By Dennis Colin

Back

The "Amplibass" Control

This natural-sounding bass-boost circuit restores the deep bass attenuated by record producers and the Fletcher-Munson effect, without "muddying up" the midrange.

You may need bass boost for one of three reasons:

1. Most popular recordings, and even some classical, have the naturally powerful and deep bass attenuated, because these waveforms are often of higher amplitude than the rest of the audio signal. Producers reduce the bass because of the infamous "loudness wars," in which sales are proportional to dB SPL.
2. The Fletcher-Munson effect: At the usual lower-than-live playback volume, hearing sensitivity of low frequencies falls off faster than at midrange and treble frequencies.
3. Loudspeaker bass rolloff.

Another reason is simply the pleasure of hearing and feeling clean, powerful deep bass. (My wife says that's a "guy thing." She's right about me!)

A MUSICAL EXAMPLE

Consider "Bayou Country" by Creedence Clearwater Revival, now available on SACD (Analogue Productions CAPJ8387SA). One of my favorite songs is "Born On The Bayou," which I must have played over 300 times since its debut around 1968 (on the flip side of the smash hit "Proud Mary"). In the key of "E," the electric bass frequently plays the open-E string (41.2034446Hz for you mathematicians).

With the lowest notes of an electric bass (and acoustic bass viol), the fundamental is several dB lower in amplitude than the 2nd and 3rd harmonics. This, plus the aforementioned record-production bass attenuation, makes it difficult to hear those deep fundamentals. With "Born On The Bayou" (and most rock recordings, old and new), I need as much as 20dB boost at 40Hz to obtain satisfying reproduction of the low fundamentals. And that's with speakers inherently flat to below 40Hz.

"AMPLIBASS" FREQUENCY RESPONSES

Figure 1 shows the bass boosts with four values of the 100k control potentiometer resistance. With R_p = 0, the response is flat (-0.16dB at 20Hz, -0.01dB at 20kHz). The potentiometer values (R_p) shown give 40Hz boosts of 20, 15, 10, and 5dB. Note that as the boost is decreased, so is the "turnover" (start of boost) frequency. For example, with 10dB boost at 40Hz, the 3dB point is 104Hz, and the boost is only 0.28dB at 200Hz.

The maximum slope (with 20dB boost at 40Hz) is –6dB/octave, because the boost circuit is first-order. However, the "turnover" point is sharper than a pure first-order response because of an added small dip effect (described later). In **Fig. 2**, the upper curve is without this dip effect; the 3dB point is 430Hz, instead of the 261Hz with the lower curve. Both curves are for 20dB boost at 40Hz; the lower one is the same curve shown at the top of **Fig. 1**.

OUTPUT NOISE

The measured output noise with full bass boost is 31µV RMS unweighted (-90dBV) and 9µV "A" weighted (-101dBV). With no boost, the noise is 9.5µV unweighted (-100dBV) and 7.7µV "A" weighted (-102dBV).

CIRCUIT DESCRIPTION

The input signal is split into two paths: a flat frequency response path, and a LF-boosted path with variable gain. Unlike conventional tone controls, this has the advantage that with the boost control set to zero, only the unaltered flat signal is transmitted to the output.

The input at J1 is AC-coupled by C1 and R2, RF lowpass-filtered by R3 and C2, then buffered by voltage-follower U1A. U1B serves as a differential amplifier. Without C11, R11, and C12, it would have unity gain and a flat frequency response. The function of C12 will be described later, but C11 and R11 equalize the effect of C12 so the flat-response signal from U1A is fed unaltered to the output at J2.

The function of U2 is to provide an amplified signal having a nearly constant frequency downslope of –6dB/octave, starting at 10Hz. A simpler circuit could do this, but the one used minimizes noise buildup. R7 and C8 provide the 10Hz rolloff pole, but the non-inverting configuration makes the downslope flatten at 57Hz. If R5 were shorted and R4 increased by R5's value, then this—with C5—would produce a lowpass pole at 57Hz and cancel the transmission zero (slope flattening) mentioned, resulting in a constant –6dB/octave downslope. I will describe the function of R5 later (R5 and C5 produce a slope-flattening zero at 343Hz).

The output of U2A is AC-coupled (through C9 and R8, forming a 7.7Hz LF rolloff) to the inverting input of U2B, which provides a variable level of the downsloping signal, adjustable with P1, the bass control potentiometer. Of inverted polarity, it's summed into the output with non-inverted polarity by being fed into the inverting input of U1B, through R13 and R12.

The function of C12 is to provide a rolloff pole at 203Hz. If the value of

C12 were 195nF, this pole would be at 343Hz, the frequency mentioned where R5 and C5 flatten the downslope above 10Hz. These would then cancel, resulting in a constant downslope without flattening. *If* C12 were 195nF.

PHASE SHIFT

The would-be constant downslope would have a phase shift very close to –90° at frequencies much above 10Hz. So, at the frequency where this signal sums into the output with the same level as the direct (flat response) signal, the overall response would be +3dB. This could be called the turnover frequency (f_t), where the bass boost is 3dB.

Now back to the actual 330nF value of C12. Because its rolloff (203Hz) is lower than the 343Hz slope-flattening point of C5/R5, the overall response of the boost signal approaches a -12dB/octave slope between 203 and 343Hz. This also increases the –90° phase lag by a maximum of –15° (at the geometric center frequency of 264Hz). Thus, near 264Hz the boost signal's phase is –105°.

If you were to sum a flat signal with a 2nd-order downslope signal (having a –180° phase shift), there would (ideally) be a complete null where the two signals had the same amplitude. (This is why one driver's polarity must be inverted in a 2nd-order Butterworth speaker crossover.) Here, the –105° phase shift, being closer to –180° (same angle as

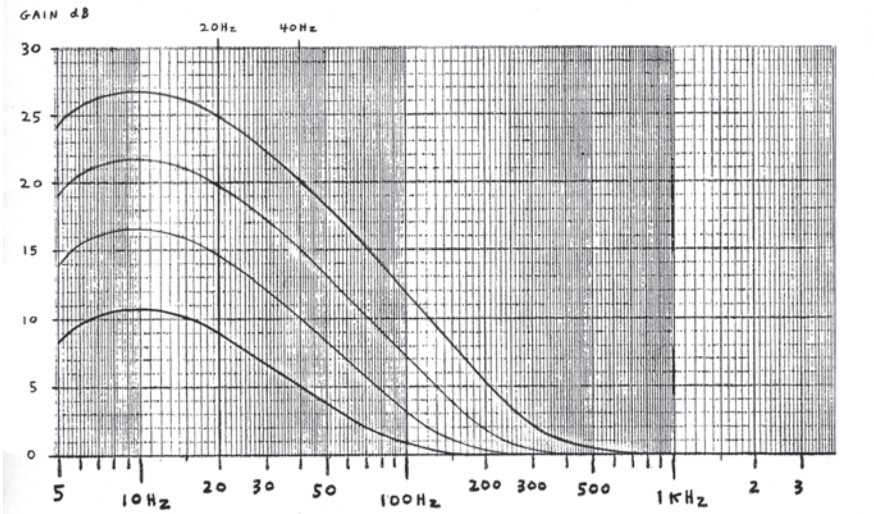


FIGURE 1: Frequency response, "Amplibass." Top to bottom: R_p = 97.3k, 52.5k, 26.9k, 11.7k. f_{3dB} = 261Hz, 167Hz, 104Hz, 57Hz.

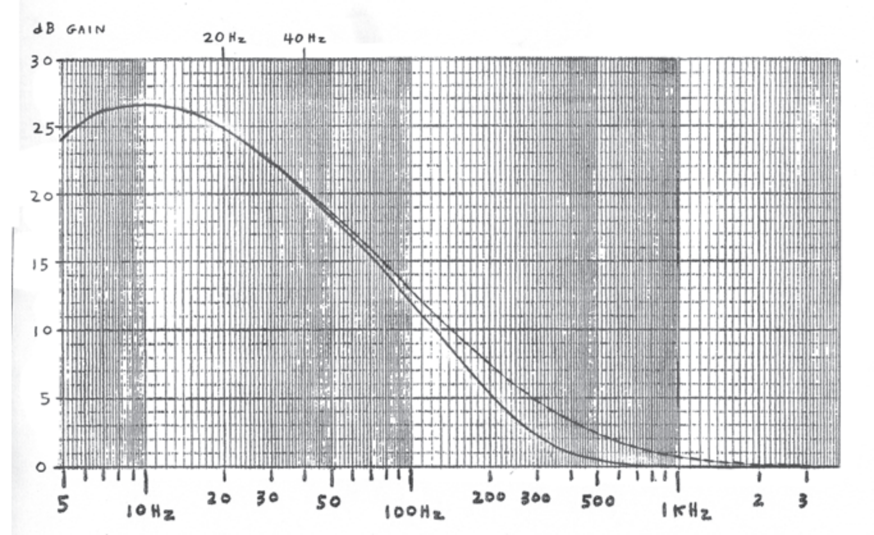


FIGURE 2: Frequency response, R_p = 97.3k. Top: C12 = 195nF (pure 1st-order). Bottom: C12 = 330nF (value used).

+180°) than to 0°, produces a small dip in the overall summed output response, if the turnover frequency is near the 203-343Hz range.

I selected those frequencies so the dip effect wouldn't produce an overall dip, but rather only lower the boost around the turnover frequency so as to sharpen the start-of-boost "corner." The effect is shown in **Fig. 2**. Second- and higher-order filters can use resonant poles and/or zeroes to sharpen the rolloff or boost corners (e.g., Butterworth or Chebyshev). A 1st-order response can't be resonant, but here I use a small amount of added resonant dip to produce what could be called a "maximally flat" 1st-order response. So rather than "cut corners" here, I decided to sharpen them!

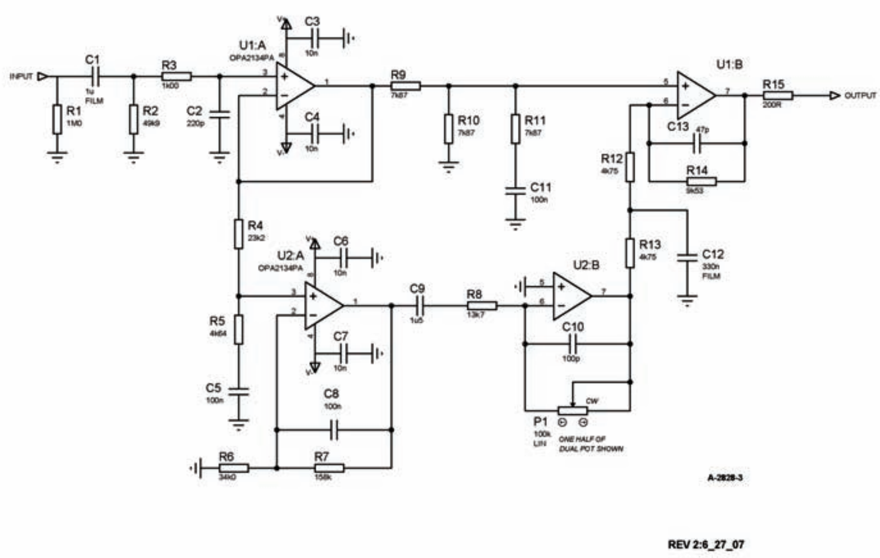


FIGURE 3: Schematic, "Amplibass" control. One channel shown of two.

Actually, the response is slightly over-compensated. Not shown in **Figs. 1** and **2**, the response does dip to a maximum of –0.18dB at 400Hz, when set for 10dB boost at 40Hz. For an exact maximally flat response (no dip), the Q of the resonant dip effect would be $1/\sqrt{3} = 0.57735$. This produces a boost at the turnover frequency of 1.761dB, where it's about 0.8dB here.

BENEFITS OF THE OVERALL TOPOLOGY

1. The boost responses minimize effects on the midrange without resorting to 2nd-order responses (which would be too steep).
2. Using C12 to extend the downslope, just before the output op amp, filters noise (above 200Hz) from the boost circuit.
3. Because the boost signal has its own separate path, when R_p is set to zero the boost circuitry is removed from the audio path.

4. The control pot (P1) implements a simple linear gain control. This allows, if desired, the U2B circuit to be replaced by an inverting voltage-controlled amplifier IC. Then, the bass boost could not only be remote controlled, but also electronically "ganged" with a remote volume control. By having the controls inverted, the bass boost would increase as the volume decreases; furthermore, the boost could be made to start only when the volume decreases to a predetermined level.

This could produce a very effective and wide-range loudness compensator. It would allow you to hear, for example, 20Hz organ fundamentals over a wide volume range.

Table 1 shows 40Hz boost versus R_p values. **Table 2** is the parts list.

A NOTE ON AUDIO QUALITY

I conducted an "intrinsic fidelity" test on this circuit. With zero bass boost, I did blind A/B and extended listening comparisons between the unit and a bypass connection. I used high-quality SACD music. The gains were matched to 0.02dB. I heard absolutely no difference, and my hearing is good (recently checked).

IMPULSE AND STEP RESPONSES AT MAXIMUM BOOST

Figures 4 and **5** show the response to a "virtual impulse," a 200µS square pulse of +8V amplitude (this input not shown; it's too narrow to be visible on the much longer time scales). Also not visible, but present at the output, is the flat-response-transmitted short input pulse. The impulse rate in **Fig. 4** is 100Hz. Time scale is 2mS/div.

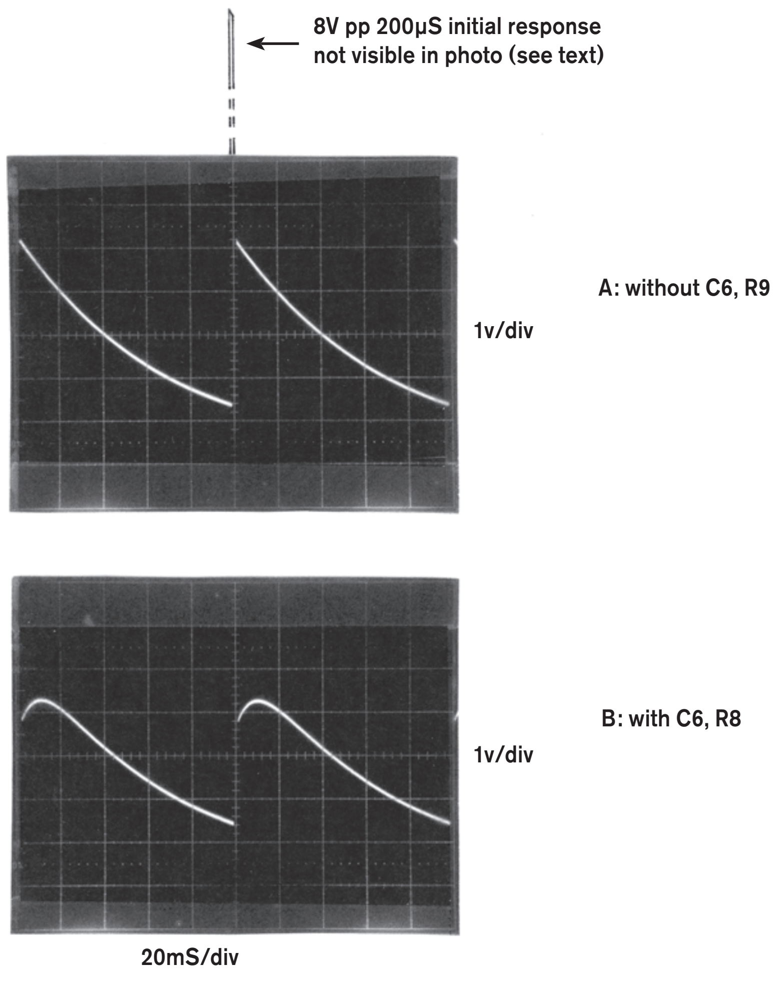
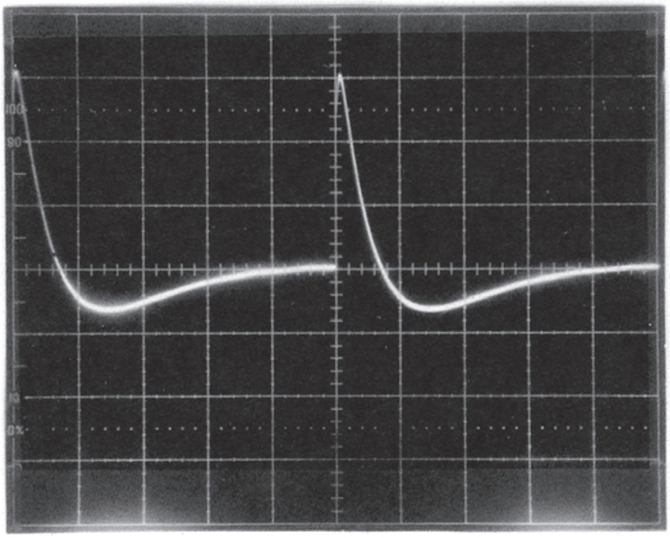


FIGURE 4: LF boost portion of impulse response, impulse rate = 100Hz, maximum boost.

Figure 4A is the output with C12 = 195nF (no sharpening). The exponentially decaying output step is from the time integration (with 10Hz rolloff) of the 1st-order bass boost. **Figure 4B** shows the effect of the turnover sharpening phase shift (C12 = 330nF). The slightly resonant effect on the impulse response is seen in the curvature following the step.

In **Fig. 5**, the impulse rate was lowered to 10Hz, showing the response on a longer time scale, 20mS/div. As with **Fig. 4**, the initial flat response transmitted 8Vpp 200µS pulse is not visible.



1v/div

20mS/div

FIGURE 5: LF boost portion of impulse response, impulse rate = 10Hz, maximum boost.

Figure 6 shows the response to a 5Hz, 0.2V pp square wave. The output amplitude of 5.4Vpp is from the large LF gain (26.5dB maximum at 10Hz). Note the freedom from ringing characteristic of 1st-order networks. With the boost control turned to zero, the square-wave response (not shown) is virtually perfect, as is the audio band frequency (and phase) response.

TABLE 1 40Hz boost vs. Rp

dB at 40Hz	Rp kΩ
-.07	0
0	0.24
1	2.80
2	5.01
3	7.16
4	9.37
6	14.2
8	20.0
10	26.9
12	35.6
14	46.3
16	59.6
18	76.3
20	97.3

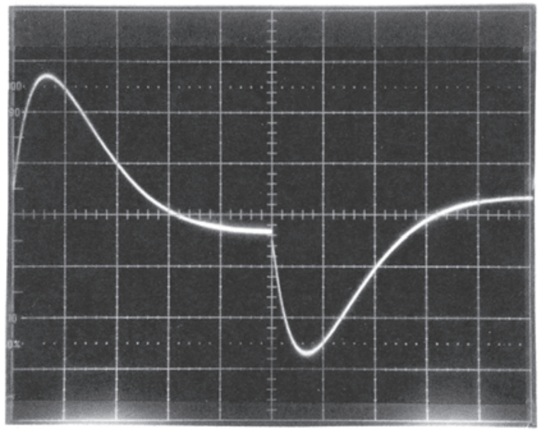


FIGURE 6: Response to 5Hz, 0.2Vpp square wave, maximum boost.

HOW DOES IT SOUND?

To my ears it provides the most natural-sounding and effective bass boost I've yet heard. I realize that it's difficult for an audiophile to be unbiased about his or her new toy. But I am unbiased; for example, I've tried many times to design the perfect speaker. But my efforts never sound quite as good as speakers designed by Joe D'Appolito, and I have no problem recognizing and admitting that.

I think a "close second" is the bass control in the Scott 222D tube amp (see my article, "A FET Standby Switch for Tube Amps," *aX* Dec. '06). On page 24 is shown the Scott amp's tone control responses. At maximum bass boost, the response is +13dB at 40Hz and +3dB at 250Hz.

EXAMPLES OF BOOST SETTINGS

With speakers or headphones flat to below 40Hz, I generally use 15-20dB at 40Hz with most rock recordings, 5-15dB with blues, 0-5dB with jazz, and no boost (except at low volume) with well-recorded classical and other acoustic bands. One exception to the latter is with pipe organs—sometimes I use the maximum boost (25dB at 20Hz) to hear and feel those low pedal fundamentals shaking me and the house! *aX*

TABLE 2 Parts list, per channel

Ref	Description	Size	Mfr.	Mfr./P/N	Dist.	Dist. P/N
C13	cap, 47pF					
C10	cap, 100pF					
C2	cap, 220pF					
C3, 4, 6, 7	cap, 10nF, film				DK	PS1103J
C5, 8, 11	cap, 100nF, film				DK	EF1104
C12	cap, 330nF, film				DK	EF1334
C1	cap, 1µF, film				DK	EF1105
C9	1µ5, film				DK	EF1155
J1, 2	RCA jack				PE	091-1120
P1	dual pot, 100k, Lin			one required for stereo unit		
R15	Res, 1%MF, 200Ω	¼W				
R3	Res, 1k00	¼W				
R5	Res, 4k64	¼W				
R12, 13	Res, 4k75	¼W				
R9-11	Res, 7k87	¼W				
R14	Res, 9k53	¼W				
R8	Res, 13k7	¼W				
R4	Res, 23k2	¼W				
R6	Res, 34k0	¼W				
R2	Res, 49k9	¼W				
R7	Res, 1% MF, 158k	¼W				
R1	Res, 1M00	¼W				
U1, 2	dual op amp			$2.63 from DK OPA2134pA		

DK: Digi-Key, PE: Parts Express