

Heathkit of the Month #29:
 by Bob Eckweiler, AF6C

Heathkit

Heathkit W-4AM
 'Williamson Type' Hi-Fi Amplifier.

Introduction:

In the late 1940's a new craze hit America. Electronic technology had made a leap during the war and quality music reproduction was in demand and now possible. The 33-1/3 RPM Long-Playing (LP) record album had recently been introduced along with new changer turntables with Hi-Fi needle cartridges. People were listening to music in their homes with new high-fidelity equipment and records. The Hi-Fi era was upon us. Stereo was still in the future, but good audio reproduction had replaced the distorted poor response audio of pre-war phonographs and shellac records.

A significant breakthrough in audio reproduction came about in 1947 when D. T. N. Williamson published a two-part article in the April and May issues of *Wireless World*. His article entitled: "Design of a High Quality Amplifier"¹ presented a new design offering low distortion and excellent frequency response. In November of 1949 D. Sarser and M. C. Sprinkle published "Musician's Amplifier"² in *Audio Engineering*, showing the design of a practical Williamson amplifier. See figure 1.

The Williamson design revolutionized the Hi-Fi industry and quickly became the standard for accurate sound reproduction. A 20 watt Williamson type Hi-Fi amplifier often boasted fre-

quency response specifications of $\pm 1\text{dB}$ from below 20 cps³ to over 100 kcps⁴ at 1 watt output. Intermodulation and harmonic distortion were also significantly reduced over other designs of the day.

The Williamson Design:

What makes the Williamson design so good? First, it relies on a large amount of negative feedback including a feedback loop that encompasses the entire circuit including the output transformer. This feedback path is from the highest impedance tap on the secondary of the output transformer to the cathode of the first audio stage. Second, no transformer coupling is used between stages, eliminating a major frequency dependent component. And third, a clever circuit is used to convert the single ended audio into split phase audio without the need of an interstage transformer.

A typical Williamson amplifier circuit consists of five tubes: a rectifier tube in the power supply, usually a 5V4, 5U4 or 5R4 dual diode; two twin triode tubes, often 6SN7 octal tubes or later on 12AU7 miniature 9-pin tubes, and two

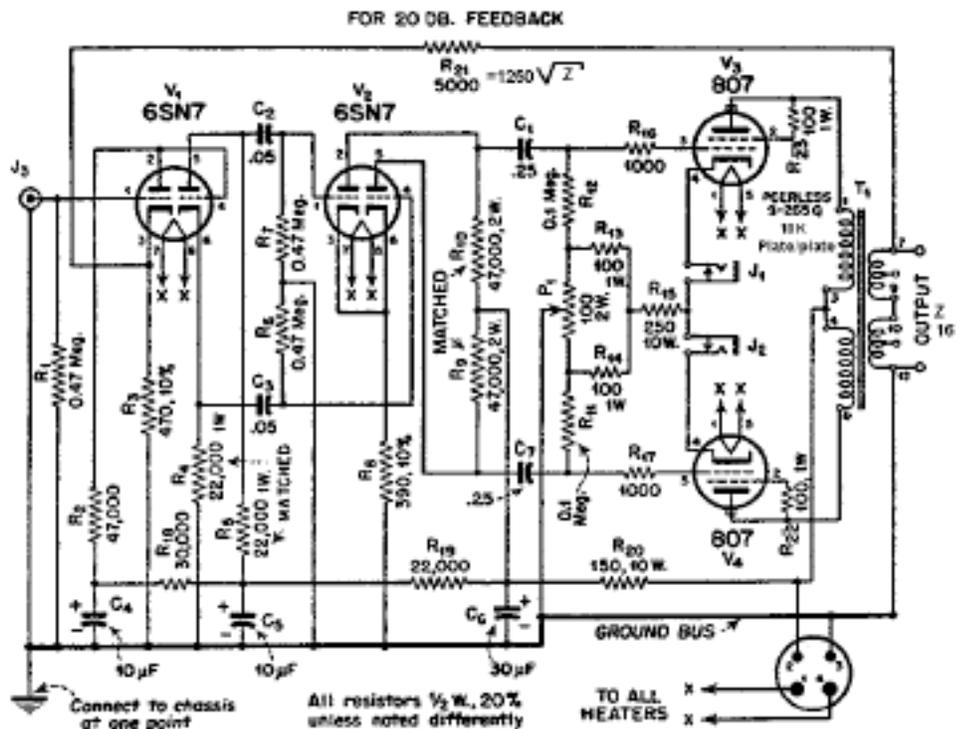


Fig. 1: The "Musician's Amplifier" circuit (circa Nov. 1949)

audio power tubes in push-pull. The first twin-triode is used as two stages of directly coupled audio amplification, the second stage providing two signals 180° out of phase, each driving one section of the second twin triode. The second twin triode outputs each drive one-half of the push-pull output stage. Various output tubes are used; mostly they are tetrodes/pentodes such as the 807, KT-66, KT-88, 5881 or the 6L6. In some early models the output tubes were connected as triodes with their screen grids tied to the plate through a low value resistor. In later units the screen grids were tied to special taps on the output transformer improving linearity even further. Acrosound, named this output transformer design *ultra-Linear*.

The Heathkit W-1 [and W-1A?]



Fig. 2: Heathkit W-1. Power Supply is on the left, Amplifier Chassis is on the right.

Heathkit's first Williamson type amplifier was the W-1. It consists of two chassis, with the power supply separated from the audio chassis. Heathkit claimed the dual chassis design gave more versatility for layout, though hum reduction may have also played into the reason. I could find little information on the W-1 except that it appears in a 1950 era Heath flyer and uses two 6SN7 dual-triodes, two 807 tetrodes and a 5V4 rectifier. Some report the W-1 is a copy of "The Musician's Amplifier circuit (which also incorporates the power supply on a separate chassis).

In the original W-1 design the 807 power tubes are triode connected with the screen grid tied to the plate through a small resistance; however evidently Heath came out with a later version (perhaps designated the W-1A or WA-1) that has an updated output transformer providing "ultra-linear" taps for the screen grids. The W-1 appeared in 1949 or 1950; I could not find the W-1A in any of my catalog references.

The Heathkit W-2M and W-3M

The Heathkit W-2M replaced the W-1 series around 1951 and is listed in their 1951 flyer. Around the same time the W-3M was introduced. Heath continued the practice of the power supply being on a separate chassis. These amplifiers use 5881 output tubes instead of 807s. The units have identical circuitry except for the output transformer. the W-2M uses a Peerless transformer and the W-3M uses an Acrosound "Ultra-linear" transformer. Because they use different transformers there are some minor component value differences between the two units, mostly in the outer feedback loop compensation. the W-2M and W-3M each sold for \$49.75; their shipping weight was 29 lbs.

The power supplies for the W2-M and W-3M are almost identical, providing around 380 - 420 VDC and 6VAC at 4 amperes for the filaments. The power transformer used in the W-3M is rated at 810 VCT at 135 ma while the W-2M transformer is rated at 750VCT at 120 ma.

The multi-chassis units are connected by a cable that uses octal tube socket connectors. The power supply has an octal socket that carries the B+, filament power and switching connections for the AC power. The amplifier comes with parts to make a 3-ft cable with an octal plug on the end that mates with the octal socket on the power supply. If a longer cable is required, user supplied cable, with heavier gauge wire, must replace the supplied cable. The amplifier chassis also has an additional octal socket that can be used to supply power to the optional WA-P1 preamplifier.

The "M" designation in these, and future, model numbers designate the amplifier unit by itself. Ordering the W-2 or W-3 without the "M" designates the amplifier and a WA-P1 (or later the WA-P2) preamplifier kit would be packaged and shipped together for an additional \$19.75 and 8 shipping pounds.

Heathkit W-3AM

The W3-AM amplifier replaced the W-3M around the end of 1956. It is basically the same amplifier with about eight minor circuit changes to improve stability and also to provide another voltage source, through pin-5 of the octal socket, to the new WA-P2 preamplifier if used.

The Heathkit W-4M, and W-4AM

The W-4 series are the first Heathkit Williamson type Hi-Fi amplifiers that have the power supply and amplifier combined on a single chassis. Very little information on the W-4M could be found. It is evidently based on the W-3M but in order to cut costs it uses a lower cost Chicago Standard output transformer.

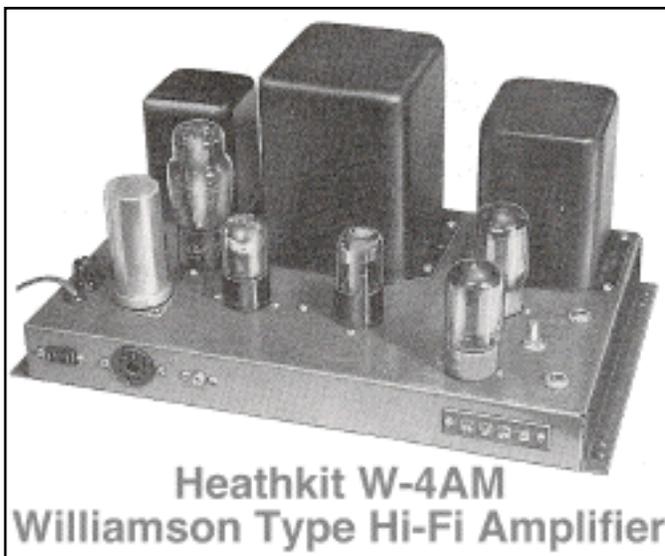


Fig. 3: Heathkit W-4AM

The W-4AM (figure 3) quickly followed the W-4M and adopts many of the stability improvements of the W-3AM in a single chassis unit, modified to meet the characteristics of the Chicago output transformer. This amplifier became very popular and is still in use by many

vacuum tube audiophiles; it is usually used in pairs for true stereo.

W-4AM Circuit Description:

Figure 4 shows the schematic of the W-4AM. Like its Heathkit predecessors it uses a pair of octal 6SN7 dual triode tubes. It also uses a pair of Tung-Sol 5881 output tubes like the W-2 and W-3. The rectifier is a 5V4G dual diode. Note that in the schematic there is an error. The cathode of the 5V4 is shown connected to pin 2 internally; it is actually connected to pin 8. The schematic external to the tube is correct.

The first audio stage (1/2-6SN7) input is capacitively coupled unlike the initial design. It is a single triode with no capacitor in the cathode resulting in lower gain but better linearity (a Williamson theme that holds for every stage except the output stage.) The grid of the second audio stage and phase splitter is directly coupled to the plate of the first stage for best frequency response. However a phase compensating network (4.7K and 420 pF) is present across the combination 47K grid and plate resistor. A similar network was added between the W-3M and W-3AM models. Matched 22K 1W resistors, one in the cathode and one in the plate circuit develop identical signals that are 180° out of phase. Each of these signals are capacitively coupled to their own section of the second 6SN7, wired in push-pull. Matching 47K 2W plate resistors develop identical but opposite signals that drive the output stage.

The push-pull output stage runs in class AB, each tube drawing with no signal about 50 - 60 milliamperes. A potentiometer is provided in the cathode circuit to balance this quiescent current in each tube. 1/4" phone jacks are provided in each cathode circuit so a milliammeter can be plugged in to read the current. The jacks are self-shorting when nothing is plugged in.

The Chicago Standard output transformer has primary *ultra-linear* taps for the screen grids. The transformer secondary has outputs for 4, 8 and 16 ohm speakers.

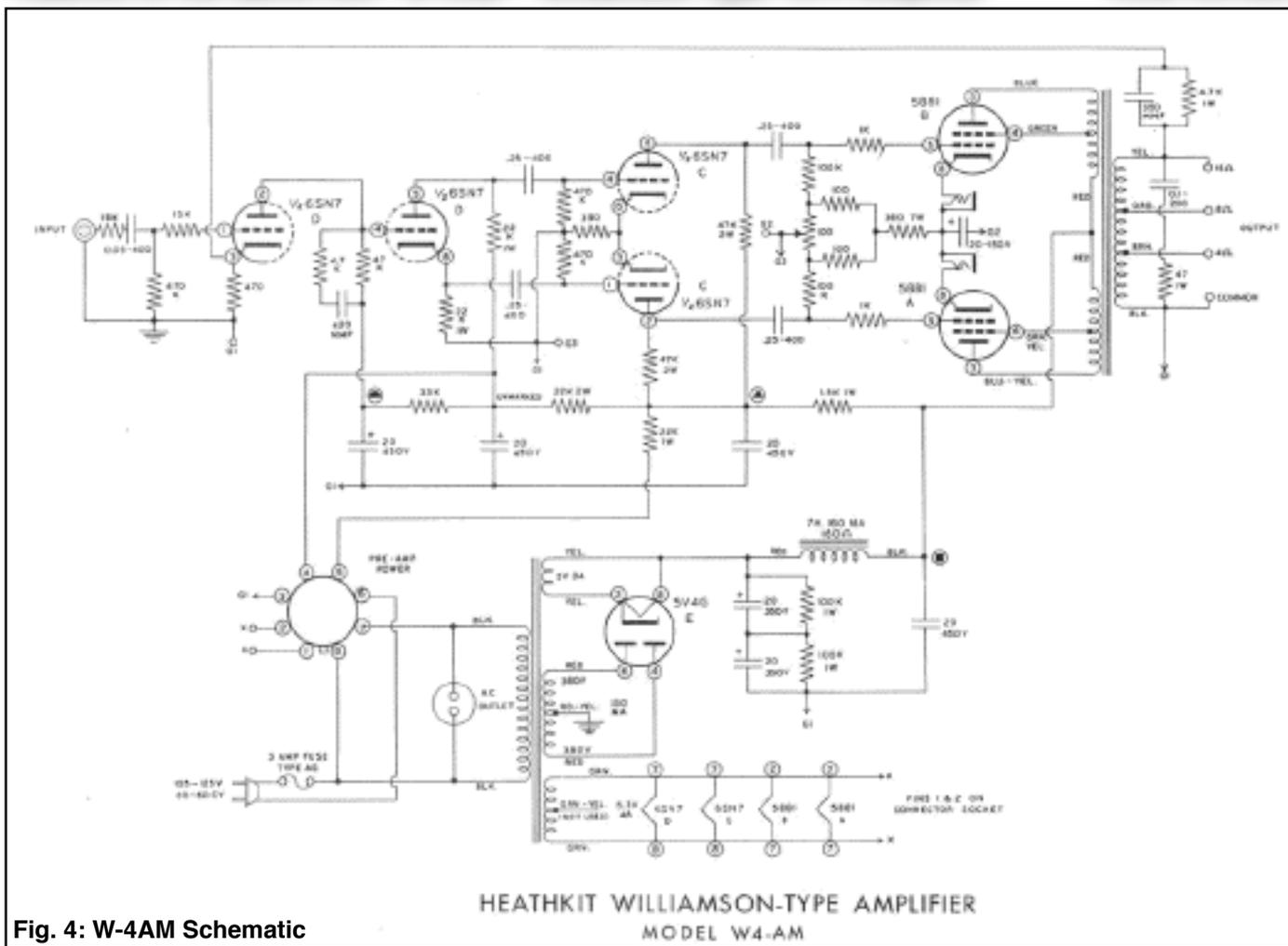


Fig. 4: W-4AM Schematic

The amplifier would not meet the Williamson criteria unless it has a feedback path around all four stages and the output transformer. This feedback path goes from the 16 ohm tap of the output transformer to the cathode of the first audio stage. It consists of a 4.7K 1W resistor shunted by 350 pF. Like the change between the W-3A and W-3AM models the W-4AM also includes a series RC compensation network across the full secondary output. This network is probably more for transient protection of the speakers than for loop stability.

Since the Heathkit W-4AM includes the power supply and amplifier on a single chassis, care is needed in grounding. The W-4AM has three separate grounds that are isolated from each other except at one common point. The grounds are marked G1, G2 and G3 on the schematic.

W-4AM Specifications

- Power output: 20 watts
- Peak output: 36 watts
- Freq. Response: ±1dB 10 to 100K cps
- Harmonic Distortion: 1.5% max at 20 watts
- Hum: 95 dB below 20 watts
- Damping factor: 28.5 :1
- Power output (1V in): 5 watts
- Power Requirements: 105-125VAC 50/60 cps
115 watts
- Dimensions: 15-1/4" W x 8-7/8" D x
7" H. Allow an additional 1-1/2" width for
cables and connectors.
- Shipping Weight: 28 lbs. (Less preamp.)

The W-4AM was produced in the mid fifties. It appears in the 1956 catalog, but by 1961 stereo had hit the market and Heathkit dropped the Williamson design for more compact modular equipment.



Fig. 5: W-5M

Heathkit built two additional amplifiers under the “W” brand in the mid-to-late fifties, the W-5M and the W-6M.

The Heathkit W-5M

The W-5M (figure 5) is the second single chassis Williamson type amplifier. It is also the first amplifier of its type to come with a top chassis cover. It also boasts a totally new tube lineup, replacing the octal 6SN7 tubes with 12AU7 9-pin miniature tubes. The power output stage uses KT-66 tubes and boasts 25 watts (42 watts peak) output. The rectifier tube is a higher current 5R4GY. This amplifier contains two tip jacks instead of the two phone jacks used to balance the output stage. A voltmeter is connected between these jacks and the balance pot is adjusted for zero voltage with no signal.

While the preceding amplifiers, with possibly the exception of the W-1 have a switched convenience AC outlet, the W-5M also includes a second non-switched AC outlet. The W-5M sold for \$59.75 in 1956.

The Heathkit W-6M

Heathkit's final “W” amplifier, (figure 6), has drawn some controversy as to whether it is a true “Williamson” design or not. The W-6M uses 5880 audio output tubes and produces 70 watts of audio power. Three other tubes are used, all different type 9-pin miniature dual triodes: A 12AU7 as audio amplifier and phase splitter, a 12AX7 as push-pull audio amplifier and a 12BY7 as the driver for the 5880s. This additional driver stage is a large part of the

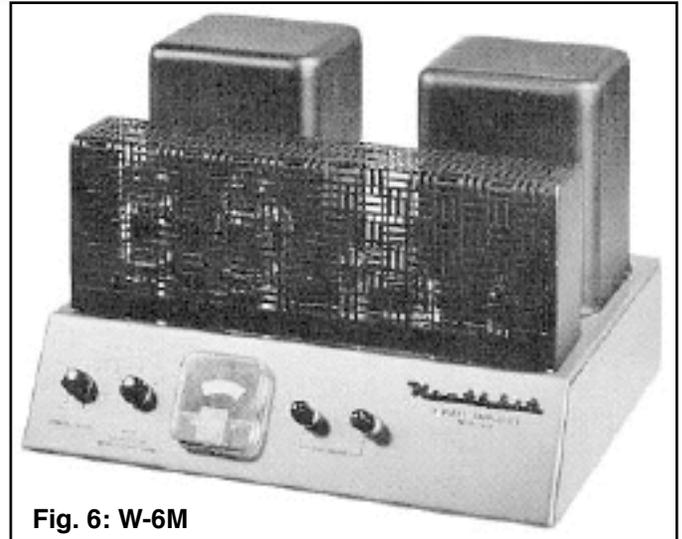


Fig. 6: W-6M

“Williamson” controversy. In fact Heathkit doesn't mention Williamson in their advertising. You may have noticed a rectifier tube was not mentioned; that is because there is not one. Heathkit took a large step forward introducing silicon diode power rectifiers in this amplifier.

Heath also added some new features to the W-6M including front controls to adjust damping and set the bias, as well as a meter to monitor the bias settings. The W-6M, with a shipping weight of 59 lbs, sold for \$109.95 in 1957.

73, from AF6C



Notes:

- 1 The article can be found in http format in two parts on the web starting here: <http://www.keith-snook.info/Articles-for-the-Web/Williamson-Amplifier-1947/Williamson-WW-April-1947.html>
- 2 A reproduction of the article in pdf format may be found on the web at: http://oestex.com/tubes/mus_amp%20.pdf
- 3 cycles-per-second. Today Hz
- 4 kilocycles-per-second. Today kHz

Remember if you come across any old Heathkit Manuals or Catalogs that you do not need, please pass them along to me.

Thanks - Bob AF6C

This article originally appeared in the May 2011 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.