Bulletin	Modifying the Ampex 350 for flat low-frequency equalization
Date	6 August 2008
Revision	1
Total pages	6

Overview

This service bulletin describes how to modify a 7.5/15 ips NAB Ampex 350 recorder to accommodate 15 ips IEC1/IEC or 15 ips MRL-Studio Master equalization.

Note that after modification, the recorder electronics will be *limited to correct operation at 15 ips only*—if you want to modify for 7.5 ips IEC1/IEC in addition to 15 ips IEC1/IEC or MRL equalization, you will need to add a second playback EQ pot (or fixed resistor) and wire that into the Ampex 350 equalization switch (see Full-Track Productions Service Bulletin *Ampex 350: Adding Dual Playback Equalization Adjustments*).

Before you Begin

The procedures described in this service bulletin assume that you have already modified your Ampex 350 to remove the no-longer-necessary high-frequency boost used to compensate for obsolete tape types (see Full-Track Productions Service Bulletin *Ampex 350: 15 in/s NAB recording equalization*).

Introduction

It is very important that you read and understand the following information. Modifying your Ampex 350 for flat low-frequency equalization will improve its performance. However, modifying the machine will change its equalization circuits so that tapes made on the machine previously will play back with a slight low-frequency boost (+2 dB at 50 Hz). An additional playback equalization adjustment could be added but is typically not required.

Problem

The standard Ampex 350 recorder was configured for NAB equalization (both NAB 3.75/7.5 and NAB 7.5/15 in/s versions) and as such, used a fixed low-frequency boost on record and a matching low-frequency cut on playback. This low-frequency equalization is not adjustable and must be removed if you want to modify the Ampex 350 for equalization standards that do not use low-frequency equalization—for example, IEC1/IEC Standard (formerly CCIR/DIN) or MRL-Studio Master (also known as *Proposed Equalization for 15 in/s Studio Master Recording*). For more information, see http://home.flash.net/~mrltapes/pub101sm.pdf.

Historical context of the NAB low-frequency boost

The Ampex 350 was designed in 1953. At the time, low-frequency flatness for magnetic tape recorders was not considered as important as other specifications (such as adequate signal-to-noise ratio, low distortion, and reasonably extended high-frequency response). And since radio broadcasters cut off program content below 50 Hz, there wasn't much concern about a literal interpretation of the NAB equalization standards (which called for an unrealistic 11 dB record boost at 16 Hz).

Consequently, Ampex approximated the NAB-specified low-frequency boost on record and matching low-frequency cut on playback in a relatively simple fashion that did not exactly conform to the NAB standard but was considered a better engineering compromise. For more information, see http://home.flash.net/~mrltapes/mcknight_low-frequency-response-calibration.pdf.

Implementing the NAB low-frequency record boost

To produce a low-frequency boost on record, capacitor C408 was used in the grid circuit of V403 (see Figure 3: *Original playback circuit for the Ampex 350*). At low frequencies, the capacitive reactance of C408 is relatively high (approximately 80 kilohms at 20 Hz) which puts into play parallel resistor R40. This effectively adds another series resistance to the voltage divider formed by R413 and R415; the result is increased signal voltage at the grid of V403 at very low frequencies. At higher frequencies, C408 presents little opposition to current flow and thus effectively shorts out R404.

Ampex 350 playback equalization

As with the earlier Ampex tape recorders (such as the model 300 and the model 400), high-frequency playback equalization in the Ampex 350 was done in the first playback gain stage with just two components—fixed capacitor C417 and variable resistor R435. These components form a simple integrating network in the feedback loop of V405 (12SJ7). As the playback frequency increases, there is less opposition to current flow across C417; this increases the amount of feedback which in turn reduces output at higher frequencies. Variable resistor R435 controls the stopping point for the integration process, thus providing the standard NAB 6 dB/octave high-frequency boost relative to the nominal integration (an adjustable high-frequency response is necessary to compensate for differences in playback head and playback cable characteristics).

Unless otherwise constrained, this simple integrating network—in theory at least—produces a playback stage with nearly infinite gain at the very lowest frequencies and increasingly less gain at progressively higher playback frequencies. In actual practice of course, gain is not infinite at low frequencies since the amplifying device—in this case, V405—can only supply so much gain before gain flattens as you approach the very lowest playback frequencies (typically around 30 Hz). Additionally, other components (coupling capacitors in the playback circuit and limited low-frequency output from the playback head) also contribute to reduced low-frequency response.

With the Ampex 350, this gain flattening from V405 at low frequencies must be eliminated if the model 350 is to be used with flat low-frequency equalization—more on that in a moment. As mentioned earlier, flat low-frequency equalization is required for both IEC1/IEC Standard (formerly CCIR/DIN) or MRL-Studio Master (also known as *Proposed Equalization for 15 in/s Studio Master Recording*).

Implementing the NAB low-frequency playback cut

To produce a low-frequency cut on playback, V405 was operated at maximum gain. This ensured that at the very lowest frequencies, V405 would run out of gain This was done intentionally to provide a flattening of the playback boost at low frequencies, thus producing a low-frequency rolloff below approximately 80 to 100 Hz. This was a clever way to implement a simple low-frequency rolloff but the tradeoff is that the exact rolloff frequency was somewhat dependent on the performance of V405 and would change as the tube aged. In actual practice, slight deviation in low-frequency response was not considered a problem at the time.

Now you may have noticed that the first playback tube (V405/12SJ7) is identified both on the chassis and on the schematics as “select.” This 12SJ7 was factory-selected for minimal low-frequency noise since it was running at maximum gain at low frequencies (as explained above). Today this is much less important given that modern tapes are recorded at much higher levels (made possible by the introduction of low-noise, high-output tape formulations). Today, the standard reference fluxivity (the nominal recorded level corresponding to a “0 VU” setting) is higher than the 185 nWb/m standard of the 1950s.

Typical reference fluxivity used today are 250 nWb/m (3 dB more output level) or 355 nWb/m (6 dB more output level). Consequently, noise introduced by the Ampex 350 playback amplifier is less of a concern.

Changing the gain platform of the Ampex 350 playback amplifier

By modern standards, the Ampex 350 playback circuit was somewhat of a compromise design, although it cleverly accomplished its design goals with a minimum of tubes. However, both the first playback stage (V405/12SJ7) and the second stage (V406/12SJ7) have too much gain. As explained earlier, the excessive gain of the first stage was required to cleverly provide a low-frequency cut (required for NAB playback). And by using the procedures outlined later in this service bulletin, we can lower the gain of the first stage to provide correct high-frequency playback equalization without the low-frequency cut.

The gain of the second stage (V406/12SJ7) is also quite high. This was done to permit a wide adjustment range using the playback level control (R438/1 Megohm pot) . Since the Ampex 350 was designed to operate with many different types of equipment, a fully adjustable front-panel level control (from complete silence to full gain) was a desirable feature. To that end, using this type of level control between the first and second gain stages was ideal in terms of flexible gain control with minimal loading of the first stage, but the drawback here is that the high resistance of the potentiometer (1 Megohm) also contributes to thermal noise amplified by the high gain of the second stage; normally this noise is masked by tape hiss, but if you reduce the gain of the first playback stage, you have to increase the playback level control, which in turn increases the amount of noise contributed by the 1 Megohm potentiometer.

In contrast, the earlier Ampex 400 did not have a level control; rather it used a playback level adjust that operated in the feedback from the plate of the output tube to the cathode of the second playback tube. This did not provide a large adjustment range of the playback output level, but it did provide an adequate adjustment range without introducing additional noise.

In this service bulletin, we are going to reconfigure the Ampex 350 playback circuit to use a gain-adjust control (similar to the Ampex 400) as well as optimizing the gain of the playback circuit.

Fix

Flat low-frequency response can be achieved by doing the following:

- Shorting the low-frequency record boost (capacitor C408) to disable it
- Decreasing the gain of the first playback stage by 6 dB to flatten the low-frequency playback response; this is done by doubling the value of feedback capacitor C417—this loss of gain is not a problem with modern recording tapes as they are normally recorded with much higher operating levels than tapes of the 1950s
- Reconfiguring the front-panel passive *playback level* control to a playback trim adjust control in the feedback loop (similar to the Ampex 400 playback circuit); this increases the input signal to the second playback stage by replacing potentiometer R438 with a fixed 820K resistor and eliminates the noise resistance that had been contributed by R438
- Lowering the gain of the second playback stage to compensate for a hotter input signal (see above) by changing the plate resistor of V406 from 330K to 270K

Required Parts

To perform this modification, you will need the following parts (for better noise performance, use either metal-film, metal-oxide, or carbon-film resistors; do not use carbon-composition resistors):

- 820K half-watt 5% resistor
- 270K half-watt 5% resistor
- 100K half-watt 5% resistor
- 47K half-watt 5% resistor
- 470 ohm half-watt 5% resistor
- 0.012 or 0.015 uF film capacitor (polyester or polypropylene)

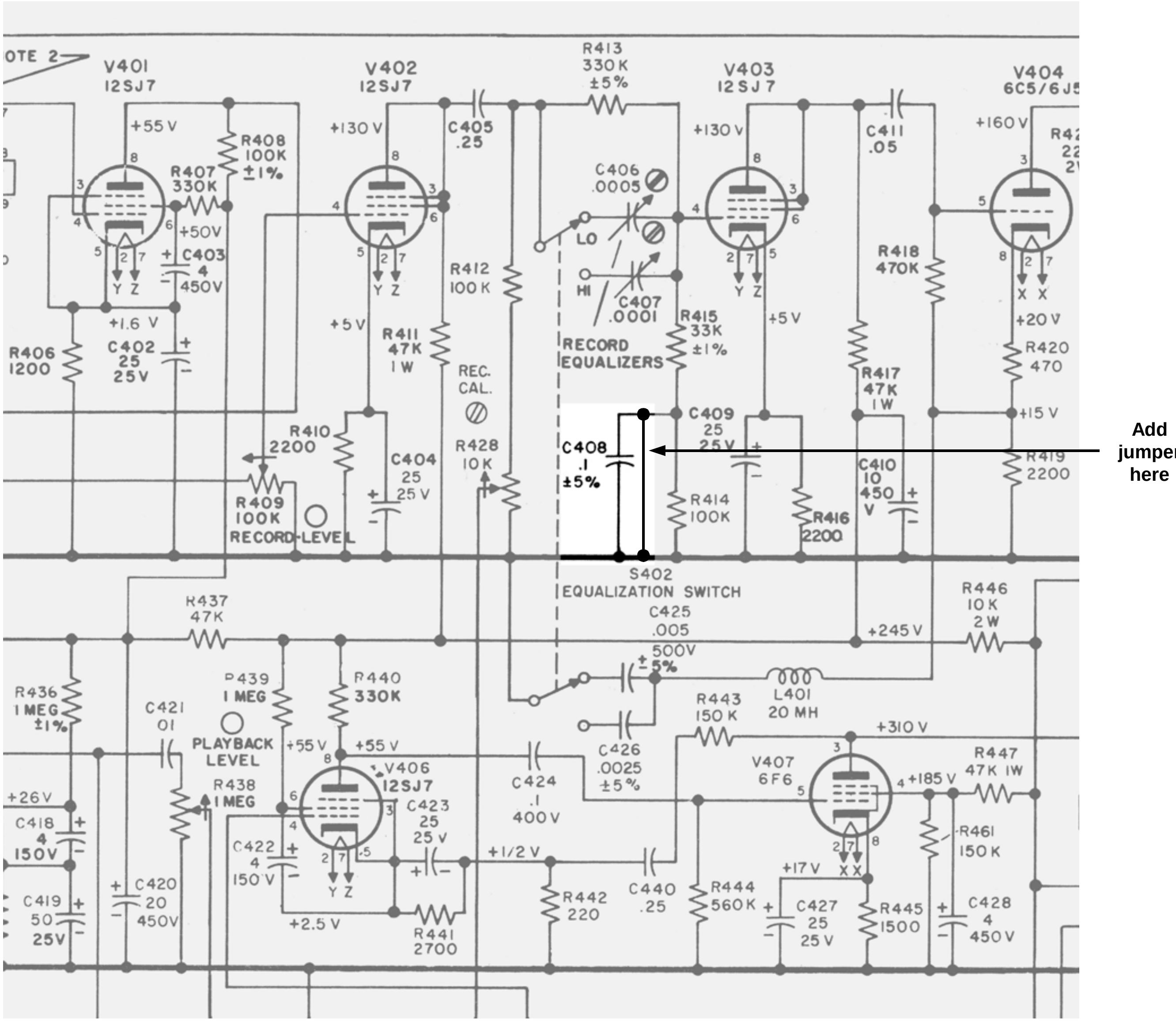

Figure 1. Disabling C408

Procedure

Note that the following procedures assume familiarity with basic electronics repair and knowledge of standard safety protocols. They also require some mechanical dexterity and access to appropriate tools (such as temperature-controlled soldering irons). Do not undertake the following procedures if you are unqualified to do so.

Part 1: Disable the low-frequency record boost

1. To avoid the possibility of potentially fatal electric shock, disconnect ac power from the Ampex 350 power supply and disconnect the power supply cable from the record/play electronics.
2. Remove the bottom cover of the record/play electronics.
3. Locate C408. It is on the terminal turret assembly on the underside of V403.
4. Make a jumper from a short length of wire (18 to 22 gauge insulated wire is fine). Solder the jumper across C408 as shown in Figure 1. This shorts the low-frequency record boost (capacitor C408) to disable it (do not remove C408 since at some future time, you may want to re-enable the low-frequency record boost).
5. If you have not done so previously, disconnect (or remove) C425, C426, and L401 as these provide high-frequency boost that is no longer needed for modern tape formulations (see Full-Track Productions Service Bulletin *Ampex 350: 15 in/s NAB recording equalization*).

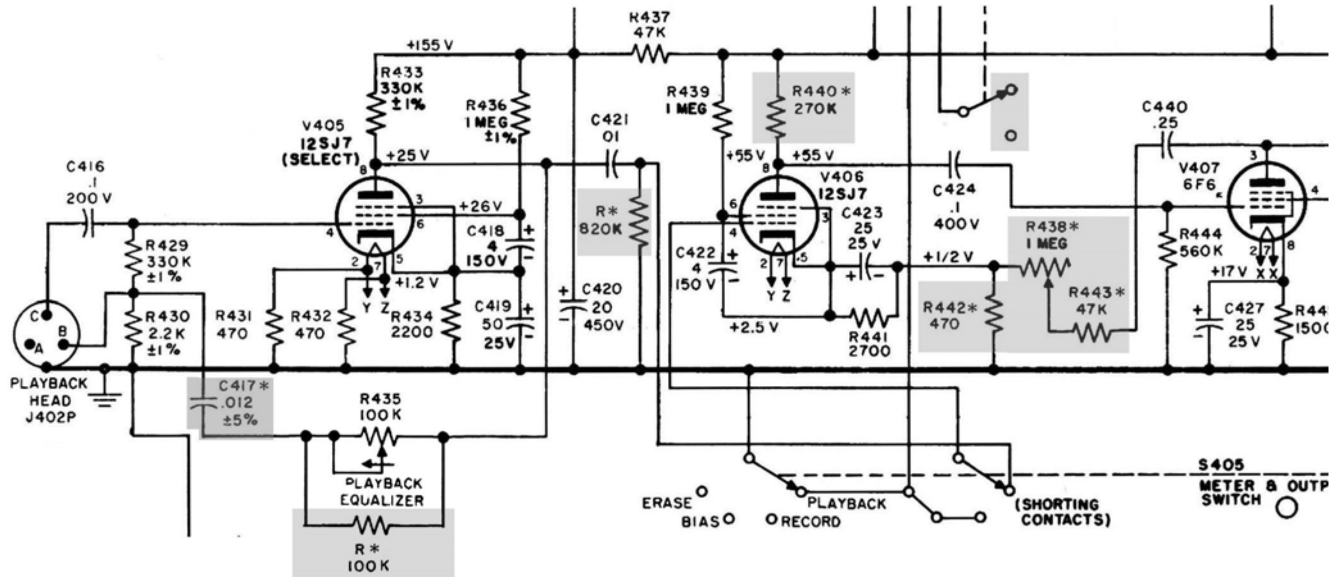

Figure 2. Revised Ampex 350 Playback Circuit

Part 2: Modifying the first playback stage

Decreasing the gain of the first playback stage to flatten the low-frequency playback response.

1 Change feedback capacitor C417 from 0.006 uF to 0.012 uF. This increases the feedback and thus decreases the gain of the first stage.

2 Put a 100K fixed resistor across R435 (playback equalizer) to bring it into a more comfortable adjustment range (or you could replace R435 with a 25K or 50K log/audio taper potentiometer).

3 Disconnect playback level potentiometer R438 but do not remove it.

4 Install an 820K film resistor in the plate circuit of V405 as shown in the revised schematic; this replaces the playback potentiometer R438 with a fixed plate-load resistor (marked “R*” on the revised schematic).

Part 3: Modifying the second playback stage

The gain of the second playback stage is reduced slightly so that the soon-to-be-installed playback trim control level (the former *playback level* control) is in a comfortable range. This done by changing the plate and cathode resistor of V406 (12SJ7).

1 Change plate resistor R440 from 330K to 270K ohms.

2 Change cathode resistor R442 from 220 ohms to 470 ohms.

Part 4: Adding playback trim control

This step rewires the playback circuit to convert the front-panel *playback level* control to a playback trim adjust control.

1 Remove R443 (150K half-watt carbon composition resistor) and discard it.

2 Wire C440 so one end connects directly to the plate of the 6F6 output tube.

3 Install a new R443 (47K half-watt 5% carbon film resistor) from the other end of C440 to the wiper of level adjust pot R438 as shown on the revised schematic.

4 Wire the remaining terminal of pot R438 to the cathode circuit of V406 as shown in the revised schematic.

Part 5: Setting playback equalization

Using an appropriate calibration tape, adjust IEC Standard (formerly CCIR/DIN) or MRL-Studio Master for flat high-frequency playback response.

Also remember that when using a standard calibration tape without fringing compensation, low frequency response will appear to be greater than normal on multi-track tape recorders due to fringing effects—this is normal and does not affect in any way how the recorder operates under normal conditions. Low-frequency response from typical calibration tapes is flat only when reproduced with a full-track playback head.

Acknowledgments

Full-Track Productions would like to thank the following individuals: Jay McKnight (*Magnetic Reference Laboratory*, San Jose, California) and Robert Cochran (Downers Grove, Illinois) for technical suggestions and Charles Bork (Seattle, Washington) for use of his Ampex model 350 magnetic tape recorder.

Appendix: Comparison of unmodified schematics and the revised schematic

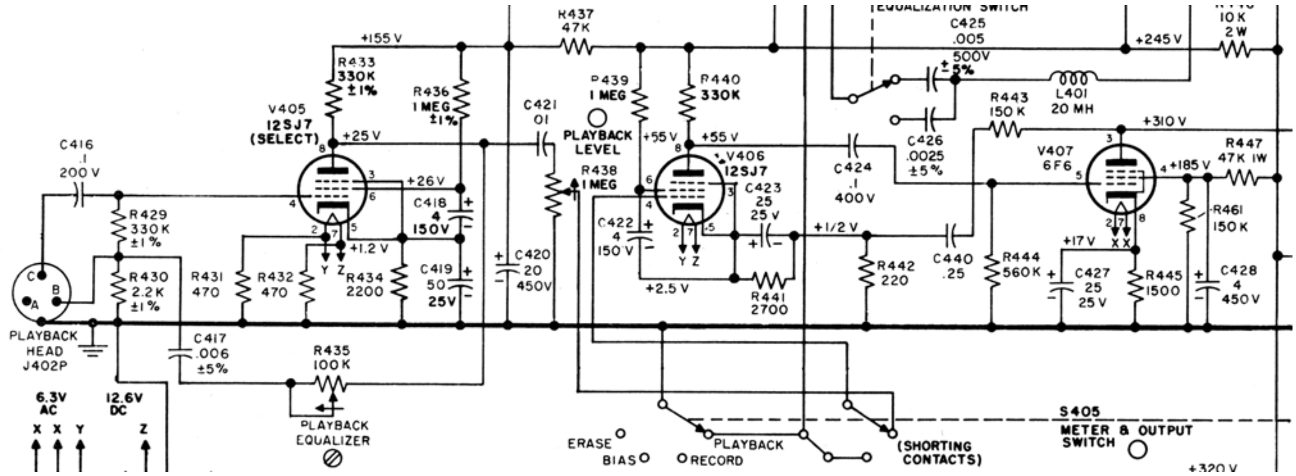

Figure 3. Original playback circuit for the Ampex 350

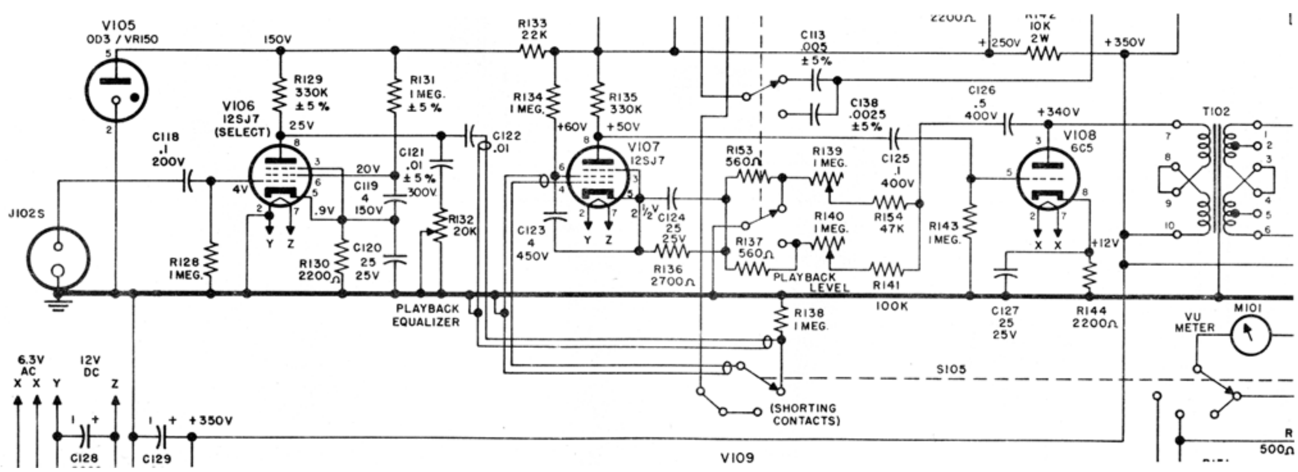

Figure 4. Original playback circuit for the Ampex 400

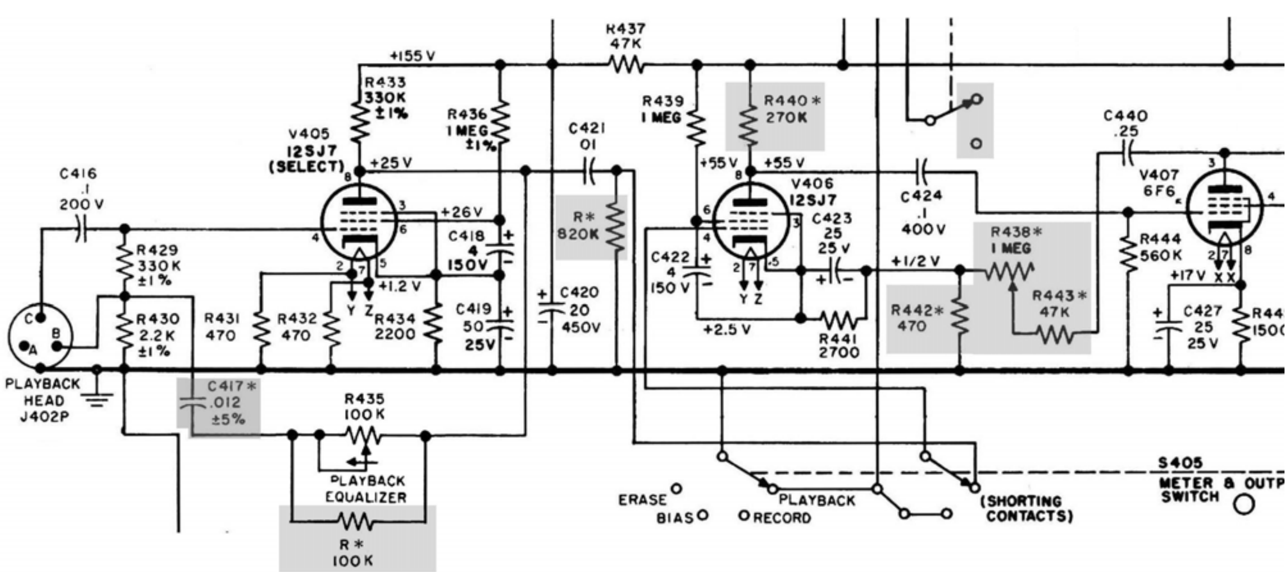

Figure 5. Revised Ampex 350 schematic, modified for flat low-frequency EQ