Chip 222 - alternative 555. PWM generator with independent frequency control

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Abstract: - The description of the chip 222 - generator with independent adjustment of the frequency and the fill factor of the output pulses is given. The chip has 6 contacts and is able to perform its functions with only three additional RC elements. Examples of possible practical applications of this chip in analog and digital circuitry are given.

Key-Words: - Chip-timer, PWM signal, PWM generator, pulse width regulation, analog and digital circuitry.

1 Introduction

In 1971, the Swiss electrical engineer and inventor Hans Rudolf Camenzind (1934-2012), under a contract with Signetics Corporation (USA), then Philips (the Netherlands), developed a universal integrated chip-timer 555 (The IC Time Machine), designed for the formation of single and repeated pulses.

The timer 555 contains two analog comparators, an asynchronous RS trigger, a resistive voltage divider and a number of other elements [1-3].

The IC 555 and its many analogues used to create timers, generators, devices, pulse width regulation, modulators, threshold devices, relay time, voltage converters, automatic control systems, etc.

2 Problem Formulation

Despite the versatility of its use, the 555 chip does not allow obtaining a pulse-width modulated signal at the output with independent adjustment of the frequency and pulse width.

Half a century since the creation of IC 555 the author of this article prompted alternative - chip 222, the main purpose of which is to generate pulse width modulated (PWM) signal with independent adjustment of frequency.

Note that the solution of such a problem using the 555 chip is directly impossible.

3 Problem Solution

Unlike the 555 chip, the 222 chip is made according to a simpler scheme (Fig.1): it contains half as many parts - including only two comparators and 5 resistors, performing almost all the same functions as its predecessor.

The big advantage of the 222 chip is that it has only 6 pins (Fig.1) and can fit into a DIP6-type housing (the 555 chip has 8 pins), and can be installed in the DIP8 panel. The DIP14 case will fit three full-fledged elements of the 222 chip or two elements of the 555 chip (556 chip).
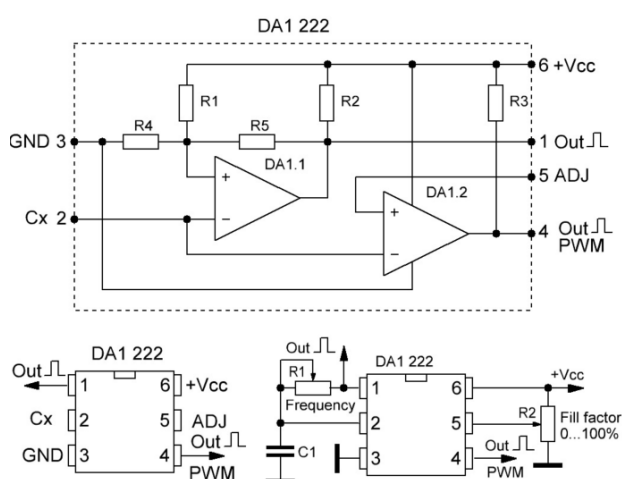

Fig.1: The internal structure of the chip 222 and the simplest PWM generator circuit with independent frequency control.

The internal structure of the chip 222 is shown in (Fig.1). Pin 1 of the chip is the output of a rectangular signals (OUT); pin 2 is the input to which external capacitor (Cx) is connected; pin 3 is the common wire (GND); pin 4 is the output of the PWM signal (OUT PWM); pin 5 is the control of the output signal width (ADJ) and pin 6 is the supply voltage (Vcc).

The simplest PWM generator circuit with independent frequency control (Fig.1) contains only 3 additional elements. These are the capacitor C1 and the potentiometer R1 (frequency adjustment), as well as the potentiometer R2, which regulates the pulse fill factor (CPI) from 0 to 100%. A positive property of the chip 222 is that when the voltage of the power source changes, the CPI of output signal and its frequency do not change.

Let's consider the main types of circuits in which the 222 chip can be used. The test model of the 222 chip (NI Multisim software package) uses an LM339 comparator and 5 resistors with a nominal value of

10 kOhm. The devices are powered from a 12 V source, although the chip model itself is operable in the supply voltage range from 2 to 36 V (for the 555 chip, the supply voltage range is from 4.5 to 18 V).

The PWM generator with independent frequency control (Fig.2) is presented in two variants of the designation of the chip 222. In contrast to the previous scheme (Fig.1), the generator contains additional elements - a resistor R2, which limits the upper generation frequency, as well as resistors R3 and R4, which provide a change in the voltage at the input ADJ of the chip in the range from 0.33 to 0.6 of the supply voltage Vcc when adjusting the potentiometer R5 (adjusting the CPI from 0 to 100%). It is within such limits that the voltage on the capacitor C1 changes according to the sawtooth law. Rectangular signals with an amplitude of 0.8 Vcc and ≈Vcc, respectively, are taken from the OUT and OUT PWM outputs.

The generation frequency can be adjusted by the potentiometer R1 in the range from 1.05 to 10.5 kHz.
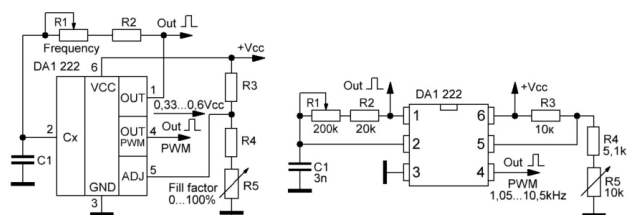

Fig.2: The PWM generator with independent frequency control.

The pulse generator (Fig.3) uses an external transistor VT1 BC557 to discharge the capacitor C1. To do this, a pulse signal with a CPI close to 99% is removed from the output 1 of the chip 222 and is fed through the resistor R3 to the base of the transistor VT1. A PWM signal with a frequency from 0.7 to 4.1 kHz is removed from pin 4 (adjustment by the potentiometer R1) with the possibility of adjusting the CPI from 0 to 100% by the potentiometer R5.
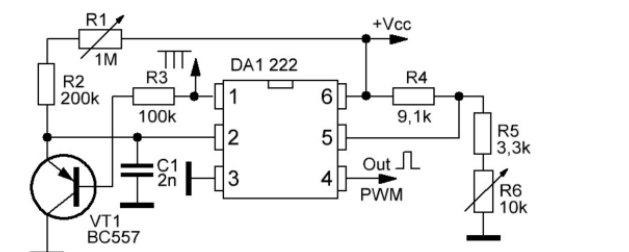

Fig.3: The pulse generator.

The pulse generator for two outputs with separately adjustable pulse filling coefficients (Fig.4) has a unique feature. From the output 1 of the chip, a PWM signal can be received, the CPI of which is

adjusted by the potentiometer R4; from the output 4, a PWM signal of the same frequency with the CPI adjustment by the potentiometer R5. The disadvantages of the device include the fact that when adjusting the potentiometer R4, the generation frequency varies from 2 to 3 kHz.
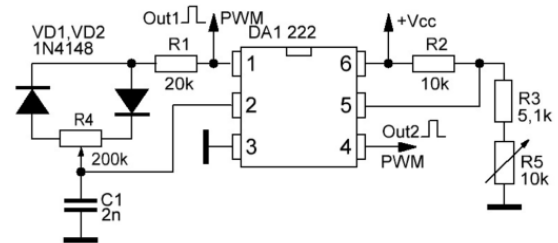

Fig.4: The pulse generator for two outputs with separately adjustable pulse filling coefficients.

The multichannel PWM controller (Fig.5), when using n 222 chips, allows you to obtain n separately adjustable PWM control channels. The example (Fig.5) shows only three channels. If necessary, the generation frequency can be smoothly or stepwise adjusted due to the R1C1.
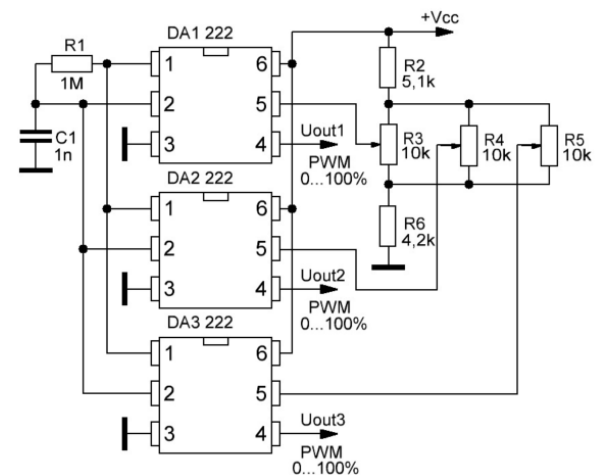

Figure 5: The multichannel PWM controller.

The sawtooth and rectangular pulse generator (Fig.6) contains a current mirror on transistors VT1 and VT2 BC558 in the charging circuit capacitor C1. The generator (pin 2) allows you to get a linearly increasing signal in time, which abruptly ends at the end of the cycle. A rectangular signal with a CPI close to 50% get from output 1. From the output 4 is a PWM signal with the possibility of smooth control of the CPI from 0 to 100%. The frequency of the generator is regulated by the potentiometer R3 from 880 to 2100 Hz.
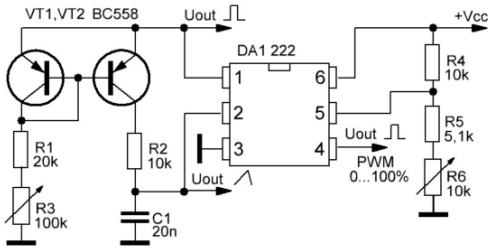
Figure 6: The sawtooth and rectangular pulse generator.

The generator of sinusoidal oscillations (Fig.7) is made using a double T-bridge on capacitors C1-C3 and resistors R4-R6. A sinusoidal signal with a frequency of 1060 Hz and an amplitude of 5.3 V is removed from the output 4 of the chip 222, the total harmonic distortion (THD) is 0.1%.
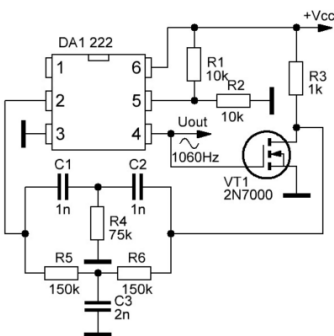

Fig.7: The generator of sinusoidal oscillations.

The generator (Fig.8) has a phase-shifting chain R3-R5, C1-C3. A sinusoidal signal with a frequency of 500 Hz and an amplitude of 270 mV, THD less than 4%, is removed from output 2. Rectangular signals can be simultaneously received from pin 4.
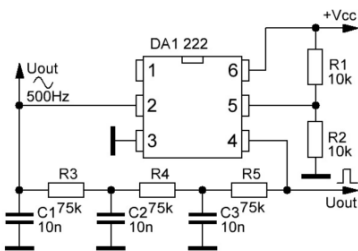
Fig.8: The generator of sinusoidal oscillations *has a phase-shifting chain*.

The functional generator (Fig.9) is a development of the sinusoidal oscillator circuit (Fig.8). The triangular-shaped signal is formed using the R7C4 chain: the resistor R7 serves as a stable current generator. The triangular signal generator also includes a transistor VT1 BC547 and a blue LED HL1 (can be replaced with a low-voltage Zener diode). A triangular signal with an amplitude of 1 V is removed from the collector of the transistor VT1.
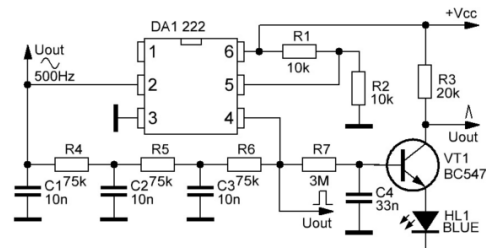

Fig.9: The functional generator.

The ring generator pulses (Fig.10) can be made on an odd number of chips 222 (3, 5, 7...). The corresponding number of phases can be removed from the generator outputs. In particular, if there are three chips, a three - phase signal with phase overlap in time is used. The frequency of the generator F [kHz]=0.33/(R [Ohms]C[F]) is determined by the RC-constants of the timing chains, where R=R1=R2=R6, C=C1=C2=C3. For the nominal values indicated in the diagram, F=400 Hz. The phase shift is regulated by the potentiometer R5.
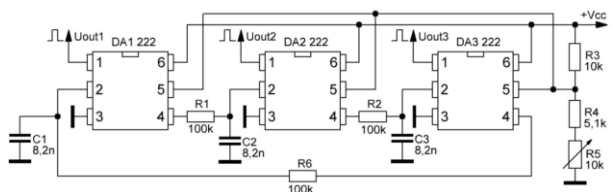

Fig.10: The ring generator pulses.

The oscillator of swinging frequency (Fig.11) includes two generators on the DA1 and DA2 222 chips. The first of the generators generates rectangular pulses with a CPI close to 98%. From the output 2 of the DA1 222 chip, a sawtooth control signal corresponding to the shape of the charge/discharge curve in time of the capacitor C1 is sent to the control output 2 of the DA2 222 chip. A signal is removed from the output of the DA2 chip, which periodically changes in frequency.
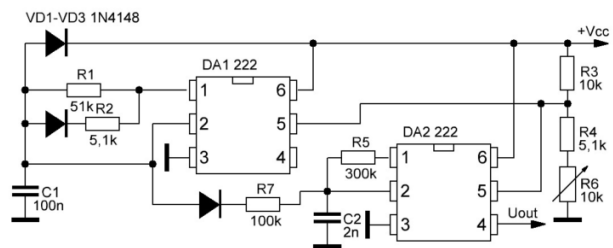

Fig.11: The oscillator of swinging frequency.

The external signal width controller (Fig.12 and 13) allows you to convert a rectangular input signal into an output signal of the same shape with a CPI from 0 to 100%.

The controller (Fig.12) converts the input signal of a rectangular shape with a frequency of 10 kHz with a CPI of 50% into an output signal with a CPI of 0 ... 100%, regulated by a potentiometer R5.
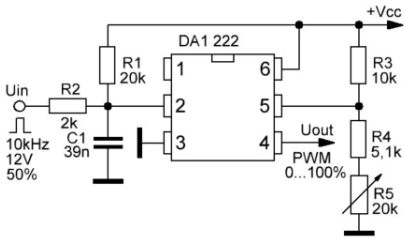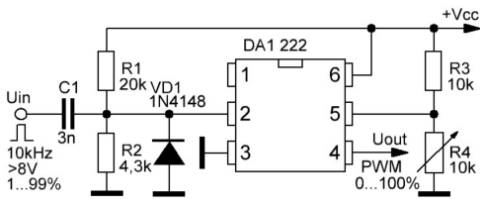

Fig.12: The external signal width controller.

The controller (Fig.13) is capable of converting a rectangular input signal with a frequency of 10 kHz with a CPI of 1...99% into an output signal with a CPI of 0...100%, regulated by a potentiometer R4.
To convert signals of other frequencies, it is necessary to correct the RC elements of the input circuits of the converters.

Figure 13: The controller is capable of converting a rectangular input signal with a frequency of 10 kHz with a CPI of 1...99% into an output signal with a CPI of 0...100%.

Converter of a sinusoidal signal to PWM (Fig.14). A sinusoidal signal with a voltage of more than 2 V is applied to the input of the device; a rectangular signal with a CPI of about 50% is removed from the output 1 of the DA1 222 chip, and a PWM signal with a CPI of 0 to 100% is removed from the output 4. The adjustment is carried out by the R2 potentiometer.
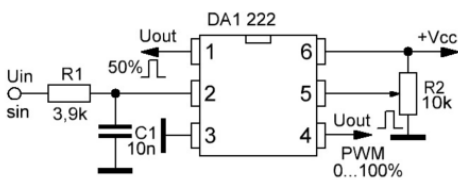

Fig.14: Converter of a sinusoidal signal to PWM.

The analog-to-digital signal converter (Fig.15) allows you to convert an input signal, for example, of a sinusoidal or triangular shape into a rectangular PWM output signal.
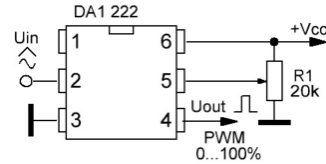

Fig.15: The analog-to-digital signal converter.

The digital signal restorer (Fig.16) is designed for cleaning noisy or restoring the shape of distorted or attenuated digital signals.
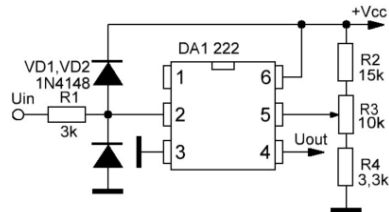

Fig.16: The digital signal restorer.

The element NOT (Inverter) (Fig.17 and 18). The microchip 222 can be successfully used as elements of digital technology, in particular, Fig.17 shows the possibility of using microchips 222 as a element NOT (inverter).
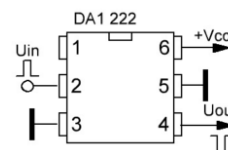

Fig.17: The element NOT (Inverter).

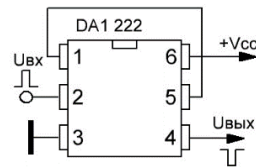The variant of the element is NOT shown in Fig.18.

Fig.18: The variant of the element is NOT.

The Repeater (Fig.19) on the chip 222 has an increased load capacity (output current up to 20 mA).
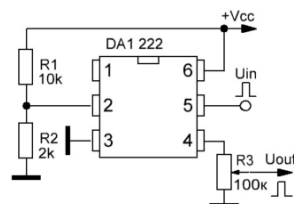

Fig.19: The Repeater.

Element 2NAND (Fig.20) is made on a chip 222 and a transistor VT1.
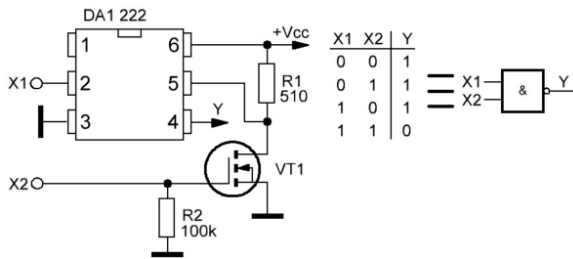
Fig.20: Element 2NAND.

The Implicator (Fig.21) is a logical element that has two inputs, one of which has priority over the other. The level "log. 0" is set at the Implicator output only if the logical level at the priority input exceeds the logical level at the second input. The scheme of such a device made on a chip 222, its truth table and the equivalent of the elements NOT and 2NOR are shown in Fig.21.
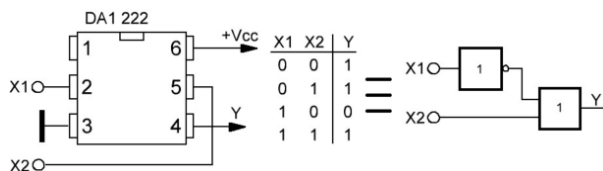

Fig.21: The Implicator.

Elements of fractional logic (Fig.22). The operation of fractional logic elements [4], which is fully compatible with the traditional one, is based on summing the currents on the input resistor R4 of the threshold element (chip 222) and fractional addition of the input currents. At the input of the resistive divider, n input signals of the "log. 1" level are converted into signals of the "log. 1/n" level, for example, "log. 1/2", "log. 1/3", "log. 1/4", etc. If the sum of the weights of all these signals is equal to one, then the output of the logical element will change the level of the logical signal.
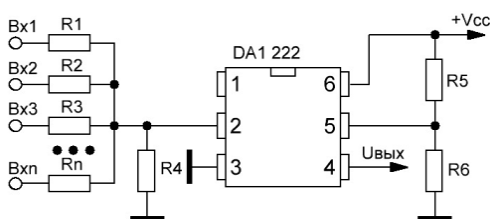

Fig.22: Elements of fractional logic.

The level converter (Fig.23) allows you to convert the input signal level to the output level required by the user, set using the potentiometer R3. The logical level of the output voltage can be either higher or lower than the input level. The maximum output voltage of the signal is 0.9 Vcc.
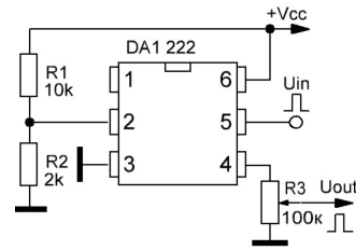

Fig.23: The level converter.

Universal converter of logic signal levels up and down (Fig.24). When rectangular pulses are supplied to the input of the device with a voltage from 1.2 to 60 V (the upper limit is determined by the dissipation power of the resistor R3, for example, 0.25 W), the output signal level can be adjusted by the potentiometer R5 from 0 to 0.9 Vcc. An unregulated signal of the 0.9 Vcc level is removed from the output 1 of the chip 222.
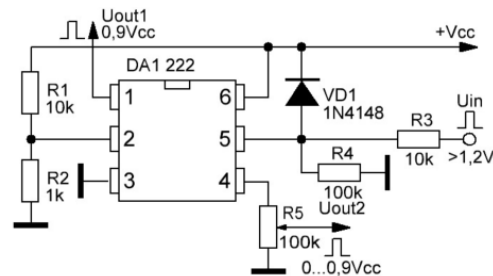

Fig.24: Universal converter of logic signal levels up and down.

A single-vibrator (Fig.25-27) is a device that converts a short-term input signal into an output signal of a given duration in time. The duration of the output signal of the single-vibrator (Fig.25) with a short-term press of the SB1 button is determined by the time-charging chain R2C1 and is 50 ms at a supply voltage of 12 V (T[s]=2.5R[Ohms]C[F]).
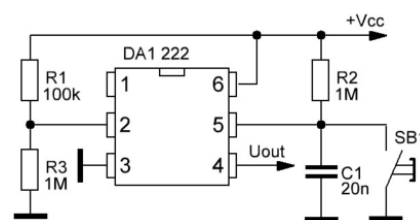

Fig.25: A single-vibrator.

For a single-vibrator (Fig.26), in which that a Zener diode VD1 1N4461 (voltage of 6.8 V), the output signal duration is 28 ms (T[s]=1.4R[Ohms]C[F]).
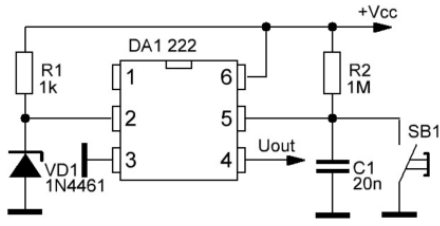
Figure 26: Single-vibrator version.

The single-vibrator (Fig.27) additionally contains a control transistor VT1 2N7000.
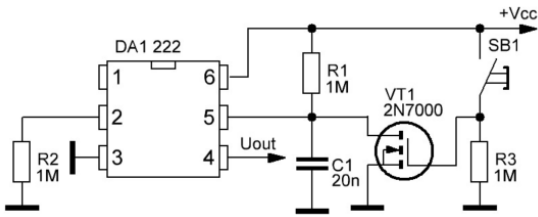
Figure 27: Another version of the single-vibrator.

The duration of the output signals of single-vibrators (Fig.25-27) depends on the supply voltage of the device.

The input signal frequency dividers (Fig.28-30) are designed to divide the input signal frequency by a user-defined integer value of a digital series.

The frequency divider (Fig.28) is made on transistors VT1 BC558 and VT2 2N6600. From the output 1 of the chip 222, a signal of the initial frequency (600 Hz) divided by the division factor is removed, stepwise set by the potentiometer R5 in the range from 1 to 4. From the output 4, the signal of the initial frequency is removed.
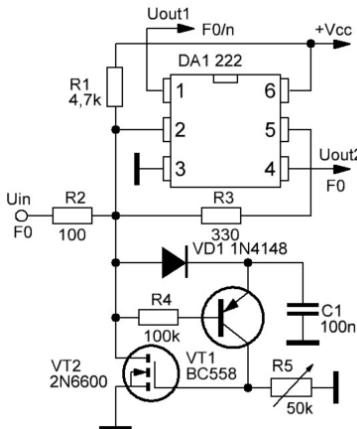
Fig.28: The input signal frequency dividers on 1, 2, 3, 4.

The frequency divider (Fig.29) contains two chips - DD1.1 CD4013 (D-trigger) and DA1 222. At the input signal frequency of 10 kHz, the division coefficient set by the potentiometer R1 can take the values 1, 2, 3 ... 20.
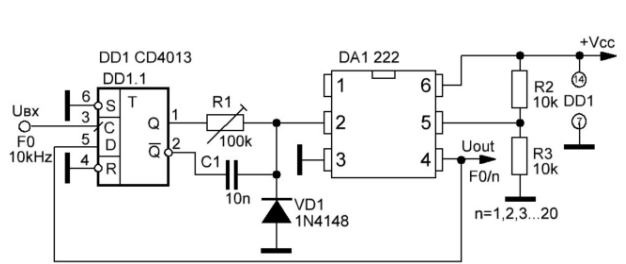
Fig.29: The frequency divider on 1, 2, 3 ... 20.

The frequency divider (Fig.30) is made on two elements of the DD1.1 and DD1.2 CD4093 chip and the DA1 222 chip. At an input signal frequency of 100 kHz, the division coefficient set by the potentiometer R1 can take the values 1, 2, 3 ... 20.
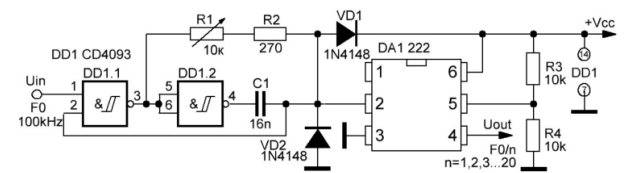
Figure 30: Another version the frequency divider on 1, 2, 3 ... 20.

In order for the frequency dividers (Fig.28-30) to work at different values of the input frequencies, it will be necessary to correct the ratings of the capacitors C1.

The frequency relay (Fig.31) is a threshold device that switches its state when the input frequency is exceeded relative to a given level.

The input circuit of the frequency relay is an analog frequency meter, the output voltage of which is proportional to the frequency of the input signal. This voltage is applied to pin 2 of the chip 222. The voltage of the level set by the potentiometer R3 is supplied to the pin 5 of the chip. As soon as the voltage on pin 2 exceeds the voltage on pin 5, the logic level will switch from "log. 0" to "log. 1"on pin 4 of the chip.
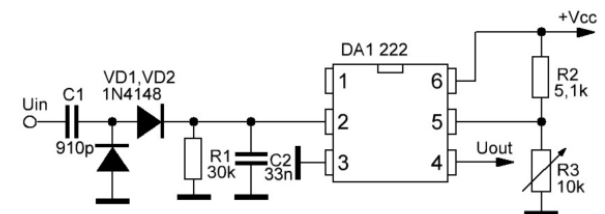
Fig.31: The frequency relay.

With the potentiometer R3, the frequency limit of switching the relay can be set within the range of up to 100 kHz.

Adjustable window comparator with PWM (Fig.32 and 33). The input circuit of the window

comparator (Fig.32) is made on a transistor VT1 BS170. The upper limit of the window switching is smoothly regulated by the R2 potentiometer. The width of the switching window is set by the potentiometer R4. The device operates at a frequency of 1 kHz, when working at other frequencies, correction of the values R2, R3, C1 will be required.
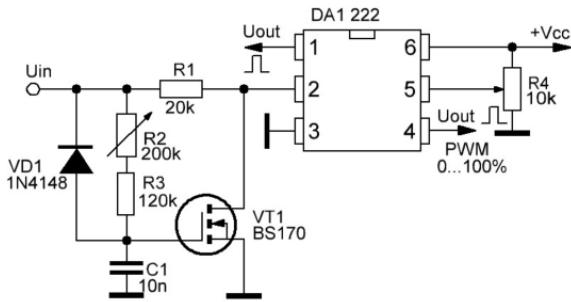

Fig.32: Adjustable window comparator with PWM.

A window comparator (Fig.33) is made on two DA1 and DA2 222 chips, as well as on the "Exclusive OR" DD1.1 CD4030 element. The boundaries of the switching windows can be smoothly adjusted using the potentiometers R2 (upper limit) and R4 (lower limit). The device compares favorably with its predecessor in that it operates in a wide frequency range.
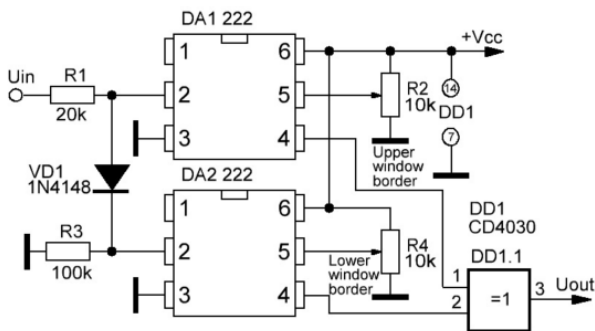

Fig.33: A window comparator.

Voltage converter (Fig.34 and 35). The converter (Fig.34) is made on a chip 222, included according to a standard scheme with the possibility of adjusting the output signal width using a potentiometer R5. From the output 4 of the microcircuit, the control signal is fed to an electronic key on the transistor VT1, from the drain of which voltage pulses are fed to a classical rectifier, which allows to obtain a negative polarity voltage at the output.
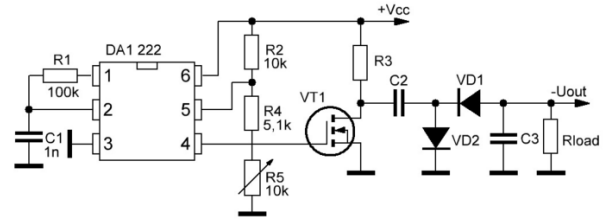

Fig.34: Voltage converter.

The voltage converter (Fig.35) is made according to a similar scheme, but the load of the transistor VT1 is the inductance L1; an output voltage of a higher level than the supply voltage of the device is created at the output of the converter.
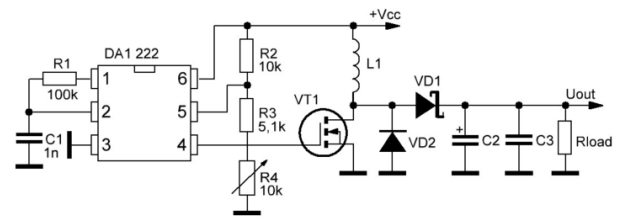

Fig.35: Voltage converter with inductance.

Note that pin 5 of the chip 222 (Fig.34 and 35) can be used to stabilize the voltage on the load.

A low-frequency amplifier (Fig.36 and 37). The low-frequency amplifier on the chip 222 (Fig.36) operates in the frequency band at the level of -3 dB from 0.15 Hz to 220 kHz. The transmission coefficient of the amplifier is 9.6 dB, THD 0.001%. Rectangular pulses with a CPI of the order of 50% are removed from output 4.
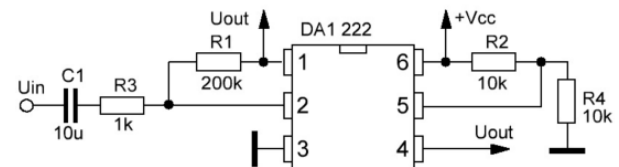

Fig.36: A low-frequency amplifier.

The low-frequency amplifier (Fig.37) is also made on the chip 222. Its bandwidth is at the level of -3 dB from 16 Hz to 5.8 MHz with a transmission coefficient of 46 dB and THD of 0.02%.
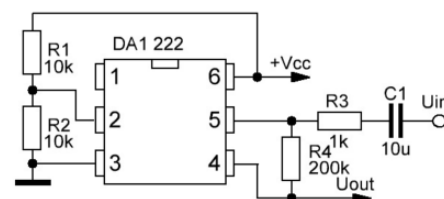

Figure 37: Low frequency amplifier optionю

The D-class amplifier (Fig.38) consists of a rectangular pulse generator on the chip 222, a stable current generator on the transistor VT1 BC557, which allows charging the capacitor C1 according to a linear law, and a modulator on the transistor VT2 BC547. The operating frequency of the generator is 47 kHz. The width of the output pulses is modulated by a low-frequency analog signal supplied to the input of the device. The output stage and amplifier filters are not shown.
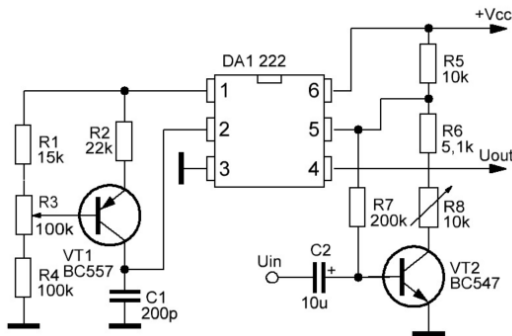

Fig.38: The D-class amplifier.

A light pulse generator or a flashing light (Fig.39). The pulse generator of the low frequency range on the chip 222 controls the alternate switching of the LEDs HL1 and HL2. The switching frequency is set by the resistor R1 and the capacitor C1 and is approximately 2 Hz.
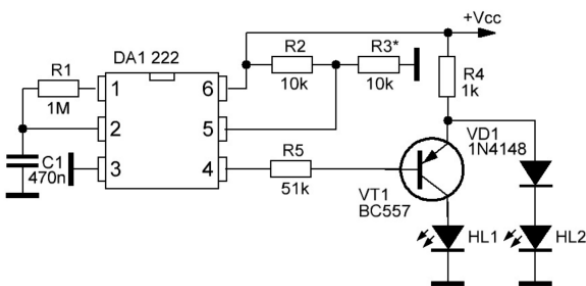

Fig.39: A light pulse generator or a flashing light.

The visual indicator of illumination or temperature (Fig.40) contains a pulse generator on the chip 222, the width of the output pulses of which is set using a controlled resistor made on a VT2 2N7000 field-effect transistor.

The sensitive element of the device is a photo- or thermoresistor R5. When the intensity of the light flux or temperature changes, the resistance of this resistor changes and, accordingly, the resistance of the source-drain channel of the VT2 transistor changes. There is also a change in the width of the output signal taken from the output 4 of the chip 222.
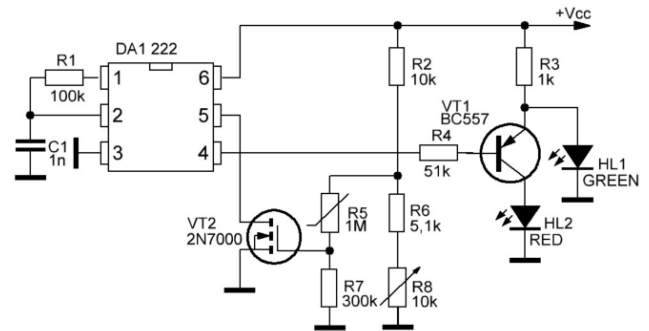

Fig.40: The visual indicator of illumination or temperature.

The output stage load on the transistor VT1 BC557 is the LEDs HL1 and HL2 of green and red glow, respectively. An increase in the intensity of the luminous flux or temperature will be accompanied by a change in the total color of the radiation of two multi-colored LEDs. So, the predominance of the red hue of the total glow of the LEDs will correspond to an increase in the temperature in the room.

Photo- and thermal relay (Fig.41). Depending on the temperature (light) coefficient of resistance, the sensing element (photo- or thermoresistor) can be included in the upper or lower arm of the resistive divider R1, R5 according to the scheme (Fig.41). The second arm of the resistive divider includes a tuning resistor of a close nominal value. The switching threshold of the relay is regulated by the potentiometer R4.
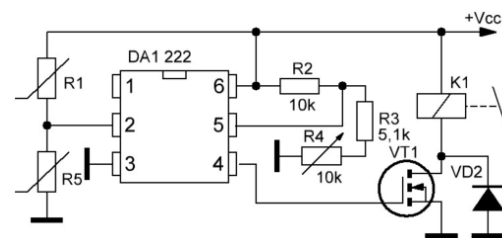

Fig.41: Photo- and thermal relay.

Time relay (Fig.42). When the SB1 button is pressed, the capacitor C1 is smoothly charged through the circuit R1, R2 to the switching voltage level set by the resistive divider R3, R4. After that, the relay K1 is triggered, including the load with its contacts. The VD1 diode contributes to the rapid discharge of the capacitor C1 when the SB1 button is not pressed. The time interval of the relay operation is regulated by the potentiometer R1 in the range from 1 to 100 s and can be defined as $T[s]=(R1+R2)[kOm]C1[uF]$.
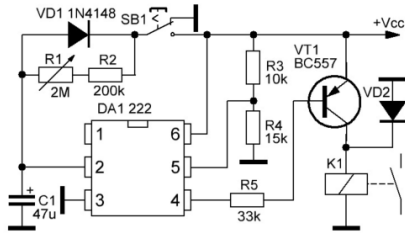
Fig.42: Time relay.

The siren (Fig.43) is made on DA1 and DA2 chips and VT1 BC557 and VT2 BC547 transistors. The first low-frequency generator on the DA1 chip, whose frequency is adjusted by the R2 potentiometer, controls the operation of the pulse generator of the audio frequency range on the DA2 chip. The volume of the output signal is adjusted by a potentiometer R8.
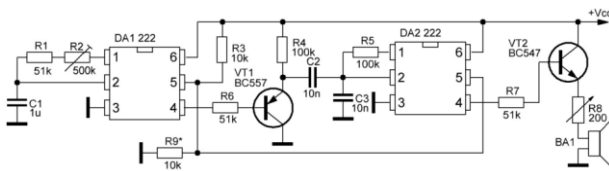

Fig.43: The siren.

The "BEEP-BEEP" generator (Fig.44) allows you to get audio frequency signal packets at the output. On the DA1 chip, a low-frequency oscillator is made that provides the duration of the sending and pause pulse. A controlled generator of audio frequency pulses is made on the DA2 chip.
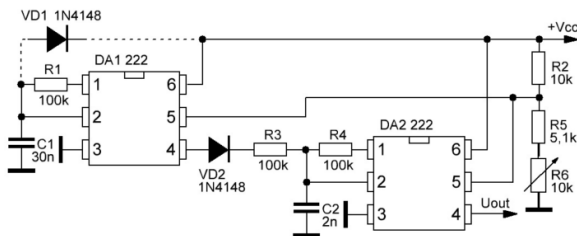

Fig.44: The "BEEP-BEEP" generator.

4 Conclusion

The list of devices given in the article is far from being exhausted. Based on the 222 chip, it is possible to create a number of generators, timers, autoregulators, converters, various kinds of relays, charging and indicator devices, voltage monitoring systems, security systems, industrial and household automation systems, and much more.

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