RADIO AGE

The Vintage Radio Journal of the Mid-Atlantic Antique Radio Club

Volume 36 **December 2011** **Number 12**

The Should-Have-Been RCA Model 23K: Analysis of a 23-Tube Prototype Receiver Chapter 2 - The Main Chassis

BY LEIGH BASSETT W3NLB

[*Part 1 of this article appeared in the June 2006 issue of* Radio Age. *As noted in that article, this 1930s RCA prototype receiver was saved from the dumpster and donated to the Radio & Television Museum in Bowie, Maryland. Leigh Bassett agreed to study it and write articles for* Radio Age *about its design. Part 1 described the "Magic Brain" portion of the receiver, and this second part describes the main chassis. The history of the radio is not known, but one can speculate that RCA was considering producing a high-end receiver to compete with the Scott All-Wave 23 and the Zenith Stratosphere. Why was this radio never produced? Perhaps RCA felt that the number likely to be sold would be too small to justify the cost of tooling to produce it. In any case, it is an interesting set to study, and we are very grateful to Leigh for taking the time to do that and report to us.– Editor*]

First of all, permit me to apologize to all of you out there in radio land for the unconscionable delay in finishing this analysis. In fact, it is not finished, and I must admit that I will not be the one to finish it. There are unresolved issues, and the available information is insufficient to enable their resolution. Add to this the fact that I'm an RF guy, not an audio guy, but much of the complexity of this radio is in the audio sections. I shall therefore leave it to subsequent investigators to complete the task.

The Prototype and the Product Family

As pointed out in Chapter 1, this prototype was most certainly based on the Model 15K from 1936. The mechanical parts are virtually identical in design and fabrication details, and bear the same part numbers in some instances. The prototype has exactly the same frequency range as the Model 15K, from 150 kHz through 60 MHz continuous, but with a gap around

(Continued on page 3)

(Continued from page 1)
the 460 kHz IF. Both models use the same tuning mechanism, with identical part numbers.

The set may have provided some features used in the 816K and U109 radios in the 1937 model year. However, no set in the RCA product line had all the features of this prototype. The Model D22-1A from 1936, with a similar tube count, is a vastly different radio.

Most of the engineering work appears to have been centered on the audio performance of the set. This affects the IF string as well as the actual audio circuitry, as will be discussed.

A block diagram of the radio is shown on page 4.

Circuit Analysis

After leaving RCA, this radio continued to provide service for at least 20 years, based on the presence of repair parts that were first manufactured in the 1950s. Some circuits, particularly the audio section and power supply, underwent extensive repairs and/or modifications at the RCA engineering lab or later. All of the following schematics and descriptions are based on the original circuitry, to the best of my ability to recreate the design.

I've elected to analyze the set by section, starting with the Magic Brain in Chapter 1 of the series. This enables me to present partial schematics, which can be reproduced in *Radio Age* at a readable size. The entire schematic for the radio is ridiculously large. It can be downloaded from the web.

All of the measurements taken in the radio, with the exception of some tests on the Magic Brain in isolation, were done with no power applied to the set. Some of the methods are discussed in Appendix A. Deterioration of the components and wiring may adversely affect the measurements. Although the techniques used were selected to ensure a high level of accuracy, some deviation from design values is to be expected.

The resistors are regular dog-bone types having standard Body-End-Dot (BED) color codes, with one exception: One resistor, apparently 1000 ohms nominal, has two red dots rather than one, so the BED is BRN BLK RED RED. There are several of these, none of which are overheated or otherwise damaged.

All of the schematics are based on components I could actually see, looking at the set. Due to the unique nature of the radio I did not open any IF transformers, so their internal structure, and presence of additional components, cannot be determined. These are complex parts, using as many as nine terminals. They are double-tuned. I've drawn them with fixed capacitors on both primary and secondary, but this is just an assumption based on examination of similar parts from a Model 15K chassis. The numbers penciled on the parts (2836-50x and 21036-50x) are apparently engineering drawing numbers. The format does not match RCA part numbers.

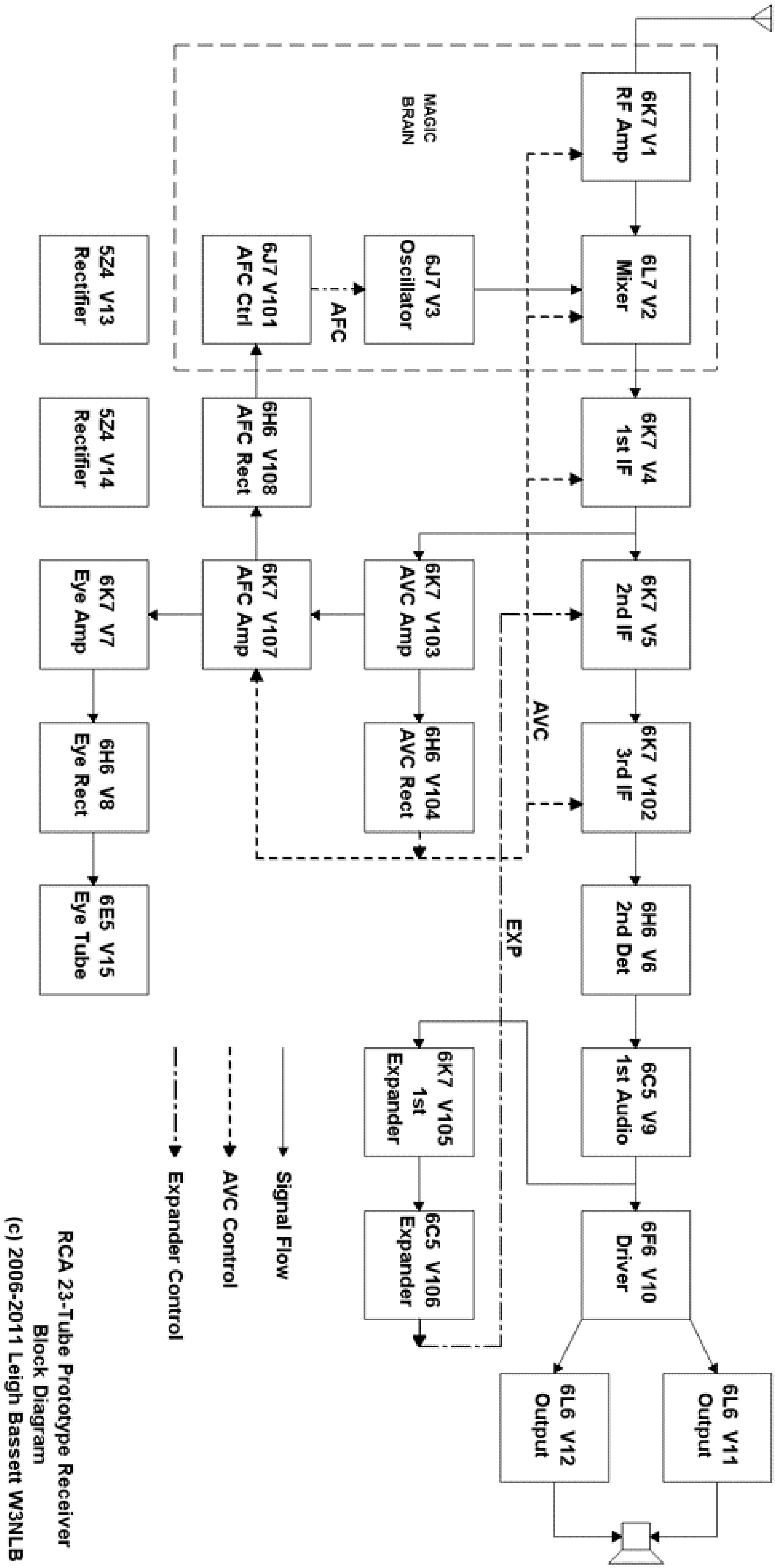
I adopted an experimental strategy in the first chapter that was a mistake. Since the prototype is based on the 15K, I elected to use component numbers from that set's schematic where it appeared that they were duplicated here, and provide my own numbers for other components. As I got further into the radio, it became obvious that this would not work, so I've renumbered all components in the set, and used those numbers in all current documentation.

Unique Prototyping Features

The chassis bears numerous notations in pencil, identifying all the tube types and functions, all the controls, and some other components. When these notations are referenced in the following text, they are rendered in **bold face**.

One unusual aspect of this set is the presence of a five-position screw-type terminal strip on the rear apron, to which several circuit points are connected. Presumably this was done so that various circuit parameters could be monitored without turning over the chassis.

In This Issue



Block Diagram of the Prototype

The terminals bear the following labels, from left to right:

Audio Grid
Detector Out
1st AF Cathode Bias Adjust
Ground
Last IF Cathode

There is a metal link connecting the last two terminals. The last IF cathode has a bypass capacitor installed. I think this was a connection for a milliammeter to monitor AVC operation.

There is a double-pole double-throw toggle switch mounted on a bracket next to this terminal strip, and originally connected to it. Unfortunately the wires have broken loose, so it's difficult to ascertain its exact function. An RCA phono jack is connected to the switch. This could have been an alternate input to the audio grid, providing an input for test equipment used to evaluate the audio section independent of the radio.

At some points in the circuitry changes were obviously made, with some components disconnected or re-wired after initial assembly. These are discussed in the appropriate sections of the narrative.

Circuit Description

General notes:

- Parts that are permanently mounted to the chassis (including tubes) have one- or two-digit part numbers. All other parts have three-digit numbers.
- To avoid excess clutter, connections for common circuits like B+ are shown as labeled boxes.
- The 6.3-volt filament circuit (from a single transformer winding) used twisted-pair wiring to minimize hum.
- The Magic Brain is isolated electrically and mechanically from the main chassis by rubber grommets. Electrical isolation was important because one side of the filament is grounded in the Magic Brain, but not in the main chassis. In the Magic Brain the ungrounded filament line is RF bypassed.
- P1 and P2 are octal sockets used as connectors for the Magic Brain.
- Resistor values are nominal based on color codes or other markings, unless otherwise indicated. Some values were marked in pencil on the chassis. Measured values appear in the parts list.
- All tube types and functions were actually penciled on the chassis. The same is true of switches and controls.
- Two Candohm resistors are used, their terminals identified with single letters.

The Magic Brain (RF, LO, and Mixer)

The Magic Brain was covered in detail in Chapter 1. I'll discuss it only briefly here.

The Brain is patterned after the three-tube version used in the 15K, and most components appear identical. The prototype Brain has a fourth tube, a 6J7, used as an AFC control on the broadcast band only. The prototype Brain is significantly wider than the one in the 15K. The dial components are identical on the two radios.

AVC is applied to grid 1 of the 6K7 RF amplifier and the 6L7 mixer through 100K isolating resistors.

IF Amplifier and Detector (Schematic 1 on page 6)
(Note: in these schematics, p/o means "part of.")

The IF chain consists of three 6K7 amplifier stages, followed by a 6H6 detector. All four transformers in the chain are double-tuned. AVC is applied to the grids of stages 1 and 3 through 100K isolating resistors; those cathodes are grounded. The stage 2 grid and cathode are connected to the expander, operation of which is not well understood.

The five-position **H.F. Tone** switch changes the bandwidth of the first three IF transformers. A fourth section of this switch changes capacitors in the audio stage, attenuating the high-frequency response in the first two positions. Table 1 on page 7 shows the 3-dB bandwidth for the five positions, **Min**.to.**Max**. Appendix A discusses the measurement technique.

AVC, AFC, and Tuning Eye (Schematic 2 on page 8)

The AVC, AFC, and tuning eye sections each have a 6K7 amplifier inductively coupled to a 6H6, with the IF signal being fed from one amplifier to the next through tertiary transformer windings. The AFC has an extra variable inductor, with the 6H6 configured as a discriminator. The other two circuits use the 6H6 as a simple rectifier.

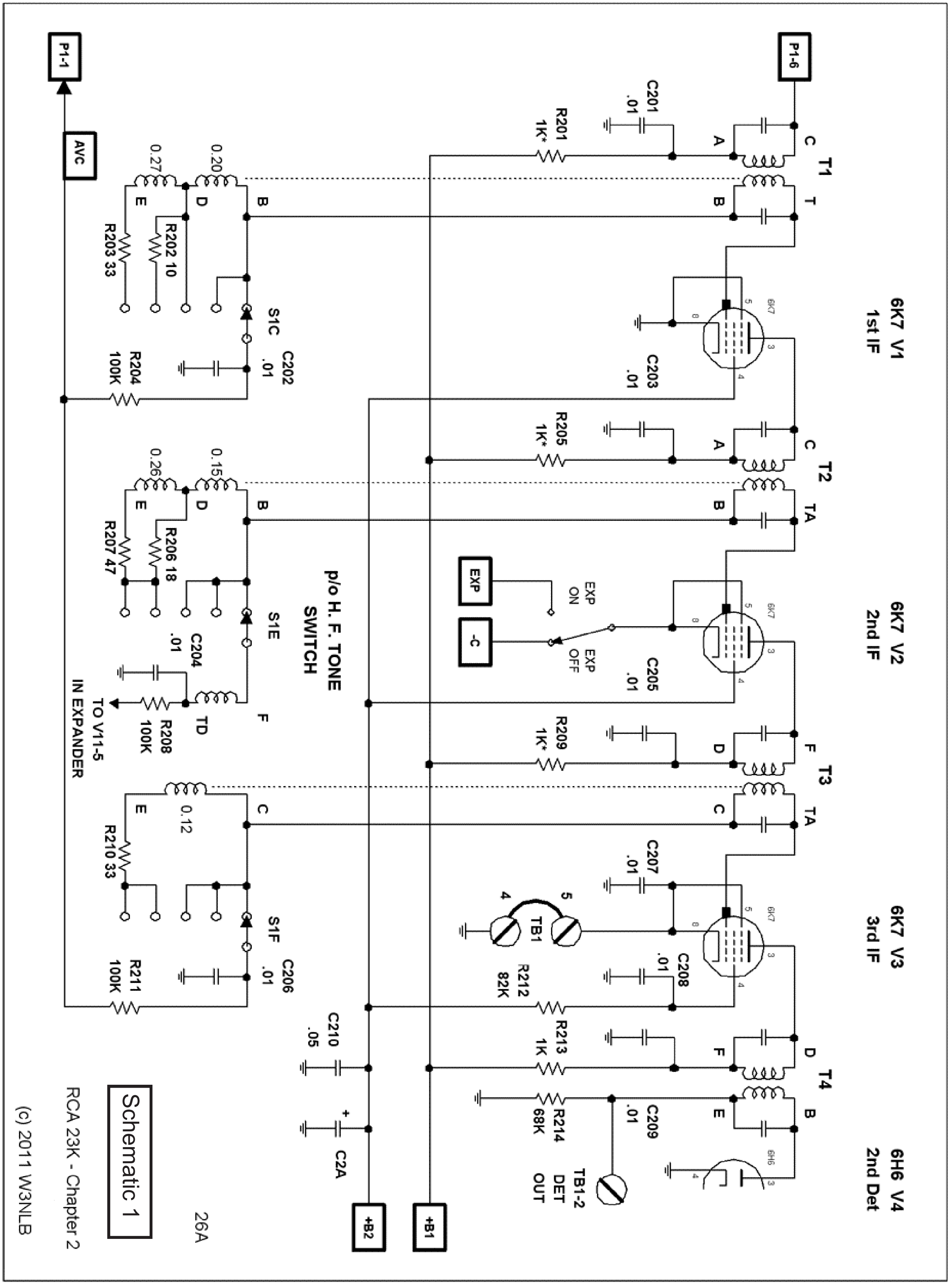

Schematic 1
RCA 23K - Chapter 2
(c) 2011 W3NLB
26A
6K7 V1
1st IF
6K7 V2
2nd IF
6K7 V3
3rd IF
6H6 V4
2nd Det
T1
T2
T3
T4
P1-6
P1-1
AVC
C201
.01
R201
1K*
C202
.01
R204
100K
C203
.01
R202 10
R203 33
0.20
0.27
S1C
R205
1K*
C205
.01
0.15
0.26
R206 18
R207 47
S1E
C204
.01
R208
100K
TO V11-5
IN EXPANDER
p/o H. F. TONE
SWITCH
EXP
EXP
ON
EXP
OFF
-C
R209
1K*
0.12
R210 33
S1F
C206
.01
R211
100K
C207
.01
C208
.01
TB1
R212
82K
R213
1K
C209
.01
R214
68K
TB1-2
DET
OUT
C210
.05
C2A
+B1
+B2

Table 1

3-db Bandwidth for Each of the Three IF Transformers
for the Five Settings of the H.F. Tone (Bandwidth Selection) Switch

IF Xformer #	Min	2	3	4	Max
1	*	*	10.4	26.4	49.2
2	8	8	8	21.2 **	21.2 **
3	18.8	18.8	18.8	51.2	51.2

***Note:** The first two switch positions for IF transformer 1 exhibit a relatively flat passband with a level about 18 dB below the level at the other positions. This is likely the result of a component failure or a bad solder joint, and does not represent the original design. I would expect a value of 10.4 kHz for these positions, the same as position #3. The set will not function properly with the switch in the first two positions.

**** Note:** Switch positions 4 and 5 at IFT 2 seem to have been connected together early on, as the switch terminals don't appear to have been re-soldered. This makes no sense given that each position has its own resistor, and they are of different values. This probably reflects experimentation by the engineers during development and testing.

AVC is applied to the RF amplifier, the mixer, the 1st and 3rd IF amplifier stages, and the AFC amplifier.

<u>Audio Amplifier, Driver, and Power Amplifier (Schematic 3 on page 9)</u>

The audio section is comprised of a 6C5 First Audio followed by a 6F6 Driver and a pair of 6L6 Output tubes operated in push-pull.

Input to the first stage comes from rear-apron terminal strip TB1 terminal #1. Audio from the detector is available on adjacent terminal #2. The cathode of this stage goes through two resistors to ground. The junction of these is brought out to TB1 terminal #3, labeled **1st Audio Cathode Bias Adjust**. Presumably this was the connection point for an external pot. The first audio plate load is a large chassis-mounted choke with a DC resistance of 5400 ohms. I was unable to read its inductance, probably because the high resistance swamped the impedance bridges.

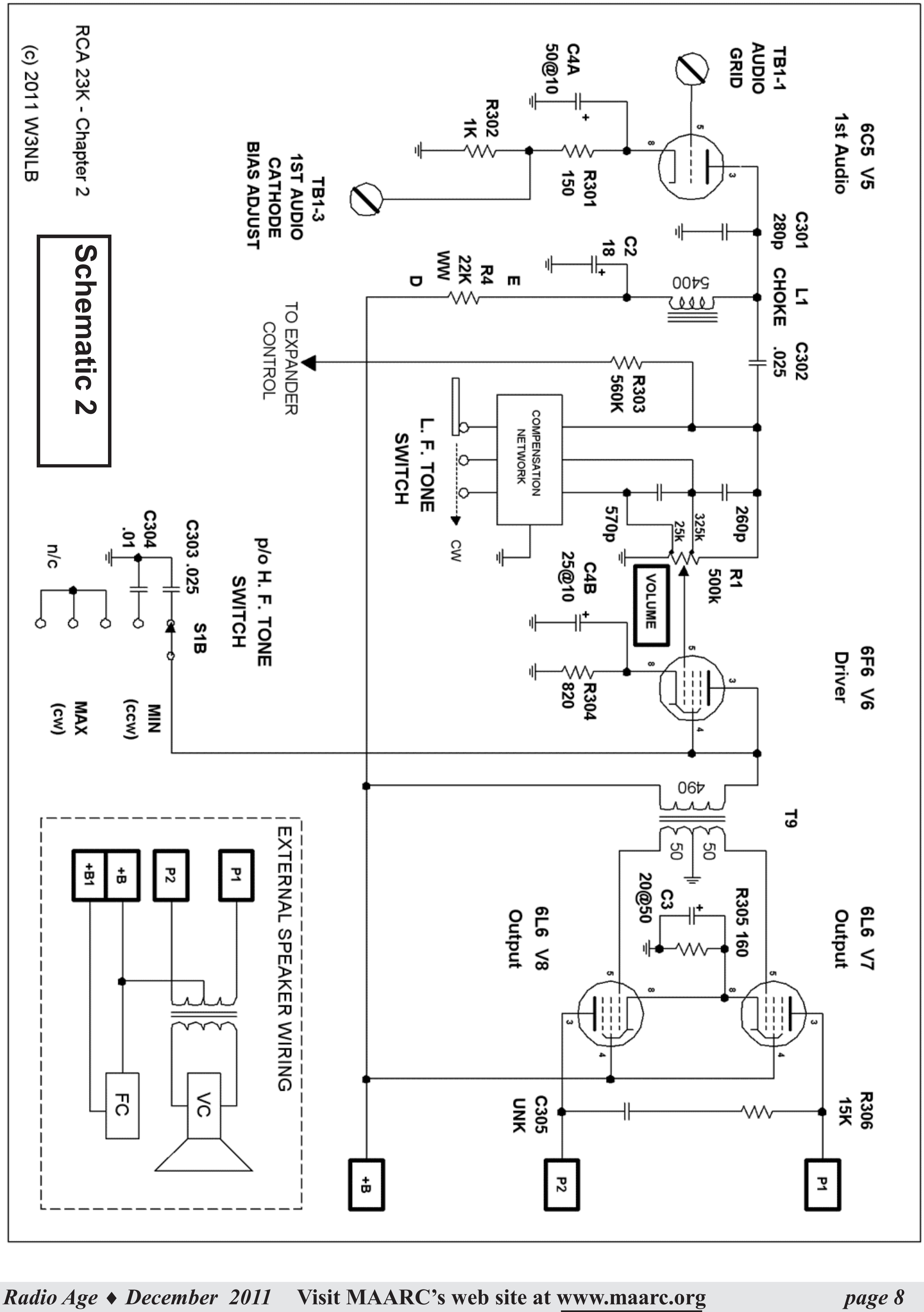
The volume control is at the grid of the 6F6 driver, which is configured as a triode, with the screen tied to the plate, as in the later 816K. The driver is transformer-coupled to the 6L6 grids, with the center tap grounded.

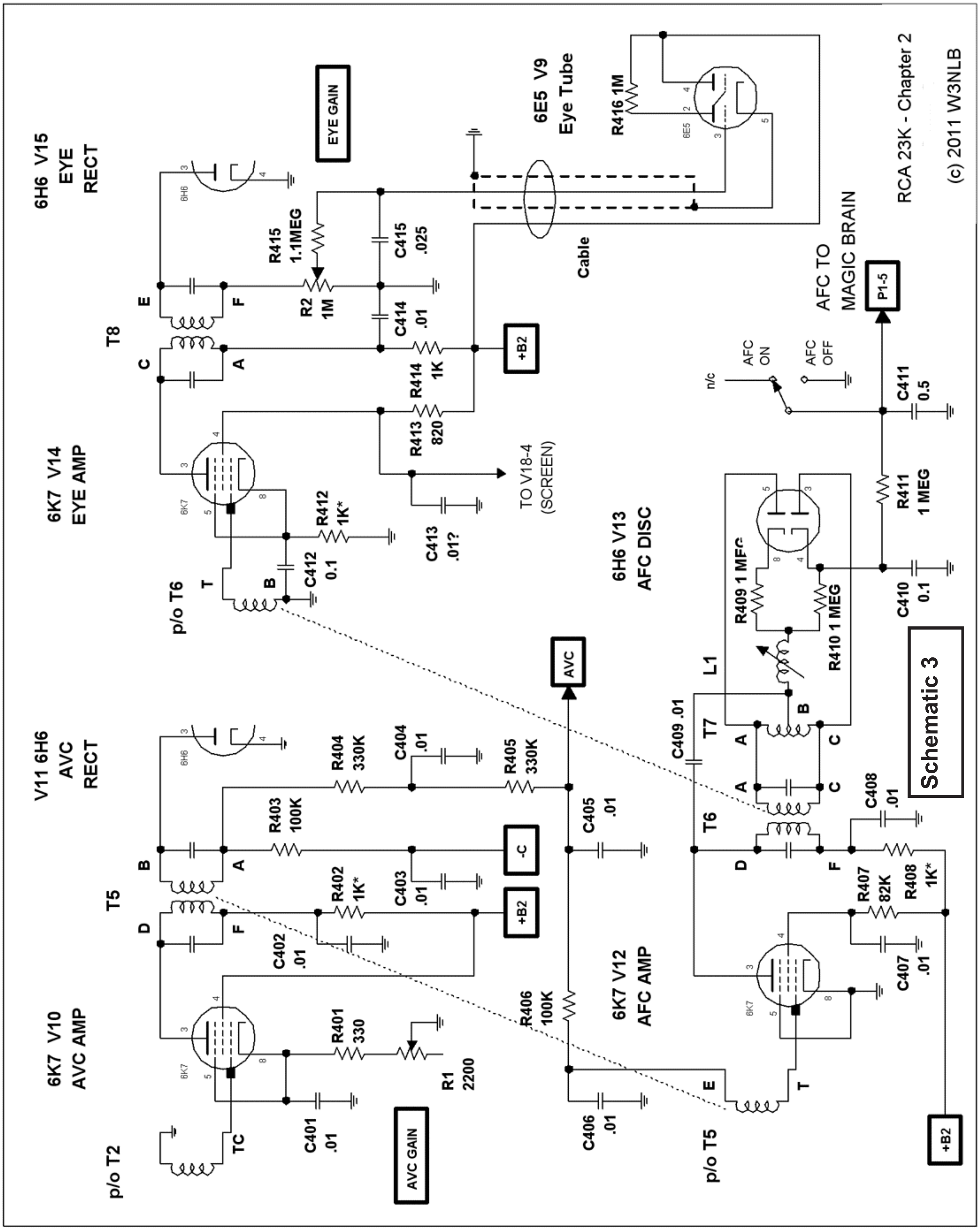
The 6L6s operate with cathode self-biasing; no fixed bias is used. B+ for the audio section is derived before the field coil, to get higher voltage but slightly higher hum.

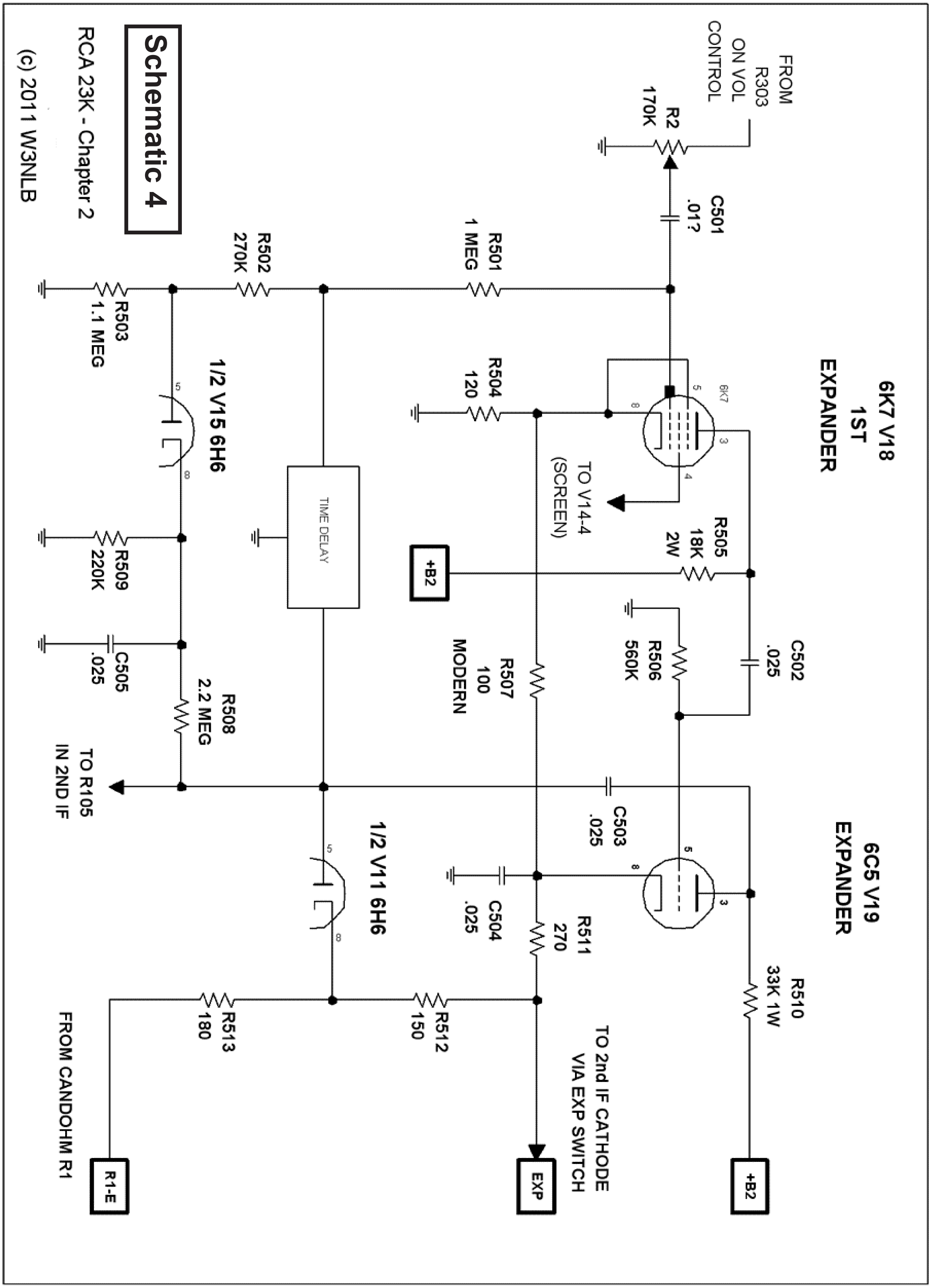
The output transformer was speaker-mounted, with connection via a four-pin speaker socket on a cord. Two pins provide connection for the field coil; the other two go to the output tube plates. The radio was mated to a very large commercial RCA speaker, which also served as the console base. However, the connections to this speaker are quite different from the four-pin socket on the umbilical, and no adapter cable exists.

Separate LF and HF tone controls are provided. The LF control is a three-position rotary switch that connects to a **Compensation Network** which in turn connects to the dual-tapped volume control. The contents of the network are unknown. The 500-kilohm volume control has one tap at about 325K and another at about 25K. Two small mica capacitors are attached across the control segments. All of these connections go into the **Compensation Network**.

◀ Schematic 1


6C5 V5
1st Audio
TB1-1
AUDIO
GRID
C4A
50@10
R302
1K
R301
150
TB1-3
1ST AUDIO
CATHODE
BIAS ADJUST
C301
280p
C2
18
L1
CHOKE
5400
R4
22K
WW
E
D
C302
.025
R303
560K
TO EXPANDER
CONTROL
COMPENSATION
NETWORK
L. F. TONE
SWITCH
CW
260p
570p
325K
25K
R1
500K
VOLUME
C4B
25@10
6F6 V6
Driver
R304
820
p/o H. F. TONE
SWITCH
C303 .025
C304
.01
S1B
n/c
MIN
(ccw)
MAX
(cw)
Schematic 2
RCA 23K - Chapter 2
(c) 2011 W3NLB
490
T9
50
50
R305 160
C3
20@50
6L6 V7
Output
6L6 V8
Output
R306
15K
C305
UNK
P1
P2
+B
EXTERNAL SPEAKER WIRING
P1
P2
+B
+B1
VC
FC


Schematic 3
RCA 23K - Chapter 2
(c) 2011 W3NLB
6K7 V10
AVC AMP
V11 6H6
AVC
RECT
6K7 V12
AFC AMP
6H6 V13
AFC DISC
6K7 V14
EYE AMP
6H6 V15
EYE
RECT
6E5 V9
Eye Tube
AVC GAIN
EYE GAIN
AFC TO
MAGIC BRAIN
P1-5
AFC ON
AFC OFF
n/c
Cable
TO V18-4
(SCREEN)
AVC
-C
+B2
p/o T2
p/o T5
p/o T6
T5
T6
T7
T8
L1
R1
2200
R2
1M
R401
330
R402
1K*
R403
100K
R404
330K
R405
330K
R406
100K
R407
82K
R408
1K*
R409 1 MEG
R410 1 MEG
R411
1 MEG
R412
1K*
R413
820
R414
1K
R415
1.1MEG
R416 1M
C401
.01
C402
.01
C403
.01
C404
.01
C405
.01
C406
.01
C407
.01
C408
.01
C409 .01
C410
0.1
C411
0.5
C412
0.1
C413
.01?
C414
.01
C415
.025


Schematic 4
RCA 23K - Chapter 2
(c) 2011 W3NLB
FROM R303 ON VOL CONTROL
R2 170K
C501 .01?
R501 1 MEG
R502 270K
R503 1.1 MEG
6K7 V18 1ST EXPANDER
6K7
R504 120
TO V14-4 (SCREEN)
R505 18K 2W
+B2
C502 .025
R506 560K
R507 100 MODERN
TIME DELAY
1/2 V15 6H6
R509 220K
C505 .025
R508 2.2 MEG
TO R105 IN 2ND IF
C503 .025
6C5 V19 EXPANDER
C504 .025
R511 270
1/2 V11 6H6
R510 33K 1W
R512 150
R513 180
TO 2nd IF CATHODE VIA EXP SWITCH
EXP
FROM CANDOHM R1
R1-E

The **H. F. Tone** [*Bandpass might be a better term than tone. –Ed.*] rotary switch has three two-pole sections; one pole was never wired. Three poles set the bandpass of the first three IF transformers. One pole switches shunt capacitors in the plate circuit of the driver.

The fifth pole was originally wired with capacitors to ground, but is now disconnected. It is not shown on the schematic. The three lower positions all connect to a 130 pF capacitor. The fourth position has an 800 pF capacitor, while the **Max** position has a 600 pF cap. The common goes to one end of an inductor. The winding measures 1,300 ohms with a center tap. The other two leads are not connected.

The location of the parts and proximate wiring suggest that this was originally connected to the grid of the driver. That grid circuit also contains the **Volume** control, the **Compensation Network**, and the **L. F. Tone** switch, so perhaps there were just too many things going on in the same circuit and they removed the H. F. Tone function.

Audio Expander (Schematic 4 on page 10

The Expander circuit's purpose is to increase the dynamic range, emphasizing loud passages and attenuating soft passages. Some other high-end RCA radios have an expander as part of the phonograph, but none has an expander for the RF receiver.

The circuit consists of a 6K7 First Expander, a 6C5 Expander, and two 6H6 rectifier sections. The expander controls only the operation of the 2nd IF amplifier stage. I won't attempt to explain its operation since I don't understand it.

Audio to the Expander circuit is picked off from the top of the volume control through a 560K isolating resistor.

A **Time Delay** module is used in the circuit, its details unknown. It's a chassis-mounted metal box with three leads, one of which is grounded. There is no DC continuity on any combination of leads, but there are capacitance readings in the 0.5 to 1 µF range.

The foregoing is my best guess as to the original configuration. The circuitry on the schematic may not be original.

As received, the plate and screen of the 6K7 were shorted together, with a modern electrolytic capacitor from that junction to ground. Also, the 6C5 tube was gone, and the 6K7 socket had a tube lacking a grid cap, so the circuit is completely inoperative in its current state. The circuit probably wouldn't work even with the right tubes installed.

Power Supply (Schematic 5 on page 12)

The power supply is a standard full-wave bridge with a two-section capacitor-input filter. The supply uses two 5Z4 rectifiers with their sections wired in parallel to handle the heavy current load. A pair of 6L6s in push-pull can draw over 200 mA. The 5Z4 is rated 125 mA output current (typical) when used in a full-wave center-tapped configuration. With both sections in parallel, the rating would be 250 mA.

The first filter section has a 2.8-H choke, while the field coil serves as the choke for the second section. B+ for the audio section is obtained from the junction of the two chokes, providing higher operating voltage with slightly increased hum as compared with the fully filtered B+ output. Current is limited by a 100-ohm resistor between the HV center tap and the negative side of the first filter capacitor.

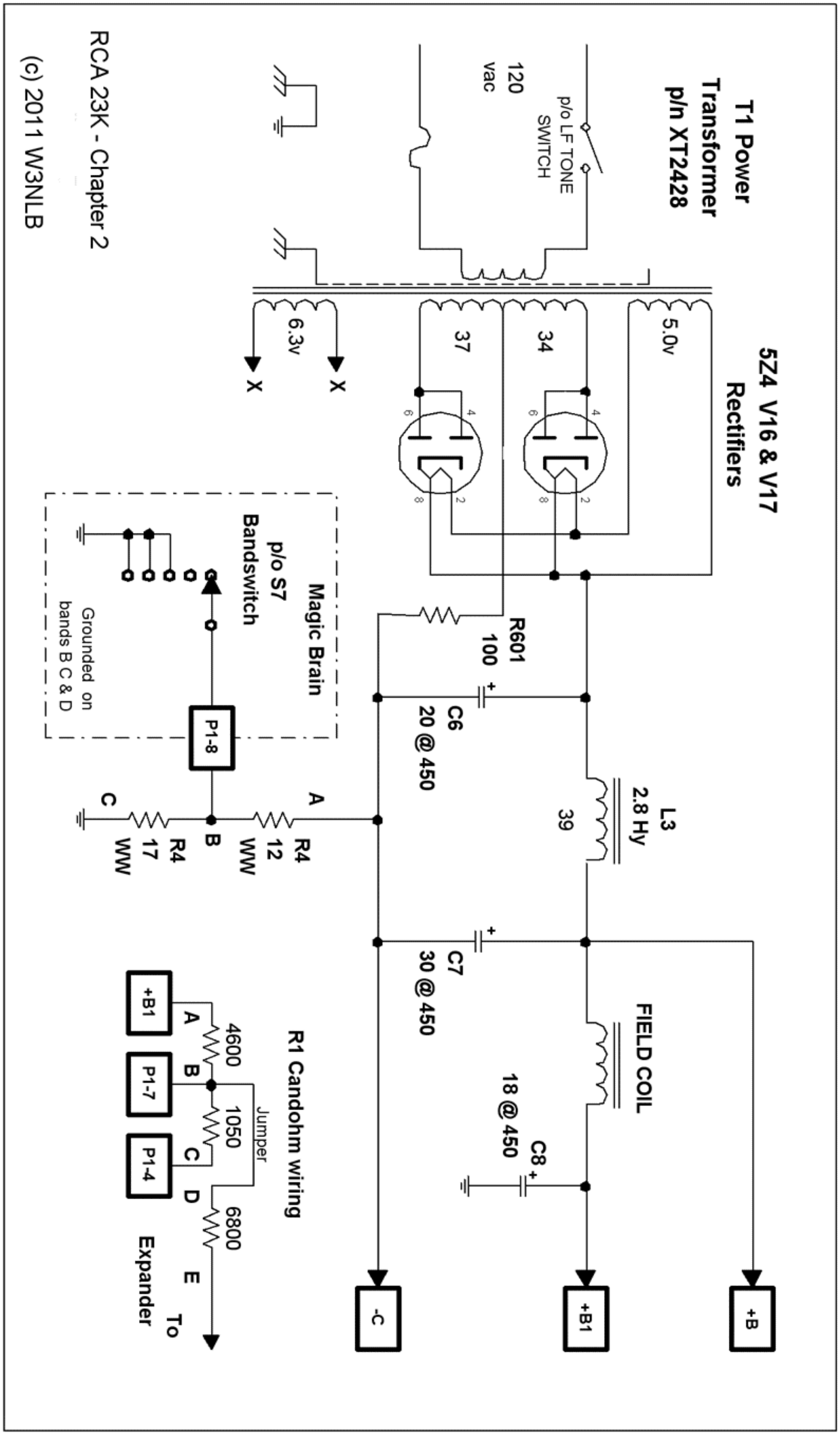
The input filter capacitor is 30 µF, while the other two are about 20 µF. The negative side of the first two filter caps is not directly grounded. A fixed negative voltage is developed across two wirewound resistors in series, 12 and 17 ohms, from this negative line to ground. On the three shortwave bands this voltage is reduced by shorting out the 17-ohm resistor, leaving only the 12-ohm resistor active. This action increases the gain by changing the AVC level. The fixed bias voltage is not used in the audio section.

Summary and Conclusion

I hope I have succeeded in documenting this important chapter in the evolution of the RCA product line, and that this information will be of benefit to those interested in the history of that great company. I welcome all comments, suggestions, and critiques at W3NLB@AMSAT.ORG. All significant information will be submitted as a follow-up.

The full schematic is available online at http://www.atwaterkent.info/akArticles.html. The schematic is a PDF file of a size D drawing (22" x 34"). The first chapter of this series is also available on that page.

In closing I would like to thank Brian Belanger, the Radio History Society, and the Radio & Television Museum in Bowie for giving me the opportunity to


T1 Power
Transformer
p/n XT2428
p/o LF TONE
SWITCH
120
vac
5.0v
34
37
6.3v
X
X
5Z4 V16 & V17
Rectifiers
R601
100
C6
20 @ 450
L3
2.8 Hy
39
C7
30 @ 450
FIELD COIL
18 @ 450
C8
+B
+B1
-C
Magic Brain
p/o S7
Bandswitch
Grounded on
bands B C & D
P1-8
A
R4
12
WW
B
R4
17
WW
C
R1 Candohm wiring
Jumper
4600
1050
6800
A
B
C
D
E
+B1
P1-7
P1-4
To
Expander
RCA 23K - Chapter 2
(c) 2011 W3NLB

Schematic 5

document this unique radio. It has certainly been a privilege. Thank you.

Appendix A - Test Methodologies

I thought a brief discussion of the analytic techniques I used might be of interest. Note that all are done with the radio OFF.

The Fox and Hound

This is a pair of tools used by telephone technicians to trace individual wires in bundles. It consists of a small audio generator (the "fox"), which emits a warbling tone. Its two output leads are connected to ground and the wire of interest at any convenient point. The audio signal is not attenuated by RF bypass capacitors.

An inductive amplifier (the "hound") picks up the tone when brought in proximity to the wire. The closer it gets, the louder the signal. When physical contact is made with the bare wire, the amplitude increases dramatically.

The device works very well for tracing wiring around a large chassis, as in the case at hand. It also provides a way to find broken wires, since the signal disappears beyond the break.

Active Circuit Tracing

This technique is very effective for walking resistor trees. The "fox" mentioned above can apply a DC voltage from its internal 9-volt battery to its output leads. Current is limited by an internal resistor. For example, connect the voltage to the AVC line at its source, then measure the voltage applied to each of the controlled tube elements.

Any fixed AVC bias can be identified by checking the B+ distribution system when voltage is applied to the AVC line. If a voltage appears on any B+ line, that line is connected via a resistor network to the AVC, providing a fixed bias level that limits no-signal gain.

A similar technique can be used to identify voltage dividers and isolation networks coming from the B+ line.

IF Bandwidth Measurement

The problem with trying to measure the passband of an IF transformer is that the test probe on the secondary loads the tuned circuit, changing its resonant frequency and invalidating the measurement.

The solution is to use an active FET probe The Tektronix P6202A probe I used has a shunt capacitance of 1.2 pF and an input impedance of 10^{12} ohms. The probe is designed to enable accurate measurements in tuned circuits since it does not change the circuit characteristics at all. The 50-ohm probe output connects directly to the input of a spectrum analyzer, enabling full analysis of the IF passband.

A word of caution, should you decide to buy and use an active FET probe: These are low-voltage devices, intended for use mainly with passive circuits. Check the maximum input voltage spec for your probe, and be careful not to exceed it. Excessive voltage will blow the input FET instantly.

Precision Resistance Measurements

Occasionally you need to determine the sequence of connections in a multi-point circuit. This can be done by measuring the resistance from one end to each point and comparing the values. An HP 3456A 6-1/2 digit multimeter was used for these tests. With a resolution of 1 micro-ohm, the resistance of individual wires is easily measured.

Appendix B - Parts Lists

Tube Complement

V1	6K7	1st IF amplifier
V2	6K7	2nd IF amplifier
V3	6K7	3rd IF amplifier
V4	6H6	2nd detector
V5	6C5	1st Audio amplifier
V6	6F6	Audio driver
V7	6L6	Audio output
V8	6L6	Audio output
V9	6E5	Eye tube
V10	6K7	AVC amplifier
V11	6H6	AVC rectifier
V12	6K7	AFC amplifier
V13	6H6	AFC Rectifier
V14	6K7	Expander amplifier
V15	6H6	Expander rectifier
V16	5Z4	Rectifier
V17	5Z4	Rectifier
V18	6K7	?
V19	6C5	Expander
Tubes in the Magic Brain		
V101	6K7	RF amplifier
V102	6L7	Mixer
V103	6J7	Oscillator
V104	6J7	AFC control ■