Making music

1 Introduction

An analog computer is not too different from a synthesizer, so the idea of making music with and on an analog computer is pretty obvious. This application note describes a pretty simple computer setup that turns an analog computer into a monophonic synthesizer controlled by a keyboard with voltage outputs for gate and pitch.

Figure 1 shows the overall setup for an analog computer to be used as a simple monophonic synthesizer. The partial circuit on top is a triangular/square wave generator. The "mod."-input is the modulation voltage which can be in the interval $[0, 1]$. The resulting output frequency varies linearly with this control voltage, so the pitch output of the keyboard can not directly connected to this input due to the required exponential voltage/frequency relationship (more on this below). Many (most?) synthesizers use a saw tooth waveform as the basis for sound creation which is due to the fact that such a signal contains many desirable harmonics which can be filtered out and mixed in a suitable fashion to yield all kinds of fascinating sounds. The triangular output signal generated here is unusual but well suited to the tone generation scheme adopted in the following.

The circuit in the middle of the figure first has a "gate" input which switches the output on and off if a key is depressed and released. The three position switch is used to select which waveform is fed to the audio amplifier connected to the output labelled "out". In the upper and lower position the switch just selects the triangular or square wave output from the oscillator circuit to the output. In its second position from top it connects the output of a variable function generator $f(x)$ to the output. This function generator is connected to the triangular wave output and can be used to generate pretty arbitrary wave forms yielding interesting sounds. The fact that it is fed a triangular wave instead of a saw tooth signal ensures that the function set on the function generator is played in a symmetric way guaranteeing that no steps (clicks) occur between the end of one period of the output waveform and the start of the next.

The most interesting subcircuit is that shown in the lower third of figure 1. The pitch output of a typical keyboard varies linearly with 1 V/octave which is convenient from a keyboard point of view but does not work with a voltage controlled oscillator as that described above, the output frequency of which varies linearly with the modulation voltage input. The reason for this is that in our western musical culture the frequency of a tone doubles from one octave to the next.

Given our traditional half-tone scheme with twelve half-tones comprising one octave, the increase in frequency from one half-tone to the next is $\sqrt[12]{2}$ so the linear voltage output of the keyboard must be fed into an exponential function generator to yield a suitable control voltage for the oscillator. Here things get a bit complicated. The keyboard used in this application note is pretty small with 32 half-tones, and its linear output voltage, which is always positive, must be mapped to the analog computer value interval of $[-1, 1]$ in order to make best use of the variable function generator used to implement the exponential function.

This mapping is done by the two summers shown in the lower sub-circuit of figure 1. The function generator actually implements

$$g(x) = \frac{7}{100}\left(\sqrt[12]{2.09}\right)^{15.5(x+1)} \tag{1}$$

instead of using $\sqrt[12]{2}$ as the basis. This is due to the fact that the triangular wave oscillator implemented suffers a tiny bit from the unavoidable hysteresis of the electronic comparator with its associated switch. Table 1 shows the 21 interpolation points of the function generator used to implement $g(x)$.

Figure 2 shows the (very simple) audio adapter which connects the output of the analog computer to a conventional amplifier or a computer sound card. The two strings of 1N4148 diodes limit the signal amplitude to avoid damage to the amplifier/sound card in case of excessive levels. Figure 3 gives an impression of the overall setup.

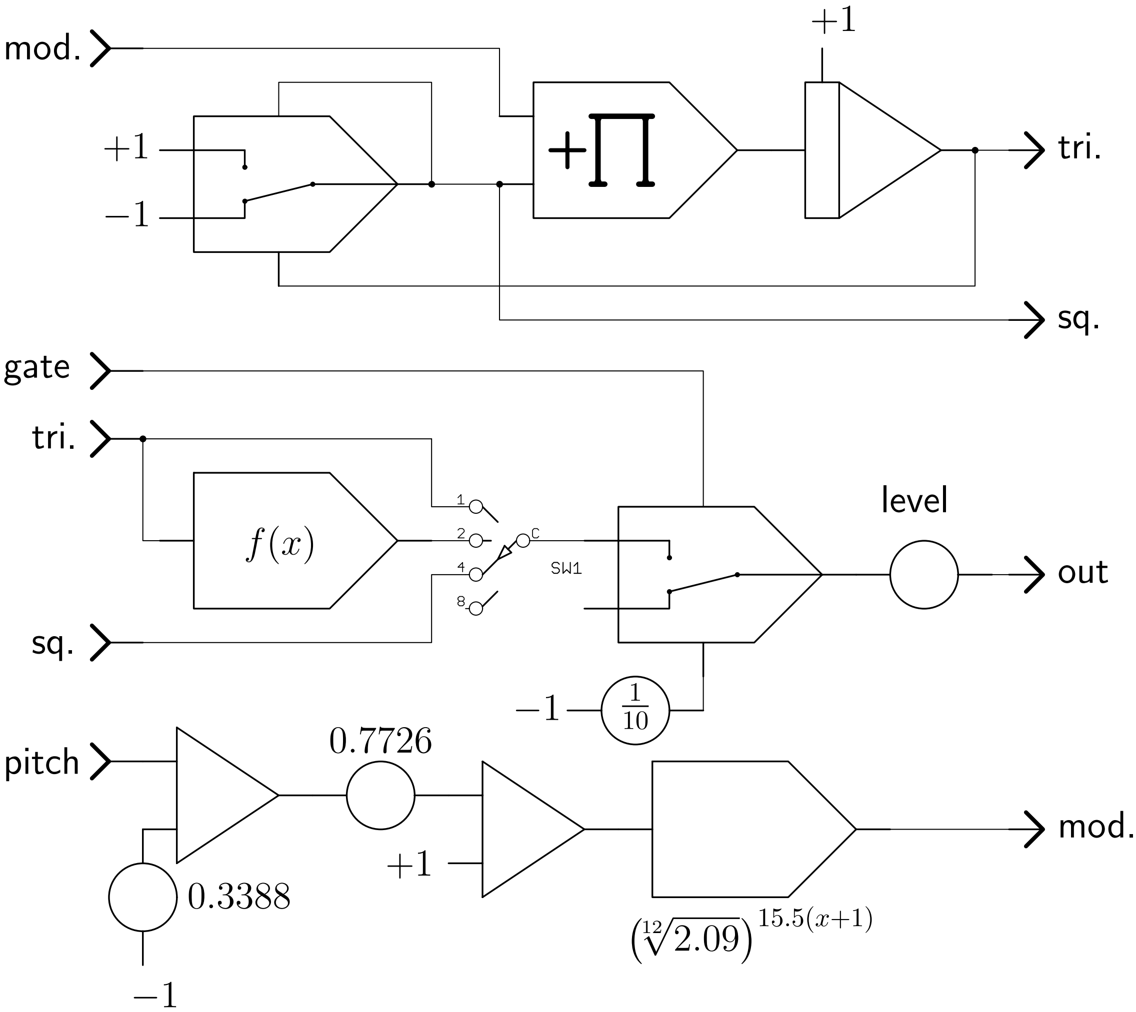

Figure 1: Analog computer setup as monophonic synthesizer

x	$g(x)$
-1.0	0.0700
-0.9	0.0769
-0.8	0.0846
-0.7	0.0931
-0.6	0.1024
-0.5	0.1126
-0.4	0.1239
-0.3	0.1363
-0.2	0.1499
-0.1	0.1649
0	0.1814
0.1	0.1995
0.2	0.2195
0.3	0.2414
0.4	0.2654
0.5	0.2920
0.6	0.3212
0.7	0.3533
0.8	0.3885
0.9	0.4274
1.0	0.4700

Table 1: Function generator setting for equation (1)

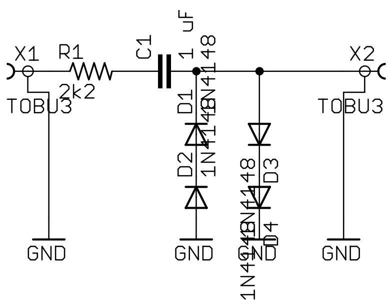

Figure 2: Simple audio adapter circuit

Figure 3: Impression of the actual setup