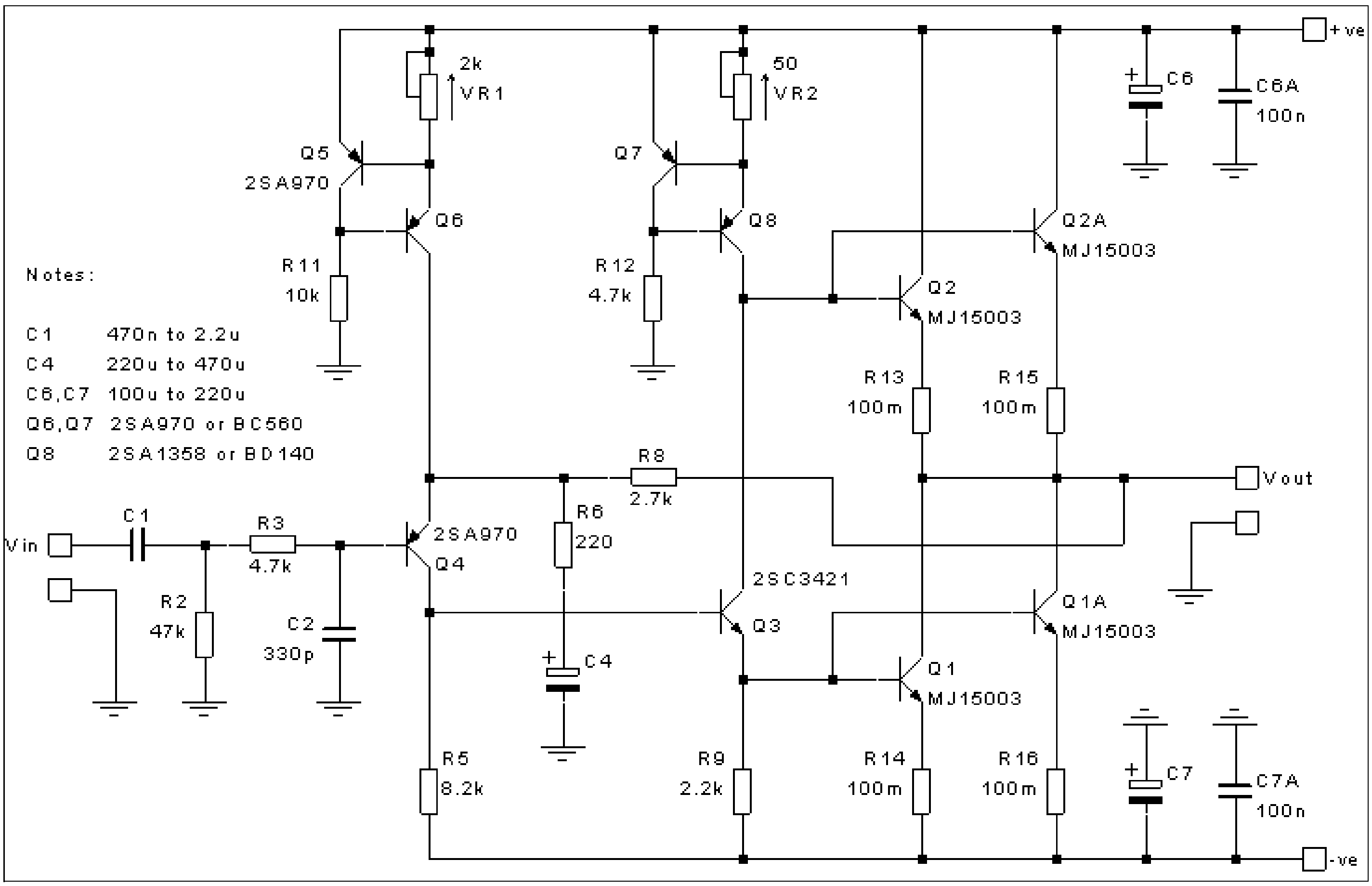


Fig 3 – The Higher Power Circuit

When used with conventional speakers, this circuit can deliver over 40W provided the supply rail voltage and quiescent current are selected to suit a specific load impedance. The supply rail voltage needs to be a couple of volts higher than the peak output voltage swing and the total quiescent current should be about 0.7 times the maximum output current. The power dissipated in each output transistor (supply rail voltage times half the quiescent current) should be limited to about 40 to 45W, assuming decent sized heatsinks are used (0.6 to 0.8degC/W per transistor).

The peak load voltage and current can be calculated from required power and the speaker’s impedance in the normal way using:

Vpk = sqrt(2*Pwr*Rload) and Ipk = sqrt(2*Pwr/Rload)

To allow for speaker impedance variations, I would suggest that current is calculated using ¾ of the speaker's nominal impedance and voltage using 1½ times the nominal value. Of course, you are free to make your own assumptions about speaker impedance variations and to calculate the required supply rail voltage and quiescent current accordingly. From feedback I have received, higher quiescent currents tend to sound better so you may wish to bias the compromise between voltage and current accordingly (whilst keeping the power dissipation in the output transistors at a safe level).

The following table indicates the maximum power output into 8, 6 and 4ohm loads for some standard transformer secondary voltages, assuming a resistive load and without any allowance for the impedance variations mentioned above. The supply rail voltages assume a regulated supply, with the consequential volt drop, and the quiescent current has been calculated from either the maximum current into 4ohm or, in the case of the 25 and 30Vrms secondary, the transistor power dissipation limit.

Secondary Voltage (Vrms)	Supply Rail Voltage (V)	Quiescent Current (A)	Power 8ohm (W)	Power 6ohm (W)	Power 4ohm (W)
18	18	2.8	16	21	32
22	23	3.7	28	37	56
25	28	3.2	42	56	42
30	33	2.7	60	45	30

[Back to Index]

HISTORY: Page created 27/11/2002
28/11/2002 Original table replaced with one based on transformer secondary voltages
15/03/2003 Note regarding ccs PSRR improvement added
17/08/2003 Note regarding ccs instability added
Tim's comments updated