DEDICATED To
my dear wife, an indispensable assistant in my graphomaniac activity and the godmother of this device.

MICE AND CATS

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This article is not related to high audio, although the sound is still emitted, and is addressed to all do-it-yourselfers who know how to hold a soldering iron in their hands,
and not to audiophiles. The article provides a diagram of an ultrasonic generator designed to fight mice.

The main motive for writing this article and its publication on the site was the unexpectedly high efficiency of the appliance and, accordingly, its high utility in the household.

The mice are out!

With the onset of autumn, the mice were drawn to winter apartments, and everything would have been fine if these gray freeloaders had not leaked (it is not entirely clear how) into the space behind the drywall slabs. Unfortunately, knowledgeable people informed me about this possibility too late. In the future, I took this information into account and took all sorts of anti-mouse measures, but in two rooms the repair was already completed. As it

got cold outside, the resettlement went on more and more intensively, judging by the noise created, they began to drag heavy furniture and refrigerators. And one evening my wife hinted to me that this noise bothered her greatly. Something had to be done. A carefully placed

mousetrap with a terribly tasty crust turned out to be ineffective. Then my eyes turned to a sweetly sleeping cat, and the idea arose of cutting through the wall and decorating a hole for the cat. Another close look at the cat destroyed all my illusions: the cat was also getting ready for winter, and with its size (thinking about expanding the window), the chances of catching someone in a narrow space were negligible. The problem turned out to be more difficult than I thought, it was necessary to somehow drive the mice out of this space without using poison and without destroying the walls. The fact emerged from the depths of memory that ultrasonic vibrations repel rodents. Digging through old magazines and browsing the net, I found several publications on this topic [1]. [2]. It took several days to think over the problem and make the generator.

Having rushed home with the generator, I immediately launched the emitter behind the plasterboard wall and began to wait for the effect. Of course, I didn't hear the paws of mice running away in panic, only the cat showed increased interest in the hole where I inserted the emitter, and then importantly retired. Having gained patience, I began to wait what will come of this venture. The first signs that the device had some effect on the mice appeared in the evening - the activity of the mice decreased sharply. Every day the signs of mouse fuss became less and less, and after four days they disappeared completely.

The generator has been in operation for about a month, during which time some regularities have been experimentally revealed. If the generator is running continuously, then mice do not appear at all, if you turn it off, then suspicious sounds appear after a few days. For certain, I don't know the mechanism of the effect of ultrasound on mice, maybe it really prevents them from living in peace, or maybe they leave, afraid to burst their stomachs with laughter, but the main thing is that they leave.

When operating a generator, certain safety precautions must be observed. Prolonged exposure to ultrasonic vibrations can have a negative effect on people and pets, so if the emitter is freely suspended in a residential area, then if there are people in it, the generator must be turned off. When the transmitter is placed in non-residential premises or in closed cavities with sufficient acoustic shielding (high-frequency vibrations propagate disgustingly in the air and are strongly absorbed even by thin barriers), for example, behind plasterboard, the generator can work continuously.

Generator circuit

The general idea of building a generator was taken from the found publications and has not undergone any significant changes, only the technical implementation has been changed. I wanted to somewhat expand the flexibility in setting up the generator (I did not find any absolutely clear recommendations on the radiation parameters) and, of course, the element base at hand left a certain imprint. The complete electrical circuit diagram of the generator is shown in Figure 1.

The heart of the instrument is the voltage controlled oscillator (VCO). It is implemented on a logic element DD1:3 with a Schmidt trigger at the input and a voltage controlled current source on the elements R11÷R13, VT3, VT4. How does a Schmidt trigger generator work?

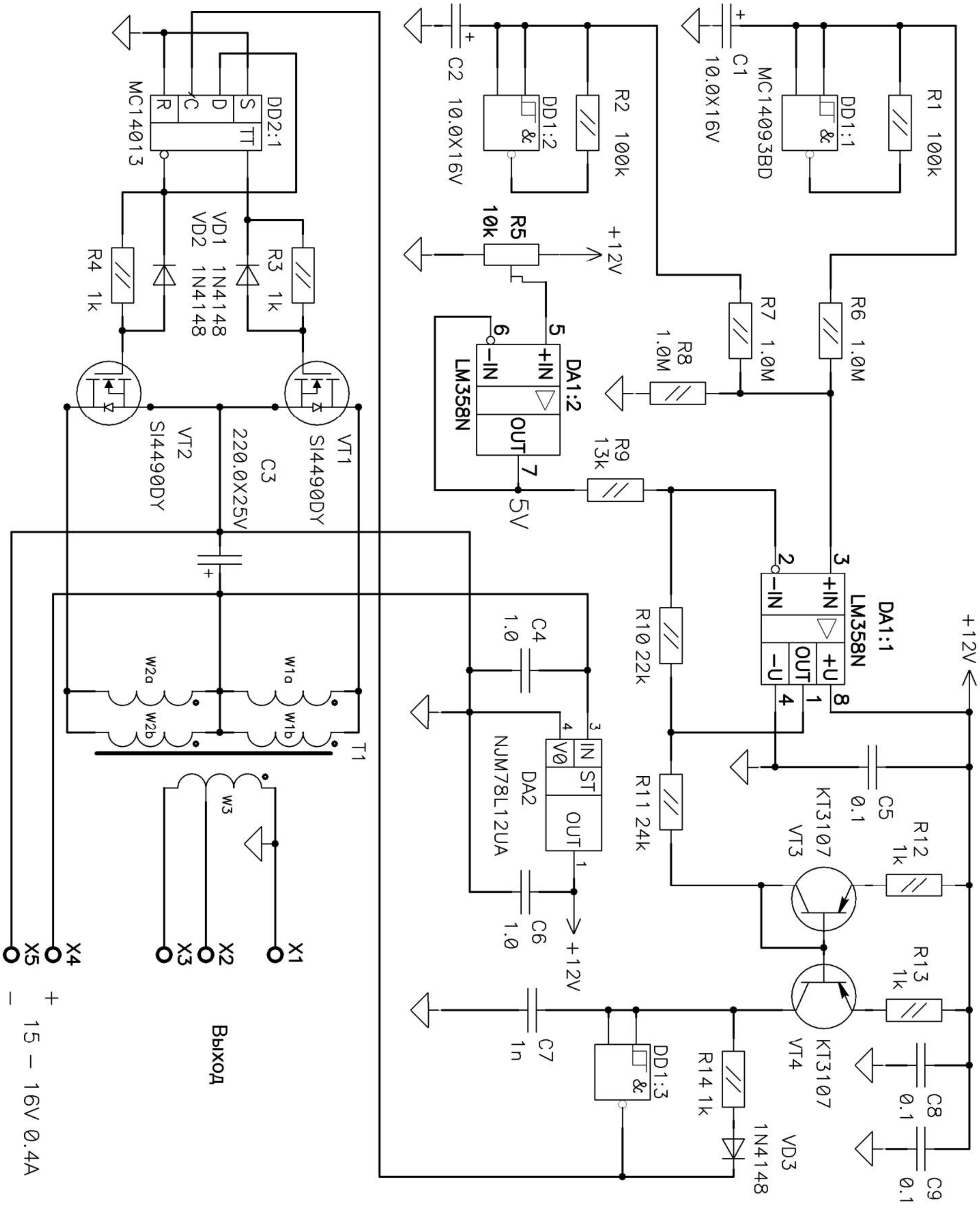
DD1:1 MC14093BD
DD1:2
DD1:3
DD2:1 MC14013
R1 100k
R2 100k
C1 10.0X16V
C2 10.0X16V
R5 10k
R6 1.0M
R7 1.0M
R8 1.0M
R9 13k
R10 22k
R11 24k
R12 1k
R13 1k
R14 1k
DA1:1 LM358N
DA1:2 LM358N
DA2 NJM78L12UA
C4 1.0
C5 0.1
C6 1.0
C7 1n
C8 0.1
C9 0.1
VT1 SI4490DY
VT2 SI4490DY
VT3 KT3107
VT4 KT3107
VD1 1N4148
VD2 1N4148
VD3 1N4148
R3 1k
R4 1k
C3 220.0X25V
T1
+12V
5V
Выход
15 – 16V 0.4A
X1
X2
X3
X4
X5

Figure 1

It is well known [3] that the difference of this circuit lies in the fact that the processes of charging and discharging the time setting capacitance C7 are separated. The capacitance is charged by the current determined by the voltage applied to the resistor R11 (in fact, the voltage is converted into current on it), since the resistor R14 is disconnected from the charging circuit by the locked diode VD3, and the discharge is carried out by the current given by the resistor R14 and the output logic element resistance. If the discharge current is chosen to be much greater than the charge current (in the operating frequency range), then the influence of the charging current on the discharge rate of capacitance C7 can be neglected and approximately considered that the output frequency of the VCO is linearly dependent on the voltage applied to the resistor R11. Thus, we get at the output of the element DD1: 3 short zero

pulses with a variable frequency. The control voltage for the VCO comes from the output of the operational amplifier DA1:1, the summing voltage from the two low-frequency generators (DD1:1, DD1:2) and the bias voltage from the output of the operational amplifier DA1:2. The gain of the adder on the DA1:1 chip and the value of the scale resistor R11 are chosen so that the VCO frequency deviation coefficient is approximately equal to 2÷2.3 (36÷80kHz). By varying the bias voltage with resistor R5, the center frequency of the VCO can be shifted by approximately ±15% without changing the amount of frequency deviation. The inputs of the adder are supplied with voltage from low frequency generators directly from their timing capacitances C1, C2. The voltage on these capacitances has an exponential shape with an average level of about half the supply voltage; the summation of two such voltages with close frequencies leads to the appearance of an amplitude-modulated voltage of an exotic form at the output of the adder (Fig. 2). The low frequency oscillators themselves are

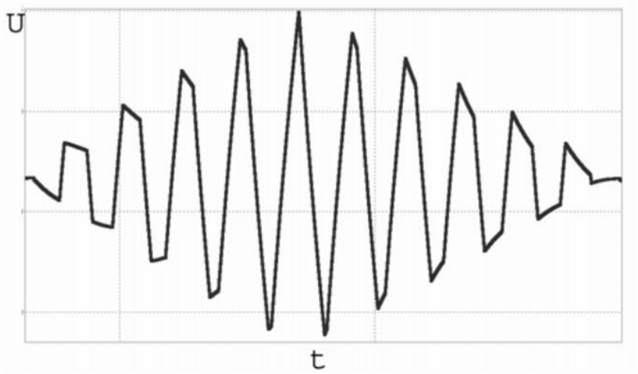

Figure 2

implemented according to the standard scheme, the generation frequency is about 1 Hz, respectively, the VCO frequency sweep rate is twice as high. The elements of the frequency setting circuits of both generators have the same ratings, a small difference in the frequencies of the generators is formed due to the spread of the parameters of the components (mainly due to the spread of the ratings of electrolytic capacitors). From the output

of the VCO, a sequence of short pulses is fed to the D-trigger DD2:1, switched on in the counting mode, where it is converted into two antiphase sequences of pulses twice as low in frequency, having the shape of a meander. These pulses directly excite the transistors (VT1, VT2) of the key power amplifier. The power amplifier has a transformer output, I understand that this complicates the design, but on the other hand, it allows you to get optimal matching with the load. It was immediately planned to use piezoceramics as a radiator, and its effective excitation requires high voltages. I wanted more of everything, including the acoustic pressure at the output.

It is not at all necessary to use a transformer output; any power amplifier circuit can be used, especially if a high-frequency dynamic head is used as an emitter. You should only remember about the load capacity of the trigger, and amplify the signal accordingly. Exciting voltages on the gates of the output transistors are supplied through the chains R3, VD1 and R4, VD2. Their main purpose is to provide a turn-on delay and a relatively slow turn-off of the transistor during fast turn-off. Of course, tightening the edge at the gate of the transistor leads to increased dynamic losses, but it makes it possible to exclude through currents and reduce voltage surges at the drains of transistors, and the presence of resistors in the gate circuits makes life a little easier for the trigger (we will touch on this issue in more detail later). The power amplifier is not equipped with additional damping and protection circuits. This should be borne in mind and, when adjusting, avoid shorting its output.

All generator units, except for the power amplifier, are powered by a low-power linear stabilizer (DA2) with a voltage of 12V and consume a current of the order of 7÷8mA.

Design, details, adjustment

As a matter of fact, there was no design as such, the generator was mounted on a scrap of a breadboard, and there is a suspicion that it will die this way. The transformer did not fit on the board and was installed next to, in close proximity to the output transistors. There are also no special installation requirements. The only thing you need to make sure that the blocking capacitances C5, C8, C9 are installed as close as possible to the microcircuit power pins (one for each package). Capacitors C4, C6 are installed next to the DA2 stabilizer chip. Capacitance C3 is installed next to the output transistors, it is desirable that the sources of the output transistors and the middle point of the transformer are directly connected to its terminals, the supply voltage is applied to the same points. Unused inputs of free logic elements should be connected to the common wire. The generator can be powered from any, including unstabilized, source with an output voltage of 15÷16V and an output current of 0.3÷0.4A.

The generator is not critical to the types of most of the components used: passive components can be any (it is desirable that the R5 potentiometer be multi-turn), logic microcircuits are replaced without any damage by analogues from the K561 or KR1561 series, the operational amplifier must allow operation with a unipolar supply and have a large output voltage range, the stabilizer can be anything, the main thing is that it provides 12 volts at the output. A more responsible approach should be taken to the selection of output transistors. The types of output transistors used are not widely used, the main reason for their use is their low input capacitance. This made it possible to connect their gates directly to the trigger outputs, but still, the trigger mode is excessively heavy. You can try to replace them with an IRF640 transistor, but the cardinal solution to the issue would be to include buffer amplifiers between the trigger outputs and the transistor gates. It can be any two channel driver (for example, TC4424 or MIC4424), a compromise option is to use buffer elements from the K561 series (K561PU4, K561LN2). This version of the circuit is shown in Figure 3. In this case, the range of suitable transistors is significantly expanded, almost any MOSFET transistor with an acceptable drain-source voltage of 150÷200V and a drain current of several amperes will do. The requirement for such a high drain-source voltage is not accidental, the fact is that a deliberate decrease in the quality requirements of the output transformer leads to an increase in its parasitic parameters and, accordingly, to significant voltage surges at the drains of transistors when they are switched. A significant allowable voltage margin ensures reliable operation of the generator.

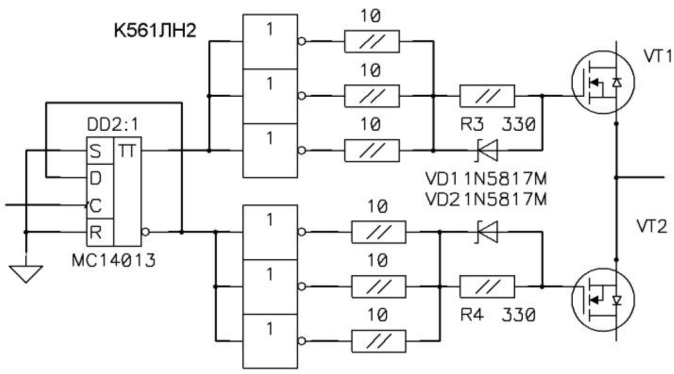

Figure 3

In the manufacture of the output transformer, an unexpected problem arose, there was no suitable core made of high-permeability ferrite. After a little hesitation, I decided to make a transformer on a core of ordinary electrical steel. Of course, this degrades the parameters of the transformer and increases its dimensions, but for this application, these deteriorations are not catastrophic. If the amplitude of the induction in the core is chosen to be small enough, then the transformer operates quite acceptable in the desired frequency range. As a result, the transformer was wound on a “outbred” core ShP-12X15 with a plate thickness of 0.35 mm, in principle, any steel core with similar or slightly larger geometric dimensions. The primary windings of the transformer are divided into two sections, which are connected in parallel, the halves of the primary windings are wound in two wires. Between the sections of the primary winding, the secondary winding is wound. The winding order of the transformer is shown in Figure 4. The primary windings are wound with PEL-2 wire Ø 0.27 mm and contain 200 turns each, the secondary winding is wound with PELSHO wire Ø 0.18 mm and contains 500 turns with a tap from the four hundredth turn. The windings are wound in bulk without the use of spacers. The inductance of the primary winding must be at least 0.1H. The transformer is capable of delivering 7÷8WA to the load without significant overheating. The secondary winding is designed for a well-

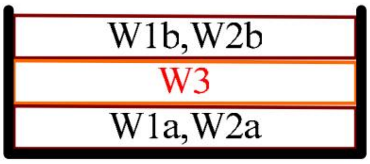

Figure 4

defined emitter, if you do not know exactly the parameters of the ceramics used, then it is advisable to increase the number of taps.

For the ultrasonic emitter, rings made of piezoceramic TsTS-19 with dimensions of 18X15.5X13mm were used. The radiator uses three rings connected in parallel, the rings are separated from each other by insulating spacers, and the entire structure is tightened with a steel pin (Figure 5, the pin is removed). The resonant frequency of the assembled emitter is 33 kHz, and the intrinsic capacitance of the emitter is 25.7 nF. The emitter is connected to the generator by a segment of a thin coaxial cable 1.5–2 m long, the outer electrodes of the rings are connected to the cable screen, which is connected to a common wire. Most likely, information about the design of the emitter will

Figure 5

be useless for you due to the lack of basic elements - piezoceramic rings. Therefore, I will give general recommendations for their replacement. For the emitter, you can use other piezoceramic elements in the form of disks, plates and spheres. The resonant frequency of the piezoelectric element should be in the range of 20÷35kHz. You should also pay attention to the own capacitance of the piezoelectric element, if it is too small, then several pieces can be connected in parallel. In an effort to obtain maximum sound pressure, that is, when setting the excitation voltage of the radiator, two limitations must be remembered. Firstly, the power given off by the output stage is not unlimited - its elements should not heat up insanely, and secondly, the permissible current of the emitter is also limited - during long-term operation, the emitter can only be slightly warm, but not hot. In passing, I want to note that when soldering piezoelectric elements, one must be careful - soldering is done with low-melting solders and quickly.

Setting up the generator begins with the fact that the middle point of the output transformer is disconnected from the power circuit, the potentiometer R5 is set to the middle position, and only after that the generator is connected to the source. First of all, the presence of a voltage of 12V is monitored, and if everything is normal, then the potentiometer R5 sets a voltage equal to 5V at the output DA1:2. This value of the bias voltage approximately corresponds to the frequency change at the output of the generator 18÷40kHz. Next, they check the presence of low-frequency oscillations at the outputs DD1:1 and DD1:2, this can also be checked with a voltmeter, but you can only control the operation of the VCO (DD1:3) with an oscilloscope. Since the rate of change of frequency at the output of the VCO is not very fast, it is possible to estimate the minimum and maximum period of the output oscillations directly on the screen (remember that the frequency of the VCO is twice the output frequency of the oscillator). If necessary, the operating frequency range is shifted by adjusting the bias voltage (R5). Be sure to check the presence of excitation voltage directly at the gates of the transistors of the output stage (VT1, VT2): the amplitude of the pulses must be at least 10V, the pulses at the gates of the transistors must be antiphase. After making sure that everything is working correctly, reconnect the middle point of the output transformer (naturally, with the power supply

turned off) and you can start selecting the excitation voltage of the emitter (my emitter is connected to the tap of the secondary winding).

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