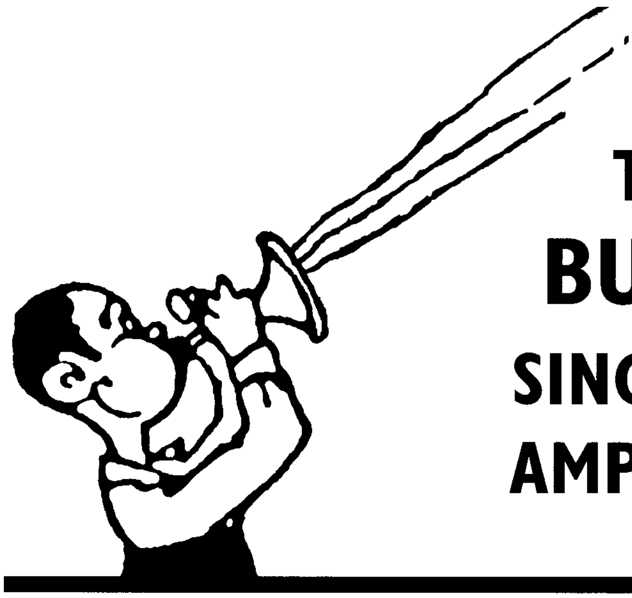


THE BUGLE SINGLE 45 AMPLIFIER

by Gordon Rankin, Wavelength Audio

The chief scientist at Wavelength throws the DIYers another bone...

For some time now I have been building obscure amplifiers under the names of some of the better brass instruments. The *Trumpet* was my original name for the *Baby Ongaku* from *SP #9*, the *Flugelhorn* is an interstage coupled parallel 45 amplifier and the *Trombone* is a cool 300B circuit. All of these designs are less than apt for today's market because of one attribute or another—unavailable tubes, "weird" idea, not enough power for the US (bull-headed) market.

Today we are going to analyze my favorite from this collection, the *Bugle*. The *Bugle* is a stereo 45 amplifier yielding a generous 2.5W of power. I don't even try to sell this amp anymore because of time and sketchy availability of the 45 tube, but sound-wise this amp would be a good investment for the DIY hobbyist. It is designed to be a simple, high performance circuit that also would be simple to build.

One nice thing is that a 45 is always a single plate tube and a lot easier and cheaper to find than the single plate 2A3. Also, there are rumblings that the Chinese are remaking the 45 tube, but I haven't seen any yet myself!

When designing an amplifier, I always start by characterizing the speakers and work my way back. I would estimate a good speaker of 95dB sensitivity or better at 8 ohms or higher to be right for this project.

So, let's pick the super-sounding 45 tube, which has a dissipation of 10W on the plate. In my experience the 45 is best with no more than 35mA plate current. We can take the plate voltage up to 275V at that point. I believe that when using the 45 (as well as other directly heated triodes) that self bias is best. The required bias at 275V for 35 mA plate current is -55V (actually, based on the dozens of 45s I have tested, you can expect between 52-54V in real life), which when added to the 275V plate voltage makes for a total B+requirement of 330V.

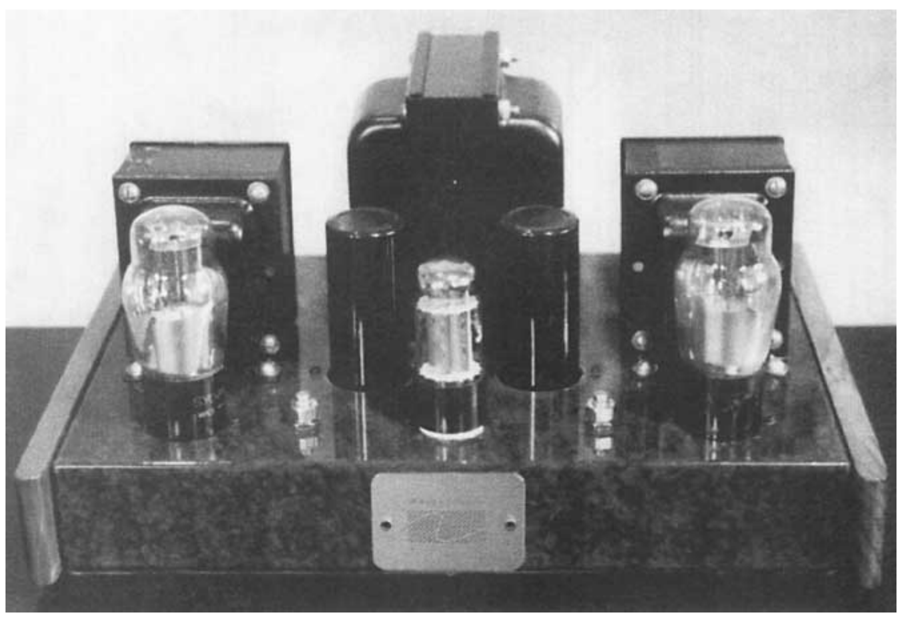
From here, we can calculate the rest of the output stage by selecting the output transformer and the biasing resistor. The plate impedance for a 45 running at 35mA is 1700 ohms. For the best results when using triodes, the transformer primary impedance should at be at least three times the plate impedance of the tube. Since there are no 5.1K primaries in stock, we can easily make do with a 5K primary transformer with a rating of about 35 mA or more.

The bias voltage is between 52-54V volts so, by Ohm's Law, we divide the mean voltage by 35mA and get a bias resistor of 1514 ohms or better yet use a readily available 1.5K unit.

We can determine the wattage dissipated of this resistor by I squared x R = 1.8375W. I try to de-rate all my wattages by a factor of 5 for long life and stability. In this application, I would use at least a 10W rated part. In my version, I used the 12W Mills MRB-12 resistor because they are really nice units at that wattage.

We can see from Sidebar A that the bypass capacitor we need is at least 22uF. A SCR AEON 24uF/250V would work fine.

For the drive stage, we see from Sidebar B that we need a slew rate drive current of 1.1ma or better. Actually we reach the maximum output well before the bias



The Wavelength Audio Bugle Stereo 45 SE – great amp but not a big seller among the power-crazy mainstream market at 2.5 Watts per side!

voltage of -55V, but it is better to have a higher slew rate current for better transient performance.

To get the most out of an input stage I try to set it up so that with a 1V input to the amplifier, I get the maximum output. I then bias the gain stage so that the bias voltage is a factor of 1.5 to 2 times the 1V input (i.e., -1.5V to -2V of biasing). This is done so that the input stage does not clip before the output does.

In the *Bugle*, I originally set everything up for the 6072A, one of my favorite tubes. Then I also found that with the same biasing resistors, the 5751 also worked and provided a higher overall gain. I biased the 6072A at 2V @ 2mA at about 140V per plate in SRPP mode. The bias resistors for each section work out to be 1K.

You can use Sidebar A again to determine the bypass of the lower R in the SRPP. I use the Black Gate BGN 33uF/16V for the job.

I find the SRPP drive stage to be good sounding, and easy to implement,offering a lot better output capacity than plate loading the same tubes. Because there is enough local feedback in an SRPP so that it is not beating the tube for maximum gain, I find it vastly superior in sound to all the types of the mu follower designs. Following this logic, a simple plate loaded tube should sound best, and maybe it does, but then you have to use two stages and that introduces another set of problems. In my experience, the SRPP is the best sounding simple way to go.

At 2mA, the 6072A has plenty of slew rate current. This design has an output impedance of about 15K. The 45 has a maximum grid resistance of 1M in self bias mode. If we use a resistance of 470K (I found some of the globe 45s draw grid current when a higher value is used) we can determine the necessary coupling capacitor.

I found that the best plan for bypassing is to use 5Hz as the limiting low end for calculations. Most designers go way overboard with the bypass capacitance, slowing things down. So we have 1/(2*PI*F*R) = 1/(2*PI*5*470K) = 0.0677uF. I use a 0.047uF for a low end response of 7.2Hz, plenty for this type of amplifier.

Also, the smaller the capacitor the better the sound. Lately the largest coupling capacitor that I can stand is a 0.25uF in an amplifier. I would try the Audio Note copper or silver foil or the Hovland *MusiCaps*. Since there is a potential of 140V across the capacitor, a 400V or higher voltage rating is required.

Okay, so we have the gain, output stage, now we need the power supply. The 45 requires a 2.5V filament at 1.5A, 6072A needs 6.3V/0.3A each, and we need a supply B+ voltage of 330V.

I prefer a choke loaded power supply over a Pi filter because the bass is so much faster and punchier with choke input. For this design I would use the 5AR4/GZ34 rectifier because of the low B+. If you are building an amplifier with a higher B+ voltage, then you may have to use its bigger brother the GZ37. To determine the transformer necessary for the desired B+ output using the curves supplied by Amperex we see that we need a plate to plate voltage of 700-720 for the full dissipation of some 80mA (stereo circuit).

What I do to trim the voltage is to add the input capacitor Cx to get the B+ up to where I want it. The reason the circuit does not come in at the exact voltage shown in the curves is because of the resistance in the choke and losses in the power transformer. A small input cap can be used with a choke input to raise the output voltage to make up for these losses.

With the transformers and chokes I used, the correct value of Cx is 0.68uF. This cap should have a DC voltage rating of 630V or better. Some would say this is a Pi filter but because of the small amount of capacitance after the rectifier this is not really the case. It actually acts very much like a choke input. Refer to Chapter 30 in *Radiotron Designers Handbook*, 4th ed. for details on power supply calculations.[Or look up the power supply chapter in "The Radio Amateur's Handbook," published annually by *The American Radio Relay League* since the dark ages—*ed.*]

SIDEBAR A—
Determining bypass capacitor values

We know that the gain when the bypass is fully functional is mu*R1/(R1*Rp). We also know that with a unbypassed resistor R2, the gain is mu*(1/((Rp +mu*R2)/R1)).

Capacitance has a reactance at any frequency which is given by 1/(2πf).

From these three equations we can determine the bypass capacitance in the following steps:

1) Find the total gain of the circuit.

2) To find the bypass C at a desired -3-dB point, use algebra from gain equ #2:

R2=((mu/gain -1)*R1 -Rp)/mu

R2 is actually the resultant R at frequency f of the C in parallel with Rbias.

3) Then we find the phasor resistance of C from 1/R2 = 1/Zc + 1/Rbias

4) Knowing Zc we calculate C = 1/(2πf*Zc)

Example for the output stage of the Bugle

1) 5000*3.8/(5000+1700) = 2.836

2) -3dB at 5Hz makes the gain at 5 Hz equal to 0.707*2.836 = 2

3) ((3.8/2 - 1)*5000 -1700)/3.8 = 730.7 ohms

4) 1500 ohms in parallel with 730.7 yields a Zc = 1424.739

5) At 5Hz then C= 1/(2*PI*5*1424.739) = 22.34uF close enough to 22uF.

SIDEBAR B—Slew Rate Calculation

Knowing the bandwidth, input voltage and the two input capacitances of the tube, we can determine the necessary slew rate drive current to overcome the input capacitance of the stage.

1) Slew Rate = 2*PI*BANDWIDTH*Vin

2) Per Borbley and others, to fully overcome the input capacitances, multiply #1 by a factor of 5 in slew rate current calculation #4 below.

3) Determine the combined input capacitance as

Ct = (Gain +1)*Cgrid-plate (Cgp) + Cinput (Cinput is sometimes referred to as Grid to Cathode or Cgk).

Plug in the actual gain achieved in the circuit, not the mu of the tube.

4) I (slew rate current) = Ct*5*Slew Rate.

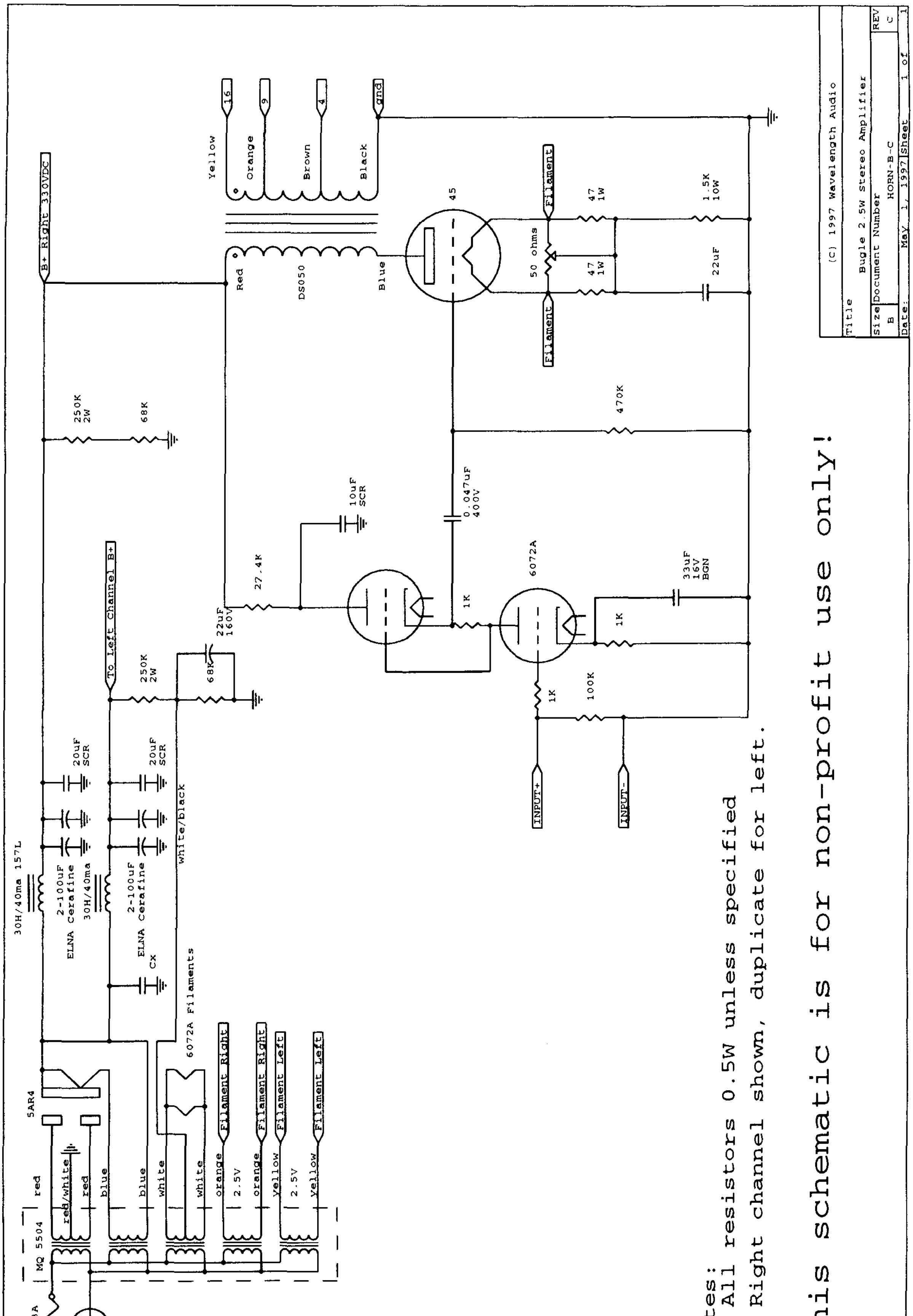
Example for the Type 45 power triode:

1) 2*PI*20Khz*55V = 6,911,503 referred to V/uS works out to be 6.9V/uS

2) 5*6.9V/uS = 34.55V/uS

3) Ct = 7pF*(2.836 +1) + 4pF = 30.8pF

4) I = 30.8pF*34.55V/uS = 1.066ma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Title
Bugle 2.5W Stereo Amplifier
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C
Date:
May 1, 1997
Sheet
1 of 1
B+ Right 330VDC
To Left Channel B+
Yellow
Orange
Brown
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16
9
4
gnd
Red
DS050
Blue
45
Filament
Filament
50 ohms
47
1W
47
1W
1.5K
10W
22uF
470K
0.047uF
400V
250K
2W
68K
10uF
SCR
27.4K
22uF
160V
6072A
1K
1K
33uF
16V
BGN
1K
100K
68K
250K
2W
INPUT+
INPUT-
20uF
SCR
20uF
SCR
30H/40ma 157L
2-100uF
ELNA Cerafine
30H/40ma
2-100uF
ELNA Cerafine
ELNA
Cx
white/black
6072A Filaments
5AR4
Filament Right
Filament Right
Filament Left
Filament Left
red
red/white
red
blue
blue
white
white
orange
2.5V
orange
yellow
2.5V
yellow
MQ 5504
3A
Notes:
1) All resistors 0.5W unless specified
2) Right channel shown, duplicate for left.
This schematic is for non-profit use only!

I have found large chokes and smaller capacitors to be the best case for choke loaded supplies, but high capacitance or multiple stage supplies are necessary for low ripple on the supply. Here we will use 2-100uF in parallel with a 20uF SCR film for a high-C, single-section supply. That will drop the ripple down to less than 30 mV p-p with a 30H Hammond 157G choke for each channel.

Since we have a B+ of 330V we need to drop this voltage for the 6072A by around 55V @ 2ma, requiring a resistor equal to 27.5K ohms. A 27.4K with a wattage of 0.5W or better should do the trick.

Also since the upper cathode of the 6072A (or 5751) will be at 140V+ volts, we want to put a positive voltage on the heaters relative to ground so that the cathodes do not exceed the rating for cathode to heater voltage (90V for both types). If we use around 70V, both cathodes will be in good shape. A voltage divider consisting of 250K & 68.1K resistors across the B+ provides the needed 70V bias.

That's it for design, now some parts notes:

I use Shinko tantalums for all my 0.5W and 1W needs these are available from *Angela Instruments* (301)725-0451. The Mills and most of the capacitors are available from *Michael Percy* (415)669-7181. The chokes are available from *Handmade* (610) 432-5732. The chassis are available from *Experiences Sonores* (418)652-8788 FAX—see ad in *SP #12* page 50, right picture is the *Bugle* chassis. The output and power transformers are from my faves *MagneQuest* (what's that number...) (215) 288-4816.

I present this work in the spirit of DIY for the personal, non-commercial, hobby use of SP readers *only.* I must restrict copying of this schematic, without written permission from *Sound Practices* and *Wavelength Audio*. Also, please do not call me and ask me what color to paint the amplifier. I can respond to *e-mail questions only* at: waudio@cinti.net. No calls please! Somebody's got to work around here!

Thanks and have a good time!

Gordon