Procedure for Tweaking Oscillator Tracking

Introduction

MOTM Oscillators are probably the most stable and accurate synthesizer oscillators ever conceived. However in some situations I felt the high frequency tracking could be improved. I use an 88 note Yamaha KX88 keyboard with my MOTM and a lot of the work I do is melodic in nature. I do have perfect pitch and to me the 300 oscillators sounded slightly flat above 1600 Hz. But in addition to that I like to use multiple oscillators tuned in unison without sync for a fat sound. If I tuned for unison at 1600 Hz the beating was somewhat irritating in the lower frequencies despite repeated adjustments of the 1v/oct trimmer. My initial measurements with a frequency counter confirmed that all three of my 300 oscillators were around 1% flat at 800 Hz about 3% flat at 1600 Hz and increasingly flat as the frequency increased above that if I had calibrated the 1v/oct trimmer for exactly 100 Hz with a -1v input and 400 Hz for a +1v input. If I calibrated for 100 Hz to 800 Hz the output was slightly sharp at 400 Hz and slightly flat below 100 Hz. Paul and I had exchanged several emails about this and he suggested changing the high frequency tracking resistor which is ultimately what I have done, but the calibration procedure itself is critical to attaining near perfect tracking. The procedure I have worked out is time consuming but I feel it is worth the trouble. I have tweaked 3 of my 300s and 2 of my 310s so far with the result being a tracking error of less than .3% from 50 Hz all the way out to 6.4 kHz. The minimum perceivable pitch error is generally considered to be 3 cents in the vicinity of middle C. Sensitivity to pitch error decreases as the frequency goes up or down from that point. Sensitivity also decreases as the volume level increases above 80 db. There are 100 cents to a half step, and 1200 cents to an octave. 3 cents is equal to frequency ratio of the 1200^{th} root of 2 cubed. This is about .2%.

I strongly recommend a frequency counter for the calibration procedure along with a very accurate voltage source. I use an Encore Expressionist for my voltage source. Frequency measurements will always deviate somewhat due to tiny amounts of electromagnetic interference in the form of hum, noise and RFI. Therefore to achieve highest accuracy I would recommend taking a series of readings and using the average. Make sure your oscillator has no inputs connected except the 1v/oct. I connect the pulse wave output to my frequency counter. It is sometimes necessary to change the pulse width as the frequency counter may become confused and display a harmonic instead of the fundamental pitch. It is very important to let the oscillator warm up for 10 minutes before doing anything. Be sure to turn the power off before connecting or disconnecting the power connector to the oscillator. Don't hot swap parts. And use no-clean solder for any changes.

1. Start with no input to the oscillator at all. Both the 300 and the 310 are designed to output 200 Hz with no input and the coarse and fine controls centered. If your oscillator is not close to 200 Hz under these conditions you probably have a component problem. This happened to me. 2 of my 300s came with a 470pF poly capacitor instead of a 4700pF. Paul very graciously took care of the problem for me but I didn't even realize there was a problem until I built my 3^{rd} 300.

2. Connect your voltage source to the 1v/oct input. Tune your oscillator to 200 Hz at middle C, or as close as you can get it.

3. Now play up two octaves again on C and adjust the 1v/oct calibration for exactly 4 times the frequency you had at middle C. Please take note that any large change in the trimmer may also change your middle C frequency so you may have to readjust your fine frequency control and repeat this adjustment several times.

4. Play C for a number of different octaves and write down your frequency measurements. The frequency should double for each octave above middle C and halve for each octave below middle C.

5. Compare your frequency measurements to the expected values. If the deviation is more than a few tenths of a percent in the higher octaves you may do better by changing R50 on the 300 or R36 on the 310.

The standard value for R50 on the 300 is 2.2M. I initially had an error of about 3% flat at 1600 Hz. If your deviation is flat you need to decrease R50. If your deviation is sharp you need to increase it. Likewise for R36 on the 310, but R36 on the 310 is normally 1.8M.

I would suggest changing these resistors in small increments. It is possible to replace these resistors from the top side of the board, but you must be very careful in your soldering and be particularly careful when removing the resistor not to take the solder pads up with it. In fact maybe you should just forget the whole thing. Just kidding! But please be careful!

By replacing my R50 with a 2M and recalibrating the 1v/oct trimmer I was able to reduce my tracking error to .16% flat at 1600 Hz and .7% flat at 6400 Hz. This begged the question if 2M was good was 1.8M better? It was and 1.6M was better still but very slightly. I ended up with an R50 of 1.5M in all three of my 300s and an average tracking error of .06% at 1600Hz and .3% at 6400 Hz.

As the tracking error is reduced by changing R50 it becomes more accurate to calibrate the 1v/oct trimmer for higher frequencies. This is what makes this procedure so complex. A change in value in R50 also affects the 1v/oct calibration and the tuning of the oscillator itself as well, so after R50 is changed you must start the calibration procedure over. I adjusted the trimmer for a frequency ratio of exactly 4 for 2 octaves between 200 Hz and 800 Hz initially, then exactly 8 for 3 octaves between 200 Hz and 1600 Hz as I got closer with R50, then 16 for 4 octaves between 200 Hz and 3200 Hz. As you calibrate for the larger intervals and the higher frequencies the lower octaves tend to go slightly sharp above middle C and slightly flat below middle C so it is necessary to take readings at all octave intervals for each adjustment. Make sure you do not sacrifice tighter tracking at the higher frequencies for looser tracking in the lower ranges. It takes me about 3 hours to calibrate one oscillator!

For the 2 310s I have calibrated I found the standard R36 value of 1.8M to be the best. However I am working on my next 310 and it is going to need a larger value R36 for increased tracking accuracy as the deviation is much greater.

Shown below are some tables of measurements for my oscillators.

Table 1 is for 3 #300 Oscillators with R50=2M

Input V	Osc 1	Osc 1	Osc 2	Osc 2	Osc 3	Osc 3
	Freq	Error	Freq	Error	Freq	Error
-2v	50.2	-.15%	50.0	-.05%	50.0	-.05%
-1v	100.5	-.05%	100.0	-.05%	100.0	-.05%
0v	201.1	0	200.1	0	200.1	0
+1v	402.3	+.02%	400.2	0	400.2	0
+2v	804.4	0	800.0	-.05%	800.3	-.01%
+3v	1605.8	-.19%	1598.0	-.18%	1598.2	-.16%
+4v	3204.8	-.4%	3187.9	-.43%	3191.2	-.33%
+5v	6377.3	-.9%	6338.7	-1.0%	6358.7	-.7%

Table 2 is for 3 #300 Oscillators with R50=1.5M

Input V	Osc 1	Osc 1	Osc 2	Osc 2	Osc 3	Osc 3
	Freq	Error	Freq	Error	Freq	Error
-2v	49.9	-.25%	50.0	-.05%	49.9	-.25%
-1v	100.0	-.05%	100.1	0	100.0	-.05%
0v	200.1	0	200.2	0	200.1	0
+1v	400.3	+.02%	400.5	+.02%	400.7	+.12%
+2v	800.9	+.06%	801.0	+.02%	801.4	+.12%
+3v	1601.7	+.06%	1601.7	+.01%	1602.8	+.12%
+4v	3199.4	-.07%	3200.2	-.09%	3201.0	-.02%
+5v	6381.0	-.35%	6392.4	-.22%	6385.9	-.27%

Table 3 is for 2 #310 Oscillators with R36=1.8M

Input V	Osc 1	Osc 1	Osc 2	Osc 2		
	Freq	Error	Freq	Error		
-2v	50.0	+.05%	50.2	+.2%		
-1v	100.0	+.05%	100.3	+.1%		
0v	199.9	0	200.4	0		
+1v	399.4	-.1%	400.5	-.07%		
+2v	798.1	-.2%	800.1	-.2%		
+3v	1596.0	-.2%	1600.2	-.2%		
+4v	3194.9	-.11%	3204.0	-.07%		
+5v	6412.0	+.2%	6429.0	+.25		

Obviously you can play around with calibration for hours. In the days of my misspent youth I used to do quite a bit of repair work on synths. I spent many hours trying to calibrate Moog and Arp oscillators among others and you couldn't get anywhere near this accuracy. In fact you couldn't do it. It was literally impossible! Between the temperature induced drift, the poor quality single turn trimmers and the interaction between 1v/oct and high tracking trimmers it was simply impossible. The quality of the MOTM oscillators is simply astounding!

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