Tone Control Adventure

Engineer James Langham proves again that curves don't always mean results

By JAMES R. LANGHAM

IT was some time ago that the XYL came home with a story about a friend's big, fancy, custom-built radio. "Instead of just one knob that cuts out the highs, they have *two*. One boosts the lows, and one boosts the highs. Couldn't you rig us up something like that?"

"Why, I guess we can manage," I remarked foolishly. "You see, we make up an M-derived or constant K-filter section for highs and another for lows and . . ."

"I'm no engineer," she said. "You figure it out, and I'll build it."

I was young and innocent then: I *believed* what the textbooks said about filters, and I thought I knew a lot about electronics. So I got out the books and slide rule and spent about 2 hours computing the constants for a pair of bridged-T filters. I figured the sizes for 4 coils and 4 condensers and even plotted the theoretical curves for each. I drew up a sketch so she'd know just where to put them into the circuit and then tossed the papers lightly in her direction and departed. I don't know if I thought she'd have built it by the time I got home that afternoon or not. I may have. So help me, I may have.

The XYL was a mite irritated when I got home. "Look, knucklehead," she said, "you may be a fire-ball of a designer, but you sure aren't very practical."

"Mmmm?" I inquired. Mild curiosity. "Something troubling you, dear?"

She had a lot of catalogs and a worried look. "Where were you planning on getting these fancy chokes? Such as 0.183 henrys and 13.2 millihenries and —they're not standard sizes at all. Nobody sells them."

I grinned at her. "That's right, dear. You'll have to wind them up yourself or get someone else to do it."

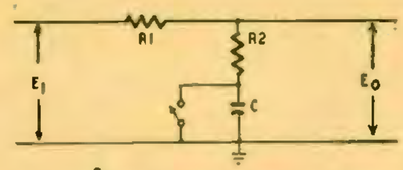
My tone was a mistake. She announced immediately (and loudly) that by all that was holy she was not going to wind up any coils. If I could persuade someone else to do it, O.K. If not, I would have to wind them myself.

Well, after I phoned downtown to a couple of places, I announced I would be glad to wind them. "I don't see how they can expect $15.00 for winding a simple little coil. I'll do it myself."

For the next month I wound coils. Air core and iron core. I used an egg-beater hand drill and bought quantities of wire. Then I would go over to the technical school and check them on the bridge. Then I would add or take off turns until the inductance was right. Then I would check the Q, and then get another form and start over again. Finally I had the 4 coils. They were within 2% of the design values, and they were nicely potted (beeswax and rosin). And I decided I had learned something valuable—it isn't easy to wind coils.

The XYL kept her word and wired the things up. She bridged condensers and found room on the chassis and did her wiring neatly with squared corners. She was really excited about it.

She put on Scheherazade—lots of highs and lots of lows. She wanted to twist the two new knobs and hear the ends go up and down.



$$E_0 = E_1 \frac{R_2}{R_1+R_2} \quad \text{WITH SWITCH SHORTED}$$

$$E_0 = E_1 \frac{\sqrt{R_2^2+X_c^2}}{\sqrt{(R_1+R_2)^2+X_c^2}} \quad \text{WITH SWITCH OPEN}$$

Fig. 1—A circuit to boost the bass notes.

Something was a little wrong. The low control made the hum level go up and down, but it didn't seem to affect the low notes in the music. The high control was better. You could hear an increase in the high level when the control was twisted, but there seemed to be an unpleasant accompanying distortion there too.

We stood there glaring at each other. "The wiring *looks* nice anyhow," I got in the first blow.

"The engineering looked good too," she said sweetly. "Those curves were lovely. The theoretical ones, I mean."

I called for peace. "I guess that bass filter needs more shielding. It picks up hum."

She nodded. "I'll say it does."

We tried shielding the coils. (Incidentally, the best shielding seemed to be beer cans.) Then we tried putting a higher level into the filters so the induced hum would be lower than the signal. We even lit the low-level filaments with d.c. so the hum would be low enough.

After we did enough things it got almost fair. There were limits to the amount of boost we could give it, though. If we turned up the bass much, it sounded muffled; and if we turned up the treble to match, the distortion came up with it. One day I came home to find the XYL showing off our outfit to a friend. She pointed to a newly blank panel. "No tone control at all," she said. "We find that if the tonal balance is proper, tone controls aren't needed. In fact, we avoid distortion by not having any tone controls."

I listened and it sounded good. She had jumped over the filters and, by golly, it sounded better than it had for some time. So I adopted her line of reasoning and argued with the fellows that really high-fidelity amplifiers shouldn't have any tone control.

I was squelched soon by this argument: "What if your pick-up or your speaker or the record falls off at the

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I figured the sizes for 4 coils and 4 condensers and even plotted the curves for each.

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low end or the high end? Aren't tone controls desirable to compensate for unbalance in other parts of the system?" That argument is right and proper, so I shut up.

I breadboarded. I spent my evenings for some time reading up on controls, trying them out and wondering what made them work. Finally I saw what was going on. All I wanted was an a.c. voltage divider that used reactances in one leg. Something that would give a different ratio at one frequency than at another.

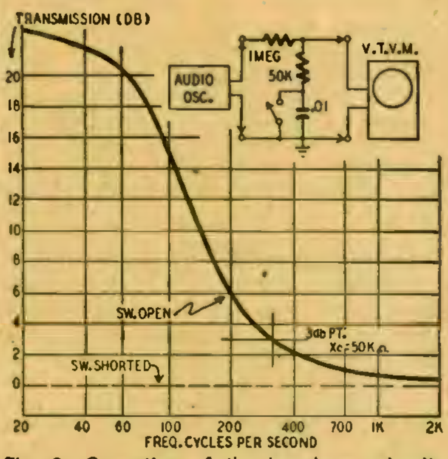

Fig. 2—Operation of the bass-boost circuit.

This is what I ended with: Fig. 1 shows the basic circuit for lows. Close the switch and you have a normal voltage divider.

$$\text{Output is } \frac{R2}{R1 + R2} \times \text{input.}$$

Now let's open our switch—the condenser then comes into the circuit. At low frequencies the reactance is high and we have an output:

$$\frac{\sqrt{R2^2 + XC^2}}{\sqrt{(R1 + R2)^2 + XC^2}} \times \text{input.}$$

We can easily pitch that anywhere we want by juggling the size of C and R2. We will end with a curve like Fig. 2. The bass rise will start up and be 3 db where the reactance of C equals R2. It will go up at a rate that approaches 6 db per octave until it starts to level off. The leveling-off spot (3 db from the top) will be where R1 equals the impedance to ground or $(R2^2 + XC^2)^{1/2}$.

O.K. you say, but you're still not boosting the bass! You're just cutting down the treble. That's right, but you don't have to look at it that way. You can say this is a filter with an insertion loss of N db. When the switch is flipped, you get a bass boost of 0.8N db. Try it and see. You can make the resistors 1 meg and 50,000 ohms, which will give an insertion loss of 26 db and a bass boost of approximately 20 db (when you flip your switch). Make C a .01-μf condenser, and the bass rise will start around

400 cycles and go up very nicely. What's that? You want smooth control and not 20-db boosts? Okay, take out the switch and put in a potentiometer. Try a 500,000-ohm pot and see how nicely you can bump up the bass in your radio programs.

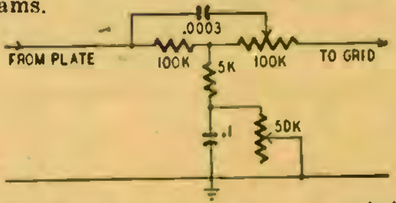

Fig. 3—A treble boost condenser is included.

How about treble? Easy! Now we want a series condenser instead of one to ground. Let's put an isolating resistor at the output of our bass booster and run a condenser across it to the input of the next stage. Since we have pretty high resistances it will have to be a small condenser to have just the highs affected, so let's cut everything down by 10. We can use a 100,000-ohm, series-dropping resistor, 5,000 ohms in the leg to ground and, a bass condenser of 0.1 μf. Then let's use another 100,000 ohms to isolate the back end, and fool around with different-sized condensers for the treble. A .0003 mica seems about right. The treble rise begins around 2,500 to 3,000 cycles. Amazingly enough, that's where the reactance of the .0003 condenser equals the 200,000 ohms in parallel with it. Fig. 3 shows how it works.

That one can be made smoothly adjustable too. Let's make the isolating resistor a 100,000-ohm variable. Then the condenser will slide back to where our bass-boost voltage divider will keep any highs from getting through, or slide up toward the next grid where our highs will pound out like mad.

Here's something to remember: if you keep your resistances and reactances in the same proportion, you can multiply your constants by 10 or 1/10 or anything else. That means you can juggle things around to suit varying conditions. If this circuit is to follow a triode with low plate impedance, keep the 100,000 ohms, 0.1 μf, and 5,000 ohms. If you are using a pentode, you'll lose gain with it because a pentode likes a higher load resistance. O.K. then, change to 1 megohm and .01- and 50,000-ohm values. It'll still act the same. If you want your bass or treble boosts to come lower in the audio band, just increase the capacitance a bit; if you want higher boosts (louder, I mean), juggle your resistance ratio. I prefer these sample values because they suit my ear and my turntable rumble. Don Lee put out something like $1,500 for his turntables because he wants the rumble to be very low. Us guys with our $10 motors —we can't boost our bass too much or we listen to rumble instead of music. Don't forget, too, that we are throwing away gain with this business. We throw away 26 db with these constants and get about 20 db back at the extreme ends of the band. Our middle is still down 26 db. So let's plan on having an extra 26 db of gain somewhere else in our system.

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Another thing. This whole system merely illustrates a method of correcting tone. You can use any part of it anywhere in an amplifier if you keep your levels and impedances in mind. To get 1 volt out at 1 kc, you have to put in 21 volts. So don't try to get 20 volts out. Not many tubes will put 400 volts in. Also if you run in a millivolt, you'll get only about 1/20 millivolt out; and that's pretty low, and you may have troubles with hum.

The hum has to be kept down with any system that boosts bass. You can shield your early filaments or even use d.c. if the level is very low and you want a lot of bass. Care in layout and wiring is most important. A 100-ohm potentiometer across the filament leads with the center to ground is handy. Most filament center taps aren't at the center, and you can balance out hum beautifully with a potentiometer. This was standard practice in the old receivers which used 26's and 45's in the audio end, and some of them had pretty good quality!

We arrived at this particular system by trial and error and fooling around. Others have also arrived at it. In case you never ran across it or in case you never understood it—here it is. The controls are completely independent of each other, and you'll be pleased with the way it works.