ST-70A Modifications Package

A set of design enhancements for the Eico ST-70 integrated amplifier

Rev.7a

2010-2023 by Stephen H. Lafferty.

WARNING!

Voltages used in the Eico ST-70 may be LETHAL. Always make sure that the power is disconnected and discharge each power supply cap AND C37 and C38 before wiring in the unit. Watch out for coupling caps too. When testing inside the unit while it is operating, BE EXTREMELY CAREFUL. Use only one hand when possible. Remove jewelry. HV DC can contract muscles and prevent you from releasing grasp of a HV terminal. Dead techs aren't much fun.

Contents

New

ST-70a Modifications Package

Introduction

This describes a set of modifications (**mods**) to the Eico ST-70 stereo integrated amplifier, which I will call the "**ST-70a**". The upgrade fixes problems with line-level noise, phono preamp bass response, increases low frequency and high frequency power output, reduces distortion and improves power amplifier stability into difficult loads. After listening to the ST-70a for many hours now, I can say that the project has been an audible and gratifying success.

The original ST-70 kit was bought by my dad in August, 1962 and was assembled by my big brother, Bill. I remember watching in fascination as all the pretty-colored wires and components became an awesome music-maker. The ST-70 and other kits were part of the inspiration which led me to become an electronic design engineer. Little did I know, as I watched at the age of ten, that I would be redesigning it 46-years later! Calling it a "redesign" is too strong a term, though. The goal has been to do the maximum good while making minimum changes to the original design.

Important notes:

- Component names for Channel-1 will be referenced to represent both channels.
- The individual mods are: Phono preamp, driver balance adjust and line amp/power amp. You can do the mods singly *but the line amp and power amp mods must be done together*.
- The line amp mod decreases the current used by those stages. This results in a beneficial increase in voltage at power supply nodes W, Y and Z.

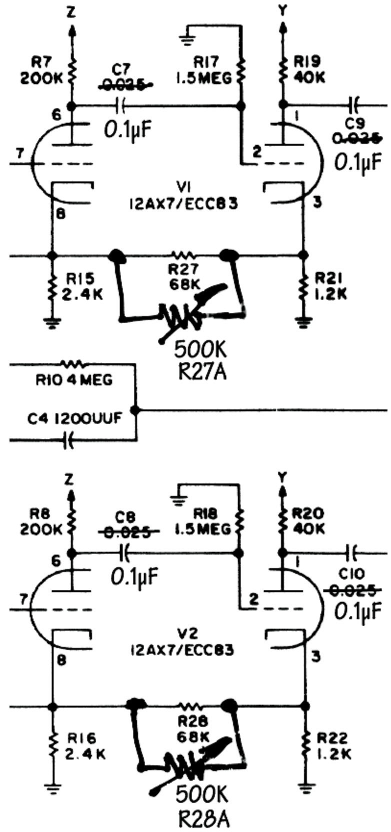
Overview

There were four motivations for the mods: (1) Too much hiss noise in the line stage. (2) Substantial bass loss in the phono preamp. (3) Lack of a grounded common at the speaker outputs which caused problems for connections to speaker switches, headphones and instruments. (4) An opportunity to increase power and decrease distortion. There is no change to the original input sensitivity for either the phono or the line inputs. The mods address three areas of the unit:

- Phono preamp positive feedback adjustment. Eico used positive feedback to achieve adequate low frequency gain in the phono stage. Unfortunately, it is sensitive to tube transconductance. Either Eico used higher gain tubes than we have now or they decided to include a free rumble filter. I measured the preamp about 10dB down at 20Hz and 4dB at 35Hz. The adjustment corrects that to 0.7dB at 20Hz and 0.0dB at 35Hz.
- Line stage noise reduction and gain increase. The presence of R41 without a stable input resistor results in high noise at low settings of the Level control. Also, level in the tone stage is unnecessarily low due to excessive gain in the power amp. Changes increase the gain of V3A by about 10dB and eliminate the noise enhancement there. A side benefit is 12DW7s are replaced by more obtainable 12AX7s.
- Power amp (**PA**) gain reduction, distortion reduction, stability improvement and common speaker grounding.
  - The ground was moved from the 4Ω tap to the common speaker tap and this was taken into account in the new feedback and compensation components.
  - The original PA sensitivity is about 0.2Vrms for full output. This is changed to about 0.65Vrms to reduce the effect of hum and noise from V3 and V5.
  - Additional loop compensation in the PA permitted the resulting 10dB increase in loop gain. This led to a 3X reduction in PA distortion which in turn increased low frequency

and high frequency power output (measured at 1% distortion).

- Moving feedback from the 16Ω to the 8Ω tap reduced distortion further at that tap.
- Adding AC Balance pots reduces distortion. It greatly reduces its dependence on R61 and R63 and on tube matching (V11/9, V7A/B).
- The new loop compensation improved stability dramatically, allowing the amp to remain stable with pure capacitive loads. Some believe that exceptionally solid high frequency stability leads to audible improvements in sound.
- Changes also improved low frequency stability and reduced overload recovery time.



Applicability to other products

The Eico ST-40 integrated amp and the ST-84 preamp both use the same phono preamp design as the ST-70, so that part of the mod can be used for those. Since the ST-40's line stage and power amp are different, the rest of the mod is not applicable.

Detailed modifications

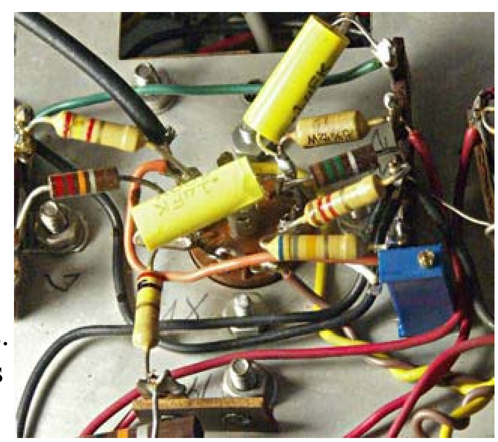
Note: All resistors can be 1/4-watt or larger carbon film unless otherwise specified. I used 1/2W when I had it, for visual harmony.

Phono preamp

In the schematic **at right**, increasing the coupling caps extends the bass response but more open loop gain is needed to support the RIAA curve. Reducing R27 with the pot boosts positive feedback, increasing open loop gain and allows adjustment to accommodate tube variations.

Changes

- ❑ C7 from 0.025µF to 0.1µF, 400V.
- ❑ C8 from 0.025µF to 0.1µF 400V.
- ❑ C9 from 0.025µF to 0.1µF 400V.
- ❑ C10 from 0.025µF to 0.1µF 400V.
- ❑ Bridge R27 with a 500K pot (15-turn preferred).
- ❑ Bridge R28 with a 500K pot (15-turn preferred).

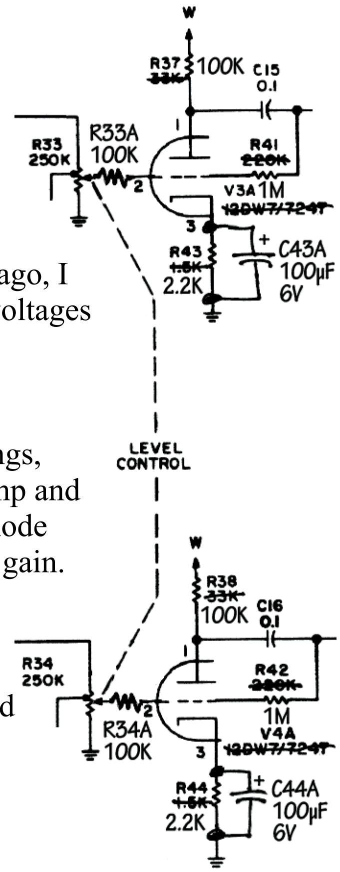


As shown in the photo of the bottom of V1 **at right**, I mounted the pot by super-gluing its back end to the chassis. It is also braced against the terminal strip and its top lead is soldered to the adjacent terminal.

Adjustments

- ❑ Preset the pot for highest resistance.
- ❑ Apply 1kHz 10mVrms to phono input and read level at tape output (1.14Vrms nominal).
- ❑ Change frequency to 35Hz and the reduce the generator level by 18.2dB (to 1.23mVrms).
- ❑ Adjust R27A for the same level as before at the tape output.

- ❑ Repeat for the other channel.
- ❑ Adjust hum balance for both channels.



Fixed resistor alternative

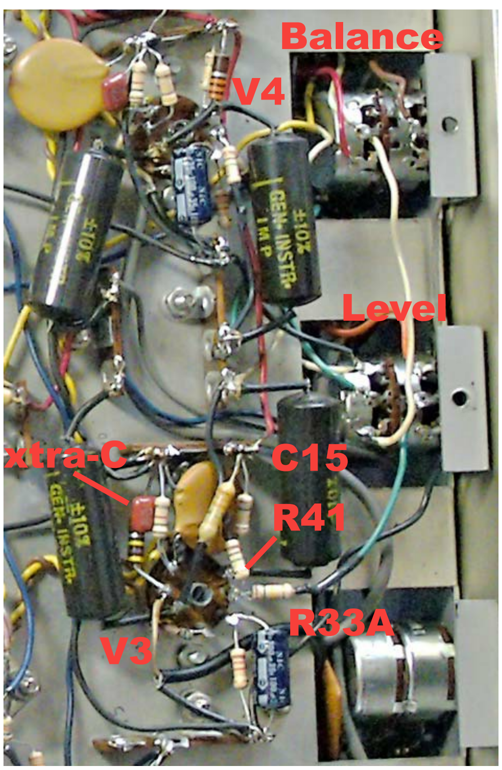
If you are unable to make this kind of adjustment, you may be able to get adequate performance by bridging R27 with a fixed resistor. The values of the pots in my ST-70 were about 420K and 290K. I would recommend using 360K, based on this. In the ST-84 I worked on years ago, I settled on 200K fixed resistors. Though it's the same circuit, the plate voltages there are roughly *half* those in the ST-70, accounting for the difference.

Line stage

Adding R33A stabilizes the gain of the stage at low Level-control settings, reducing hiss and hum. R41 is increased to increase level in the tone amp and at the power amp, reducing hum and hiss. The tube is changed and cathode bypassed to maximize open loop gain and support the increase in stage gain.

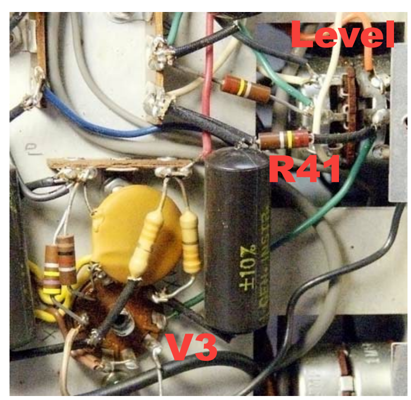
*Changes (**shown at right**), Channel-1*

- ❑ Change V3 from 12DW7 to 12AX7.
- ❑ Add R33A, 100K between wiper of Channel-1 Level control and V1-2. (Channel-1 section is closest to front panel.)
- ❑ Change R37 from 33K to 100K.
- ❑ Change R41 from 220K to 1M.
- ❑ Change R43 from 1.5K to 2.2K.
- ❑ Add C43A, 100µF aluminum electrolytic. 6V or higher.



Changes, Channel-2

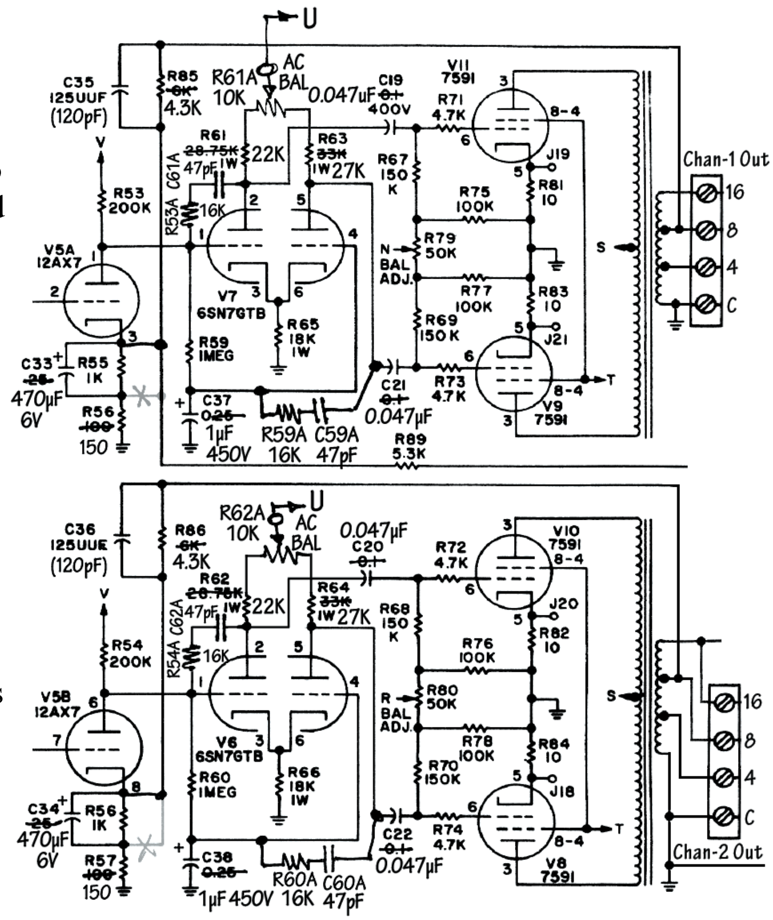
- ❑ Change V4 from 12DW7 to 12AX7.
- ❑ Add R34A, 100K between wiper of Channel-2 Level control and V1-2. (Channel-2 section is farthest from the front panel.)
- ❑ Change R38 from 33K to 100K.
- ❑ Change R42 from 220K to 1M.
- ❑ Change R44 from 1.5K to 2.2K.
- ❑ Add C44A, 100µF aluminum electrolytic.



Physical layout

In the original layout **at right**, the grid of V3 and R41 tie to the wiper of the Level control. We need to insert R33A between the grid and the wiper, so the new value of R41 must go to the grid pin instead of the wiper, as shown **at left**. Extend one lead of R33A to reach the wiper of the control. R41 is also extended to reach the terminal of C15. R41 and R33A should be as close as possible to V3-2. That node is sensitive to hum pickup and must be kept small.

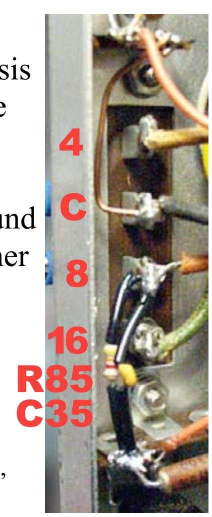
Checking C31
In my unit, C31 and C32 were reading 0.012µF instead of the nominal 0.015µF. This was causing rolloff of perhaps 1-2dB in the 20kHz region. To check it with a cap meter you will need to disconnect one side from R87. Not having a suitable replacement, I augmented the caps with an additional 3.3nF shown as “xtra-C” in the photo on the previous page. It’s a good idea to check the values of all components which can be easily read. My rule is to replace when the value is out of tolerance. You may notice in the photo that R50, R87, R88 have been replaced.



Power amplifier
As shown **at right**, the speaker outputs now have common connected to ground and the center speaker feature is no longer supported. Moving the feedback to the 8Ω output tap reduces distortion for that tap. Feedback resistors R85/86 are changed to reduce closed loop gain, complementing the increase in line stage gain. That also increases feedback factor, reducing distortion and increasing power at a specified distortion. To maintain and improve low frequency stability, C19/21 are decreased, feedback is moved to the other side of R55 and C33 is increased. The decrease in C19/21 does NOT impair bass performance, due to the loop gain. C37 is increased to support the low frequency loop gain. R53A/59A and C61A/59A are added to introduce pole-splitting frequency compensation, keeping and improving high frequency stability with the higher loop gain. Finally, AC balance control R61A is added to reduce distortion due to tube and resistor imbalances.

Changes, Channel-1:

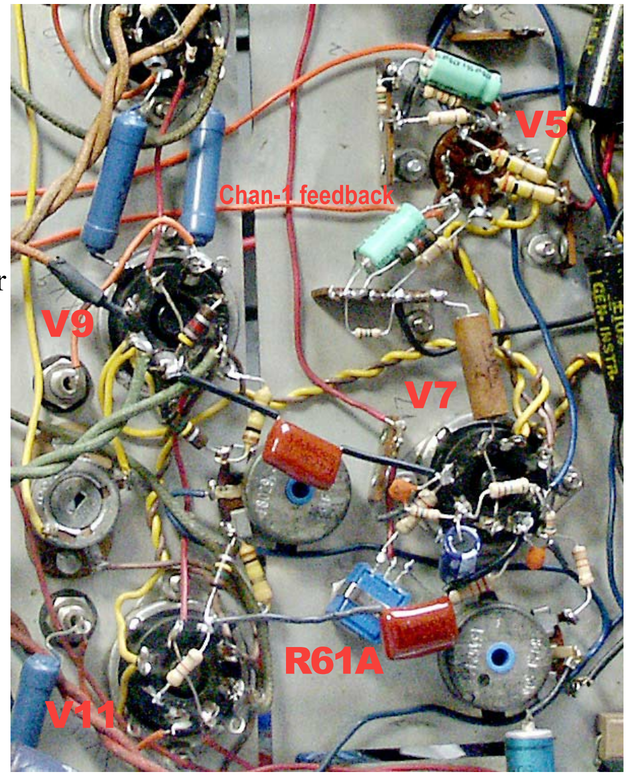
- ❑ Drill holes* and mount the new AC balance pots R61A, R62A in the chassis near the existing DC balance pots R79/80. You can see the locations in the photos of that section on the next page.
- ❑ Remove the ground connection from the 4Ω terminals. The Channel-1 terminal board is **shown at right**. Make a sturdy connection between ground and the common terminal (where the black lead from the output transformer is).
- ❑ Change R85 from 6K to 4.3K and connect it to the 8Ω terminal.
- ❑ C35 leads are too short to reach the 8Ω terminal. Replace it with 120pF.



*Since this is steel, recommended drilling tips include: start with a center punch, use cutting oil, use sharp, coated drill bits, use a drill press, set the correct speed and start with a pilot hole.

Refer to the ***photo at right***:

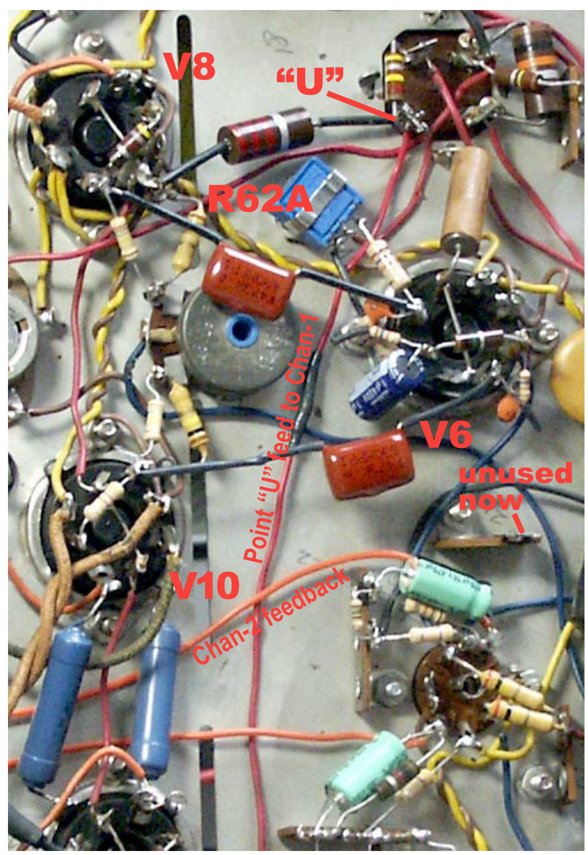
- ❑ Move the feedback wire to the other side of R55. (The wire runs from R85/C35.)
- ❑ Change C33 from 25µF to 470µF.
- ❑ Change R56 from 100Ω to 150Ω.
- ❑ Change C19 and C21 from 0.1µF to 0.047µF. (May have to extend leads.)
- ❑ Change C37 from 0.25µF to 1µF 250V or more electrolytic. Note polarity. You can solder the ground side to a lug on the V7 socket.
- ❑ Add the two RC networks R53A/C61A and R59A/C59A, as shown in the detail **at left**. Note the heatshrink at the junction. Since this is sensitive to stray capacitance, do not try to connect the junction to a terminal strip.



- ❑ Remove the existing R61 and R63. The supply terminal used by R61 is no longer needed. Remove the red wire feeding it.
- ❑ Connect new pot R61A wiper to power supply point "U" at the terminal abandoned by R63.
- ❑ Install the new 1W resistor values: R61 changes from 28.75K to 22K, R63 from 33K to 27K. Note that modern 1W resistors are smaller than the ones found in the unit.

Changes, Channel-2:

- ❑ Remove the ground connection from the 4Ω terminal of the Channel-2 terminal board. Make a sturdy connection between ground and the common terminal, where the black lead from the output transformer is.
- ❑ Change R86 from 6K to 4.3K and connect it to the 8Ω terminal.
- ❑ C36 leads are too short to reach the 8Ω terminal. You will need to replace it with 120pF.



Refer to the ***photo at right***:

- ❑ Move the feedback wire to the other side of R56. (The wire runs from R86/C36.)
- ❑ Change C34 from 25µF to 470µF.
- ❑ Change R57 from 100Ω to 150Ω.
- ❑ Change C20 and C22 from 0.1µF to 0.047µF. (May have to extend leads.)
- ❑ Change C38 from 0.25µF to 1µF 250V or more electrolytic. Note polarity. You can solder the ground side to a lug on the V8 socket.

- ❑ Add the two RC networks R54A/C62A and R60A/C60A. See detail on the previous page. Note the heatshrink at the junction. Since this is sensitive to stray capacitance, do not try to connect the junction to a terminal strip.
- ❑ Remove the existing R62 and R64. The supply terminal used by R62 is no longer needed. Remove the red wire feeding it. Since Channel-1 was fed from this terminal, re-route its feed directly to the cap marked "U" in the photo. (Since my hookup wire is rated at 300V and "U" is about 350V, I spliced the original Eico wire. Notice the (double) heatshrink.
- ❑ Connect new pot R62A wiper to power supply point "U" at the big cap C42A.
- ❑ Install the new 1W resistor values: R62 changes from 28.75K to 22K, R64 from 33K to 27K. Note that modern 1W resistors are smaller than the ones found in the unit.

Adjustments:

- ❑ Preset the new AC Balance pots R61A, R62A to approximate center.
- ❑ Connect 8Ω dummy loads to both channels.
- ❑ Allow plenty of time for warm-up and make sure DC bias and balance are set properly.
- ❑ Apply 1kHz, 0.6Vrms to a Channel-1 line level input and set Level for 15Vrms out. Make sure it is comfortably away from clipping. Reduce level if necessary.
- ❑ Adjust R61A for minimum distortion. *If you don't have a distortion analyzer, please see the Appendix, "Setting the AC Balance Adjustment Without Lab Equipment".*
- ❑ Repeat for Channel-2.

Testing the mods

These are pretty much minimal functionality tests to verify construction. Connect a dummy load to the speaker terminals of both channels. Required test equipment:

- Audio generator (If you don't have one please see the last page of the Appendix.)
- AC voltmeter, DMM or distortion analyzer
- Oscilloscope

Phono preamp

This was basically tested with the adjustment of R27a. If you would also like to check the frequency response of the phono preamp:

- Apply 1kHz, 10mVrms to the phono-B input. (Phono-B has the correct cartridge load.)
- Read reference level at the tape output (1.14Vrms nominal).
- Apply the following frequencies and levels. Read tape output levels. Deviations from reference level are response errors.

Freq	Rel. Level	Abs. Level
20Hz	-19.3dB	1.09mV
50	-16.9	1.42
100	-13.1	2.22
200	- 8.2	3.88
500	- 2.6	7.37
1K	0.0	10.0
2K	+ 2.6	13.5
5K	+ 8.2	25.7
10K	+13.7	48.6
20K	+19.6	95.7

Line stage
To test the line stage:
- Apply 1kHz, 350mVrms to a line-level input and set the Selector to it.
- Set the Level control to maximum.
- Measure the output of the line stage at the terminal where R41 and C15 join.
- It should read approximately 0.84Vrms.
- Verify that the waveform looks clean on an oscilloscope.
- If you wish to measure distortion, I read 0.07% there.
- Repeat for the other channel.

Power amplifier
Output power
- Apply 1kHz, 350mVrms to a line-level input and set the Selector to it.
- Set the Level control to maximum; Bass and Treble controls at center.
- Find the generator level at which clipping occurs. It should be approximately 350mVrms.
- Set the output voltage just below clipping
- Measure the output across the dummy load. It should be about (35W): (choose a load)
  - 11.8Vrms for a 4Ω load
  - 16.7Vrms for a 8Ω load
  - 23.7Vrms for a 16Ω load

Distortion at 10kHz
- Set up as above at 10kHz. Adjust Level for 8Vrms output.
- Measure distortion at the output. I measured 0.14%.

That completes the basic checkout. Enjoy your new amplifier! If you have problems, you can reach me at http://www.tronola.com. Post in the article reader comments or see "About" on the home page.

Before and after performance
This section presents some of the measurements I made before and after the mods. The reference line voltage was 121Vrms.

Output power (One channel, PA only, 8Ω load, 1% distortion)

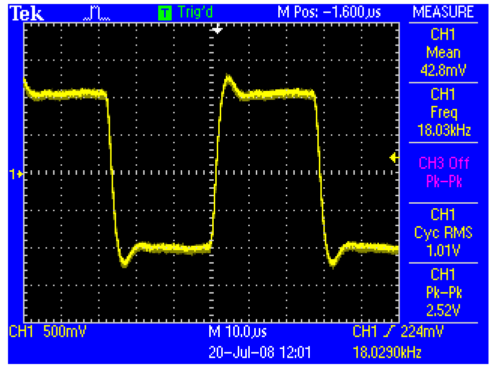
Freq	Before	After
20Hz	13W	19W
30Hz	30	33
1kHz	32	35
20kHz	10	21

Power at 20Hz increased 46% due to the reduction in distortion from the increased PA loop gain. Power at 20kHz more than doubled for the same reason.

Line-level signal to noise ratio (Full ST-70, at speaker output, 8Ω load, relative to 35W)

Freq Range	Level Control	Before	After
400Hz-30kHz	min	70dB	82dB
400Hz-30kHz	max	76	82
20Hz-30kHz	min	64	79
20Hz-30kHz	max	61	71

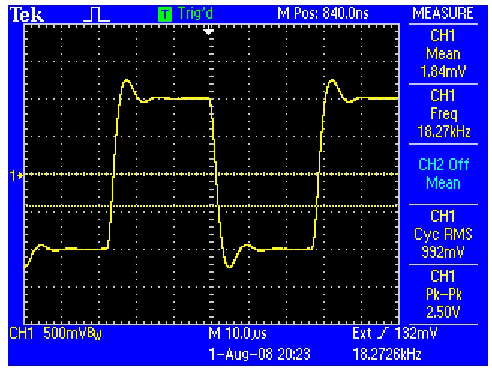
The annoying hiss at low settings of the Level control was reduced 12dB and is very quiet in a listening test with efficient speakers. Hiss can be heard 18” from the tweeter. Hum was reduced 15dB. (The 71dB figure was limited by the test setup which had to match the “before” testing.)



Distortion (One chan, 8Vrms output, PA only, 8Ω load)

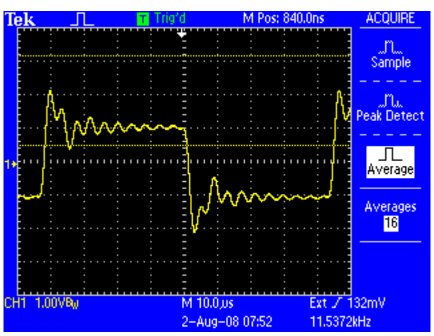
Freq	Before	After
20Hz	0.70%	0.11%
30Hz	0.43	0.06
1kHz	0.12	0.03
5kHz	0.19	0.06
10kHz	0.37	0.13
20kHz	0.85	0.33

Distortion has been dramatically reduced by the increase in loop gain, particularly at low frequencies. Adding the AC balance control and changing the feedback tap also helped. This is measured at about half the maximum voltage output.

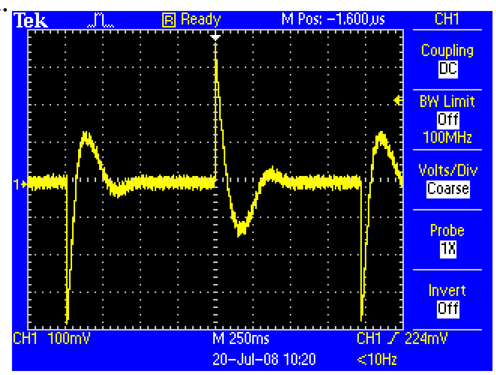


Stability at high frequency (PA only)

High frequency (18kHz) square wave response is shown before (**top right**) and after (**right**) the mods. Transient response looks about the same. (The bottom trace is thinner, due to averaging.)

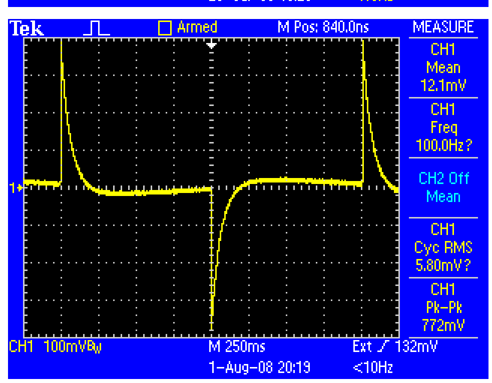


Though high frequency stability appears unchanged, the stock ST-70 has been reported to be unstable when loaded solely by a capacitive load. I found that the worst case load for stability is 0.08µF and was able to achieve stable operation with that load. Transient response with solely a 0.1µF load is **shown at left**.



Stability at low frequency (PA only)

- Very low frequency square wave response is shown **at right**, before the mods (250ms/div). Note the rebound.
- **At bottom right** after the mods, there is very little rebound, showing a more stable loop.

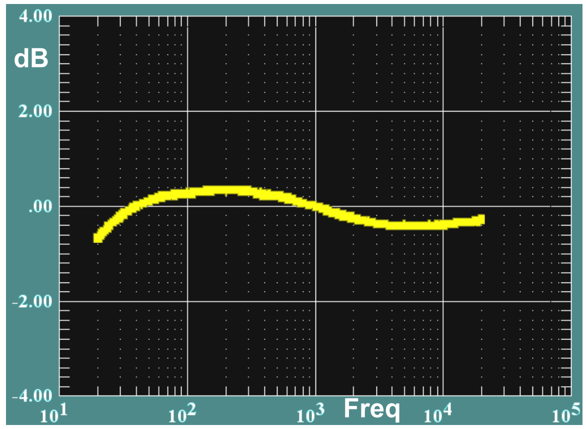


Moving feedback to the cathode of V5, along with the changes in C33/19/21 really helped low frequency stability. This can be important because it affects how fast the amp recovers from an overload. Reducing C19/21 also helped recovery time by cutting the output bias time constant in half. In listening tests, there was no discernable recovery artifact after clipping, either audibly or on a scope trace.

RIAA phono accuracy

- Before the mods, I measured phono response about 10dB down at 20Hz and 4dB at 35Hz.
- After the mods, 0.7dB at 20Hz and 0.0dB at 35Hz. Final phono response (measured at Tape Out) is plotted **at right**.

Phono preamp response is within ±0.4dB over all but the lower extremity of the range. The adjustment not only nailed the problem, it allows for corrections as the tubes age.



Frequency response (PA only)

Item	Before	After
20Hz resp	-0.02dB	-0.14dB
20kHz resp	-0.13dB	+0.10dB
LF -3dB freq	~3Hz	2.6Hz
HF -3dB freq	150kHz	138kHz
LF -0.5dB freq	na	16Hz

Although the response of the PA appears a fraction worse at the bottom end of the audio range, it is certainly not audible. The difference can be attributed to the fact that the subsonic response no longer peaks, indicating better low frequency stability now.

Acknowledgments

I would like thank my good friend David Gillespie for his advice and support throughout this effort. He suggested the component values which worked so well for the line stage. Thanks also to brad347347 on the Eico tube amps Yahoo group for various corrections.

Parts list

Qty	Reference	Description	Comment
4	C19/20/21/22	0.047uF 600V polypropylene capacitor	polyester okay
2	C33/34	470uF 6V aluminum electrolytic capacitor	higher voltage okay
2	C35/36	120pF 100V NPO ceramic capacitor	higher voltage okay
2	C37/38	1uF 450V aluminum electrolytic capacitor	250V okay
2	C43A/44A	100uF 6V aluminum electrolytic capacitor	higher voltage okay
4	C59A/60A/61A/62A	47pF 500V NPO ceramic capacitor	higher voltage okay
4	C7/8/9/10	0.1uF 400V film capacitor	
2	R27A/28A	500K 15-turn pot	Single-turn okay
4	R33A/34A/37/38	100K 1/4W carbon film resistor	1/2W okay for aesthetics
2	R41/42	1M 1/4W carbon film resistor	1/2W okay for aesthetics
2	R43/44	2.2K 1/4W carbon film resistor	1/2W okay for aesthetics
2	R56/57	150ohm 1/4W carbon film resistor	1/2W okay for aesthetics
4	R53A/54A/59A/60A	16K 1/4W carbon film resistor	1/2W okay for aesthetics
2	R61/62	22K 1W carbon film resistor	
2	R61A/62A	10K cermet potentiometer	wirewound okay. NOT carbon. Note-2
2	R63/64	27K 1W carbon film resistor	
2	R85/86	4.3K 1/4W carbon film resistor	1/2W okay for aesthetics
2	V3/4	12AX7 vacuum tube	

Note-1: New additions have an "A" suffix in the reference name.
Note-2: I hastily chose Mouser 652-51AAA-B28-A15L but it costs $8.70.

Eico ST-70 with mods, "ST-70A" Page 1 of 2
S. Lafferty 2010-2019

Eico ST-70 with mods, "ST-70a" Page 2 of 2
S. Lafferty 2010-2023

Appendix, Setting the AC Balance Adjustment Without Lab Equipment

Needed or Helpful Items

- Personal computer or laptop
- USB audio capture adapter or PC with audio input/output card (See text.)
- Passive potentiometer, preferably packaged with connectors (See text.)
- 35 Watt 8Ω dummy loads for both channels (But can get by with one.)
- Low distortion audio generator is assumed but see the last section, "In case you don't..."

Setting the AC Balance adjustments for the power amps is done to minimize distortion. It also greatly reduces the effect of tube mismatches. In previous revisions of this package of mods, this required using a distortion analyzer or equivalent. With this new appendix, I'm covering a method of measuring distortion with a personal computer and a $20 "Audio Capture Card". I use the term "capture card" loosely, because it's actually just a small adapter which plugs into a USB port. It's commonly called a "card" because it takes the place of the actual audio input/output card which used to be standard inside PCs. If you have a desktop with a good audio card it will likely be what you need for this purpose. Unfortunately, modern laptops typically substitute a monaural, low quality microphone (mic) channel for the high quality stereo line input which was once common. The mic channel isn't suitable for this technique. I use a laptop and since it doesn't have an audio line input, I bought a V.TOP "USB 2.0 Digital Audio Capture Card" through Amazon for $19, so I could test this method for readers.
https://www.amazon.com/dp/B019T9KS04?psc=1&ref=ppx_yo2ov_dt_b_product_details
(See next page for another needed item.) Below, it's assumed that you have an audio generator but that too can be provided from the computer using a DAC module or audio input/output card.

Setting up the software and the audio capture adapter

The key to using the PC to measure distortion is running a (free) software program which can take the audio from the line input and accurately display the harmonic distortion of it. I have tested this with reasonable success using two different free software packages: ARTA demo mode and Audacity. I will focus on ARTA here, operating in demo mode. The demo mode is fully functional except loading and saving of files are disabled. https://www.artalabs.hr/
Here is how I set up the software and audio capture adapter:

- Download ARTA from the URL above and install it.
- Connect the adapter to USB and Windows (10) should find it and say it's ready.
- We need to find the device's name. Under Settings|Devices|Bluetooth & other devices, "USB Audio Device" is found.
- Connect an audio generator to the left audio adapter input, set to **1kHz** and **0.6Vrms**.
- Running ARTA, it comes up in the unneeded Impulse response screen, so click the SPA icon on the row just under the main menu. The Spectrum Magnitude screen appears.
- To display the line input, click Setup|Audio Devices on the main menu. In the dialog, click the dropdown next to Input channels and select "**Microphone (USB Audio Device)**". Click OK.
- Click Setup|Graph setup. Make Magnitude axis|Top (dB): **0**, Range (dB): **100**. Freq range should default High: **20000**, Low: **20**. Frequency axis Type: **Logarithmic freq**. Click OK.
- Click Setup|Spectrum scaling. Scaling: **dBFS**. At Distortion, check **THD**. Click OK.
- On the third toolbar line, Inp is set to **Left**, Wnd is **Blackman4** and default the rest to Fs=**48000** and FFT=**8192**.

- Clicking the ▶ Start Rec icon on the toolbar line under the main menu should show you a graph with the 1kHz fundamental signal about 2 to 5dB down from the top. The top is full scale. You may also see spikes of the harmonics at 2K, 3K etc. At the bottom of the window, I see: RMS = -3.6dBFS THD = 0.053%. The -3.6dBFS figure shows the input level relative to full scale. The 0.053% figure is Total Harmonic Distortion. Your generator may show a different value. Valid values might be from 0.001 to 0.1%. We can't use much over 0.05%, so this HP-204D barely gets by.

If this works for you, you're ready to do the AC Balance adjustment! If the results are bad and you can't find the problem, I'll try to help. Just post it in detail in the Reader Comments for this article on Tronola. No signup is needed. http://www.tronola.com/html/st-70_mods.html All Reader Comments on Tronola are live and monitored.

When I did the AC Balance adjustment on the ST-70a, the final figure was about 0.17%, so it would be nice to have the distortion of the generator and analyzer far below that. Putting a cleaner generator (http://www.tronola.com/html/ig-18_mods.html) into the system here yields about 0.025%, so that's the floor with my setup. The expected final reading is almost seven times that, so it seems okay for this. This generator measures about 0.0019% in the lab, so the 0.025% floor is likely due to the audio adapter.

Handling ST-70a output level

For the adjustment, we will apply a 1kHz audio tone to the ST-70a and set Level for 15Vrms out into a dummy (resistor) load. However, an audio input card or adapter typically expects line levels of 0.8Vrms and below, so the full ST-70a output would cause it to distort and *could damage the adapter*. I found "TENEALAY RCA Audio Volume Controller" for $18 on Amazon https://www.amazon.com/Audio-Controller-Control-attenuator-RC11/dp/B08TBMP54X/ref=sr_1_1?crid=2K6CJLTFIU9ZG+&keywords=tenealay+rca+audio+volume+controller&qid=1683849404&sprefix=%2Caps%2C266&sr=8-1 which will let you reduce the level as low as needed. (There are cheaper ones too.) It's just a passive stereo potentiometer. To rig your own, you could use a 10K audio taper pot. I'll call it the **"Volume Pot"**. It has RCA connector inputs, so something is needed to go from the ST-70a speaker terminals to the RCA connector. You could cut off one end of a male-to-male RCA connector cable and strip the wires. *Keep the pot set to minimum* until you're ready to adjust it as covered below.

Making the AC Balance Adjustment

It's best to drive only one channel at a time for this procedure. Also avoid leaving it running at full level into the load for longer than needed. Having gathered the items and completed the setups above, here's how to make the adjustments:

- Preset the new AC Balance pots R61A, R62A to approximate center.
- Connect 8Ω dummy loads to both channels but swapping one over is okay.
- Connect the ST-70a Channel-1 speaker terminals to the Volume Pot ***input***.
- Set the Volume Pot to zero and connect the output to the PC audio line input.
- Allow plenty of time for warm-up and DC bias and balance should be set properly.
- Apply 1kHz, 0.6Vrms to a Channel-1 line level input and set Level for 15Vrms out.
- Make sure it's comfortably under clipping. Reduce level if necessary.
- Run ARTA. Click the SPA and ▶ (Start Rec) icons to get the Spectrum Mag. screen.
- Adjust the Volume Pot to set the red number below the graph to about RMS = -3.0dBFS.
- Looking at the THD (Total Harmonic Distortion) figure there, adjust R61A for minimum. The adjustment is expected to affect mainly the 2K and 4K harmonics.
- I was able to get the THD down to about 0.17%.
- Repeat for Channel-2.

In case you don't have a low distortion audio generator
As mentioned earlier, you can use the PC (and ARTA) for that. Most laptops have a good quality headphone output which can be used as a line level output. The only trouble is, the maximum level is quite limited. Mine only delivers 50mVrms (0.05V) at full scale. I just checked my ST-70a and found that it needs about 0.28Vrms into a line input to deliver 15Vrms out, which is what we need for the adjustment. So it requires a minimum voltage gain of 6-times (16dB) or so.

Looking on Amazon, I find "ATNEDCVH Mini Small Stereo Audio preamplifier, Headphone Amplifier, Gain 20dB" on Amazon for $26. https://www.amazon.com/ATNEDCVH-preamplifier-Headphone-amplifier-phonograph/dp/B0945RFJ6Z/ref=nav_signin?ie=UTF8&th=1
No audio specs but a decent circuit using the specified opamp should work well for this. It accepts RCA and 3.5mm cables at input and output so you could use a stereo 3.5mm male-to-male audio cable from the laptop to this preamp's input and an RCA male-to-male audio cable to go to the ST-70a. (Please let me know if you find that it or another product works well for this.)

Here's how to use ARTA to generate the 1kHz signal for the adjustment (while also showing the harmonic distortion):

- Run ARTA. Click the SPA icon to get the Spectrum Magnitude screen.
- Click Setup|Audio Devices on the main menu. In the dialog, click the dropdown next to Output channels and select Headphones or your audio output card if this is a desktop. Click OK.
- Click Generator|Run and that should send the default 1kHz 0dB (relative to full scale) signal to the headphone or audio line output.
- If using the headphone output, connect that to the Headphone Amplifier (**amp**) input with a stereo 3.5mm male-to-male audio cable. Connect a stereo RCA male-to-male audio cable to go to the ST-70a.
- If using a desktop PC with audio input/output card, it's fairly likely that it will have enough output to drive the ST-70a to deliver 15Vrms output. Then you will need to connect the audio card with the ST-70a line input, most likely with a 3.5mm male to RCA male audio cable.
- You can touch the probes of a DMM to the center and ground of the RCA male audio cable before it's plugged into the ST-70a to read AC voltage. If using the headphone amp, adjust its volume control for 0.6Vrms. If using a desktop and audio card, hopefully you will see at least 0.6Vrms. As mentioned above, my ST-70a could drive 15Vrms with as little as 0.28Vrms input. Yours could be different.
- Thus, you can do the "Making the AC Balance Adjustment" procedure *on the previous page* even without a low distortion audio generator. Leave ARTA running from this tutorial and at the appropriate (8th) step, click the ▶ (Start Rec) icon to see the spectrum.

Revision History

- Rev.7a 6/6/23 Fix Table of Contents link. Minor text changes at pp. 10, 11, 15, 16.
- Rev.7 5/22/23 Add Appendix, "Setting the AC Balance Adjust Without Lab Equipment". Various text changes. Add Revision history. Schematic: minor fix, add voltages to mod 'lytics. P.3 add comment about 12DW7s replaced. P.6 minor schematic fix.
- Rev.6 4/10/19 Redo the schematics to (greatly) improve quality while keeping file size down. Typo correction "R85/56" to "R85/86" on p.6.
- Rev.5a 1/24/19 Fix an error in the Table of Contents and give it hyperlinks.
- Rev.5 1/29/18 Add a comment about doing the mods individually and keeping line amp and PA mods together. Moving acknowledgments to end to make room.