4 in 1 Guitar Effects Pedal

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Physics 498 POM
May 13th, 2005

Introduction:

The purpose of this project was to construct an effects pedal called a ring modulator and test it with different input signals. A ring modulator multiplies two input signals together to arrive at the output. This yields sum and difference frequencies (f_1-f_2, f_1+f_2) at the output, see figure 1. I was personally very curious about driving the second input with a low frequency oscillator and the first with a guitar.

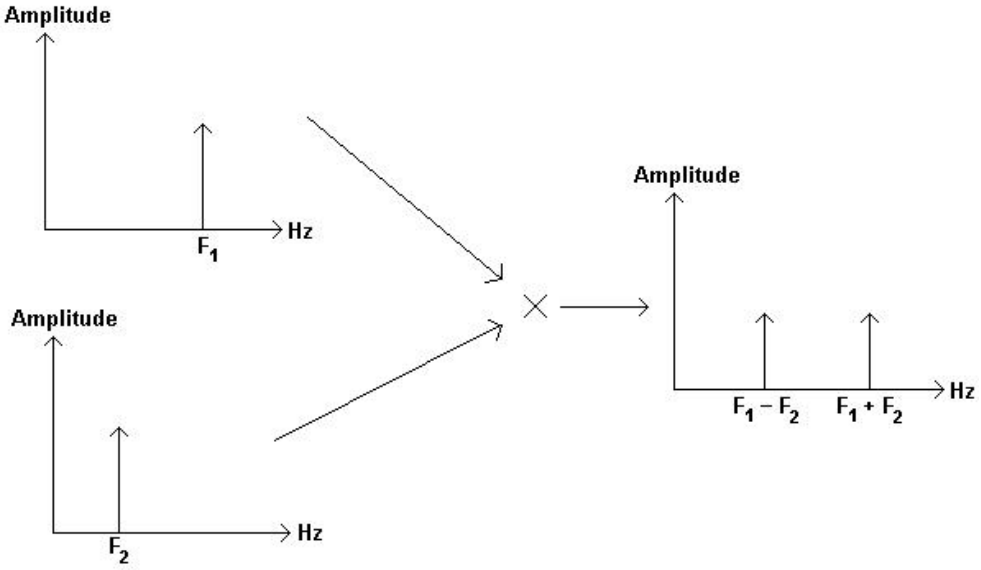

Figure 1: Frequency domain analysis of a time domain multiply (modulation).

Construction:

To construct the ring modulator, I used an AD633 linear 4-quadrant multiplier. This chip performed the multiplication (modulation) of the two signals, but amplifiers with adjustable gains were used before this to properly mix the signals. By pre amplifying, we allow for a wide range of inputs. At the output of the AD633, a master volume control was added followed by unity gain buffer drivers to drive the output cables. TL072's dual operational amplifier chips were used for the amplifiers and buffers. In order to have a wide range of possibilities and to maximize the use of the chassis, Prof. Errede suggested a circuit that had a full set of inputs and outputs. Therefore, the pedal has 2 inputs for the two signals, 2 no effects outputs (the first of which becomes an effect out when the pedal is turned on) and two effects outputs which only work when the pedal is activated. The entire pedal is turned on and off with a 3PDT stomp switch by Fulltone and the chassis was a die cast aluminum chassis by Hammond. Figure 2 shows a schematic of the ring modulator.

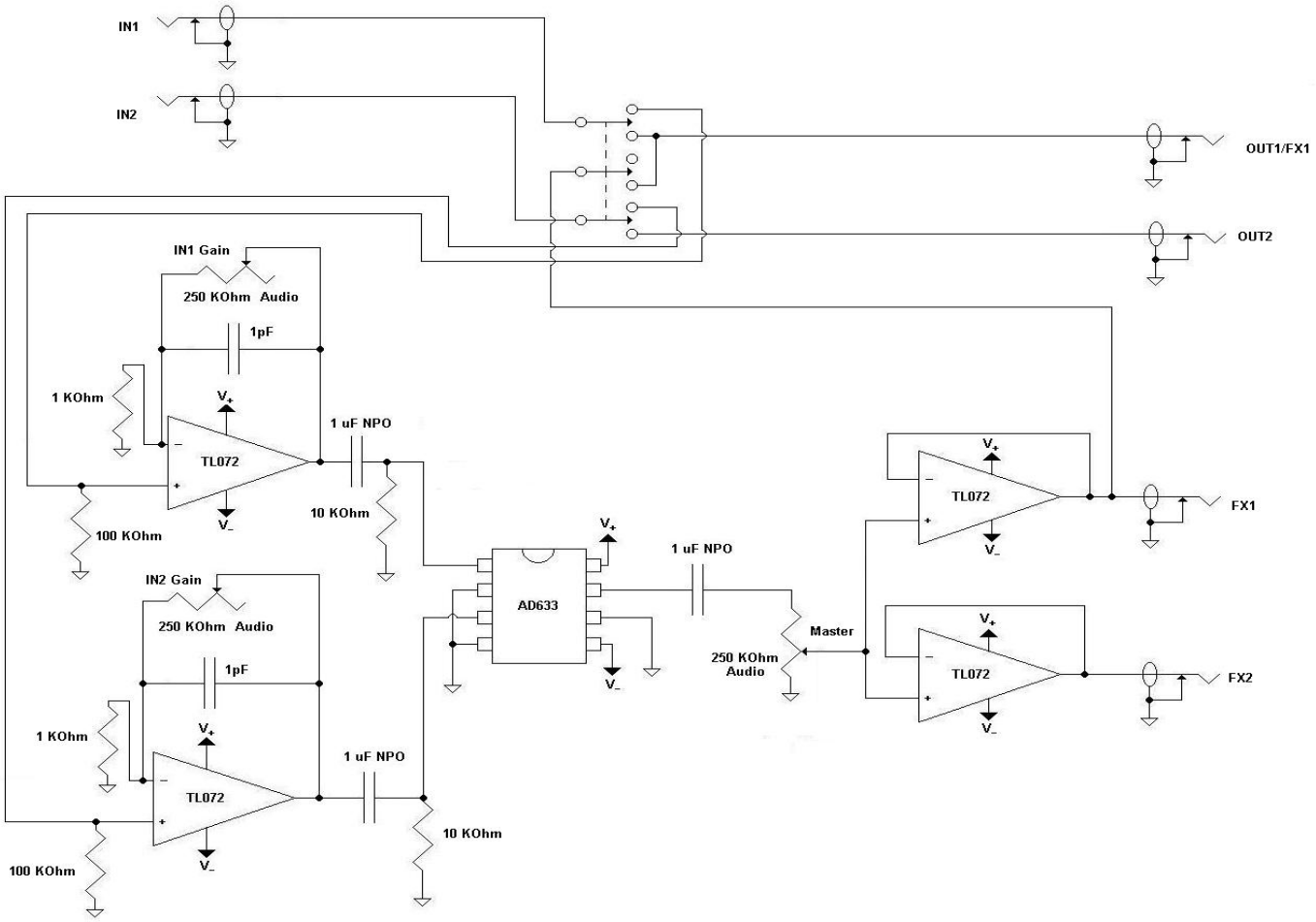

Figure 2: Ring Modulator Schematic

Results:

After constructing the pedal, I tested it with two guitars. It was hard to get a pleasing (to me) sound out of the pedal due to the highly nonlinear mapping of frequencies. I then tried it with a low frequency oscillator and got a really great sounding tremolo. This result is expected. Since the guitar input frequency is much higher than the low frequency oscillator (LFO) input, the sum and difference frequencies lay very close to the guitar frequency. If these two terms are within the critical band of the ear, we will perceive only one frequency, which will be at the average of the two output terms. This places the following constraint on the LFO frequency:

$$\left[F_{guitar} + F_{LFO}\right] - \left[F_{guitar} - F_{LFO}\right] < F_{critical\ band}$$

$$\Rightarrow 2\left[F_{LFO}\right] < F_{critical\ band}$$

If this is true, then we will only hear one pitch. However, since there are two frequencies present, a beating pattern will be observed. This beating is at twice the LFO frequency (since the LFO frequency is, for all practical purposes, rectified during the

multiplication). Therefore, if the LFO frequency is extremely low (<2Hz) we hear a very smooth tremolo.

After discovering the awesome sounding tremolo, we thought that a vibrato from the same pedal would also sound very nice. However, vibrato will not be as easy to achieve. To end up with vibrato, we want the output frequency to vary around a nominal frequency. For this result, we will need to get rid of either the sum or the difference term in the output. We can use mathematical relationships to give us this result. The solution requires us to first multiply the guitar and LFO signals. Then we must shift both inputs by 90 degrees and also multiply these two signals. By adding or subtracting the results of these two multiplies, we will get rid of either the sum or the difference term in the output. After this addition/subtraction, we still do not have vibrato, but instead we are left with a pitch shifter. The amount of shift is controlled by the LFO frequency and by switching from addition to subtraction, we will switch between up shifting or down shifting. In addition to the pitch shifter, we could put a voice signal into the second input and get a talk box type effect when the pedal is in up shifting mode. Even more interesting is if the pedal is in down shifting mode. This will give an inverted talk box effect, where raising the pitch of your voice will lower the output pitch!

So far we have achieved a pitch shifter/talk box, but we would still like to achieve vibrato. Notice that by adjusting the LFO frequency control manually while playing the guitar through this pitch shifter, we can change the amount of shift in pitch. If we were talented enough, we could stop here at a manually controlled version of the vibrato. However, to automate this, we will need to control the LFO frequency with a second LFO. By cascading the two LFO's in this way, we are performing frequency modulation. If we then apply this FM signal to the input of the pitch shifter pedal, we will achieve our vibrato effect. Notice that the finished result uses frequency modulation, amplitude modulation, and a form of quadrature multiplexing, which are all commonly used in radio communication. Figure 3 shows block diagrams of the three different effects, tremolo, pitch shifting, and vibrato using the basic ring modulator.

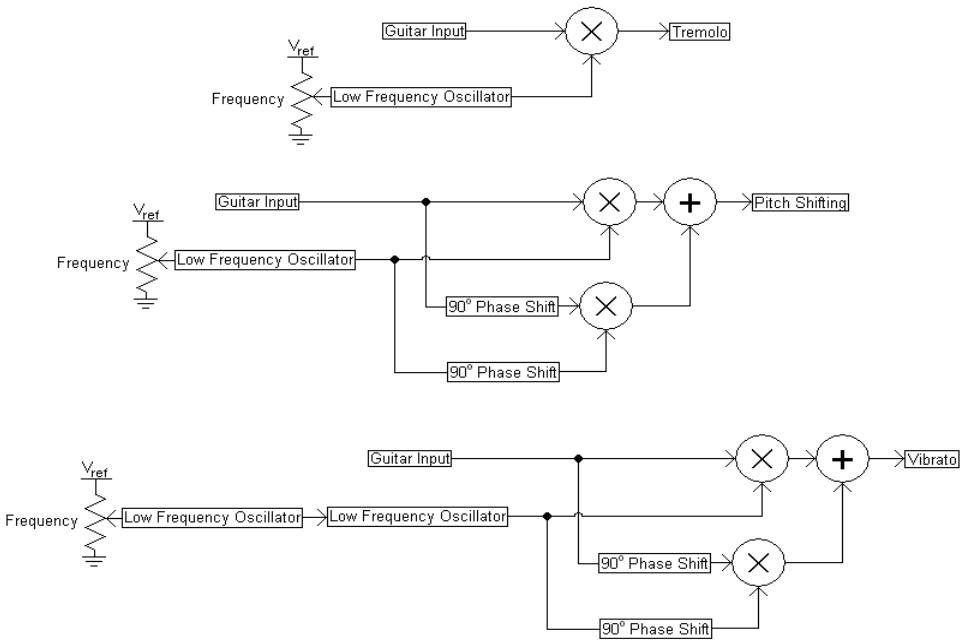

Figure 3: Block Diagrams for the three effects (Tremolo, Pitch Shifting, and Vibrato)

Conclusions:

Although, Prof. Errede and I both wanted to build this 4 in 1 pedal (ring modulator/tremolo/pitch shifter/vibrato), we did not have enough time left in the semester. We found some circuits to achieve the 90 degree phase shift for the guitar input, but they involved many components and would take a lot longer to assemble than the simple ring modulator. However, we did end up with a 2 in 1 pedal (ring modulator and tremolo), which was a very satisfying result. I plan on working on the 4 in 1 version of this over the summer, using a MAX038 oscillator chip for the LFO.

As mentioned above, all of the principles used to make this pedal are used quite commonly in radio communications. This makes me wonder if other radio communication theories would have similar results when applied to the audio range. I plan to experiment with this more in the future, and I really enjoyed constructing this pedal.