Novel Signal Gate Solution Suitable for Implementation in Audio and Recording Technologies

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Abstract:
The paper deals with the design and construction of signal gate standardly used in audio technology. The presented signal gate solution uses relatively unusual structural elements in the circuit structure. There are not therefore employed circuit elements by THAT Corporation Audio Technology or by Analog Devices SSM well-known and widely used in audio technology, but conventionally used operational amplifiers. The aim of the study was to develop a comprehensive box including four signal gates and to verify that its parameters can be compared with the commercially available devices.

INTRODUCTION

Signal gate belongs to the signal processors group for signal dynamics modification. There are the problems with unwanted noises and hums in recording and audio technology [9]. These are caused by the adverse electronic phenomenon (wrong shielding, electrical sensor hum, etc.) or by sums of acoustic unwanted effects (echoes of drum kits, clusters from other microphones [4]). Therefore, the signal gate has become an integral part of audio technology. The signal gate, with proper set of parameters of the particular device, filters these side effects from the resulting audio signal.

It is possible to scan and modify the acoustic signal [5] by the number of sophisticated electronic circuits. The acoustic signal must be first converted to the electrical form and then the changes can be pursued by the particular electronic circuit. The modified signal is necessary to retrospectively transfer into the acoustic form to allow its reproduction (e.g. sound is captured by the microphone. Then it is modified by the correction filter and subsequently amplified and played back by the speaker).

The first phase of this comprehensive process is sound scanning [4]. Scanning is performed using different convertors (e.g. microphones or sensors [5]), which convert the acoustic signal into the electrical signal. The most common type of convertor is a microphone, but it has many certain limitations and shortcomings, which can be easily detected by a human ear.

The second phase includes the actual electrical signal processing. The signal can be in analog or digital form. Then the signal is transformed by the appropriate devices. The well-known audio mixing console can be an example of such device. It allows the signal transformation in wide range of functions (bass, mid, treble, variable effects types etc.).
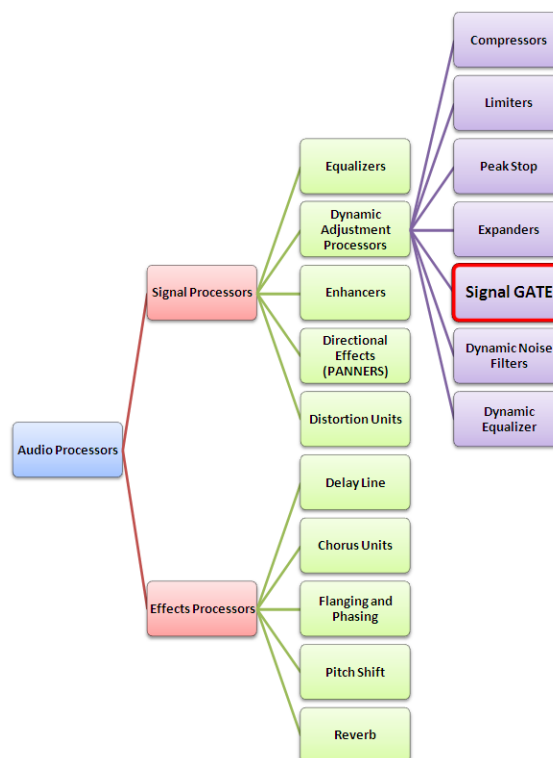

Fig. 1:   Categorization of signal gate

The third and final phase is the converting of the transformed electrical signal back to the acoustic signal and its adequate reproduction. At first, the signal is amplified by the power amplifier. Then the sound system converts the electrical signal back into the acoustic form.

The text above briefly describes the basic blocks of the acoustic signal processing chain. Individual blocks can be used separately, but if the specific processors are added into the chain, then the blocks can perform also more demanding functions. Audio processors are divided into two groups (See Fig.1) [4].

The group of signal processors [8] consists of the devices processing signal as a whole. There comes the original unchanged signal at the input of processor. The signal is then dynamically transformed by correction filters. The modified signal is then terminated at the output of the processor. The signal processors for such processing of the signal dynamics are called signal gates (GATE).

SIGNAL GATE

The primary function of signal gate is the selection of the signals depending on the amplitude level. It means that signals with lower amplitude than the selected level are not passed through by signal gate. The signals with higher amplitude than the selected level are passed through and processed by signal gate. It means that signal gate can be described as a particular filter type. Signal is more attenuated below the certain threshold level. In radical case, it can lead to signal disappearance. This process is called "gating" and device operating in this mode is referred as signal gate (GATE). Simplified block diagram of signal gate is shown in Fig.2. The position of signal gate in the signal path is behind audio mixing console pre-amplifier output. Amplifier output is often brought out through the insert connector for most audio mixing consoles. Insert connector represents both pre-amplifier output and re-enter input of audio mixing console circuit structure [6].
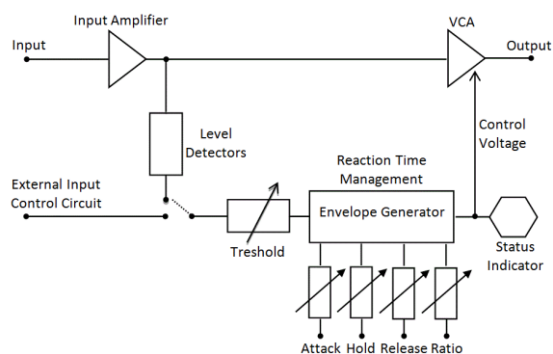

Fig. 2:   Block diagram of a simple signal gate

In almost all areas of audio and recording technologies, there are problems with disturbing phenomena. These side effects can have the electrical nature (synthesizer noise, processor interference, wrong cable shielding, electronic sensor hum) or acoustic nature, which can be simply described as acoustic environment noise. These unwanted acoustic signals are very disturbingly reflected especially in music pauses or silent parts of record. If this unwanted signal becomes part of audio record, then it is not possible to eliminate or to adequately attenuate this unwanted signal in the final record. The main risk lies in the fact that there might be a change or destruction of own record. It is very difficult to technically realize a device that automatically recognizes a useful acoustic track and also simultaneously marks or eliminates unwanted disturbing signal that is a part of useful acoustic track. Exceptions are the relatively comprehensive software tools, which have many advantages but also disadvantages. The big disadvantage is a relatively high price compared with hardware solution, which signal gate represents.

Human ear cannot detect the unwanted and disturbing acoustic signals as the part of audio record of higher level. However, if the aim is to achieve high quality audio record, the influence of the disturbing signals can not be downgraded. It is possible to eliminate unwanted and disturbing parts of audio record. The resulting signal must be accessible in the form of individual tracks, which are connected together into the resulting signal during the final mixing. Then it is very difficult to eliminate disturbing signals after the final mixing of individual audio tracks [1].

There are the short or longer pauses in the individual audio tracks. In these pauses there can be hear only background noises, hiss, brumes and hums of instruments [2], headphones crosstalk etc. Elimination of these unwanted signals in the silent parts of an audio record was realized by device operating on the principle of an electronic switch in earlier times. This device simply disconnected acoustic signal from the selected threshold level. There was then recorded pure silence in this part of audio record, but it looked very unnatural in certain passages. The device was improved later. Signal gate with adjustable response times and other parameters can be used now.

Signal gates are commonly used now in recording studios. They are suitable both for recording of voice tracks and music records. They are often used for recording of percussion instruments by microphones in field of audio and recording technologies [9]. The microphones are often located very close to the instruments. The microphone records only own audio track of the instrument and also disturbing signals described above. Signal gates allow setting of many parameters. Therefore, among other things, they are also used to simulate of many special effects (for

example reverb). They can be used separately or connected with other audio devices, in detail [1], [3], [6] and [7].

CONTROL PARAMETERS

As mentioned above, automatic device operating in the position of an electronic switch gave a number of disadvantages in practice. Another of mentioned disadvantages is the fact that device switched too soon sometimes and the resulting sounds were cut out in the final record, if the threshold level of the device was set incorrectly. This problem is solved by VCA (Voltage controlled amplifier) in the circuit structure of signal gate. VCA as well as compressor allows setting of attack time [6] and release time of signal gate. Attack time defines the time, which elapses after threshold level crossing and lasts until the full opening of the circuit. However, too frequent opening may causes the rise of commonly audible disturbing signal of discrete character in the initial phase, especially if the signal contains low frequency signal components and signal gate is fully opened in the middle of signal curve cycle. It is necessary to eliminate this disturbing signal by attack time increasing. Release time is another important signal gate parameter. Release time determines the time, which elapses after crossing the threshold level and lasts until complete close of the circuit, when there is no output signal. Some commercially produced signal gates allow setting of hold time [1]. Hold time is defined by time period during signal gate is not allowed to enter the release time, even when the signal has decreased below the threshold level.

If signal gate has a possibility of expansion ratio setting, then it is not already a classic signal gate, but expander [2]. The expansion ratio is given conversely by compressor. It means that the number indicating the expansion degree is second information in this case (for example 1:5). The expander is not fully switched off, when threshold level is exceeded, but signal is gain reduced. If the input signal of signal gate will not reach selected threshold level, then signal gate circuit will not open and a pure silence is result. In the case of expander use, there can be heard the sounds below the threshold level but with particular attenuation. For example, the ratio of 1:5 causes that each one decibel decrease of signal attenuates the output signal of 5 dB. Paradoxically, dynamic range of signal is extended to reduce it. Expander provides attenuation of small amplitude disturbing signals in record so that they cannot be heard. For the real dynamic range resolution, a process used very rarely, is suitable ratio 1:1.5 with highly set threshold sensitivity level.

Modern signal gates already contain similarly enhanced of functions as compressors. There are for example models "soft knee" [1]. Their primary function is that if signal falls below the threshold level, then the gain attenuation is higher. There are also commercially available circuit peripheral solutions with automatic control of attack and release time [7]. These devices perform the gain attenuation below threshold level more sensitively than simple solutions of signal gates. Devices with hysteresis functions represent another extension of classical signal gate [2]. This variation of signal gate is particularly useful for acoustic signal processing of signals, which do not continuously resonate, but they have waved course. If the signal falls below threshold level in deceleration phase and then it cross threshold level several times, then it can causes switching on signal gate. This event can appear like imperfect contact or cold joints in device (chattering). Devices with hysteresis functions will not allow another opening of signal gate, if signal will not fall below threshold level. In practice, it looks like there were two levels – higher level to open and lower level to close signal gate. This problem is especially common for recording of synthesizers with amplitude modulation (LFO) or guitars with dissonant intervals [11].

PRINCIPLE OF OPERATION

The basic block diagram is shown in Fig.3. There is situated capacitor CV at input of circuit (labeled IN). It is used to suppression of DC parts of input signal. Rin1 and Rin2 resistors determine the input resistance of the circuit solution. Integrated circuit TL082 [11] serves as input impedance matching. TL082 contains two J-FET operational amplifiers [12]. Another integrated circuit TL082 serves as the output impedance matching (operational amplifiers with 0dB gain). Output resistance is defined by the value of resistor ROUT, which corresponds to the resistor R10. Input voltage divider consists of potentiometers P1 and P2. Potentiometer P1 sets the basic level of signal. Potentiometer P2 (attack) sets the signal amplitude, which will be processed in the signal gate circuit. Potentiometer P2 directly sets the threshold level of signal gate. Voltage comparator is implemented by integrated circuit LM358 [11], which contained two operational amplifiers used for voltage comparison. Voltage U1 is brought at first comparator input. The signal U1 will be processed by signal gate. At the second input of the comparator, there is brought a reference voltage U2 of level selected by voltage divider (user-defined signal level, which signal gate has to pass through). The comparator compares two voltage levels U1 and U2. Then two states can occur:

1) U2 > U1 - If this state occurs, then comparator will not overturn and there is no signal at the output of signal gate. Voltage did not reach the signal level, which it is desirable to pass through (at least U2 level).

2) U2 < U1 - In the case of accomplish of this condition, comparator will overturn and pass through the signal of value U2 - U1. This difference

is marked as UC (control voltage). This signal is further processed. It has a negative value of voltage.
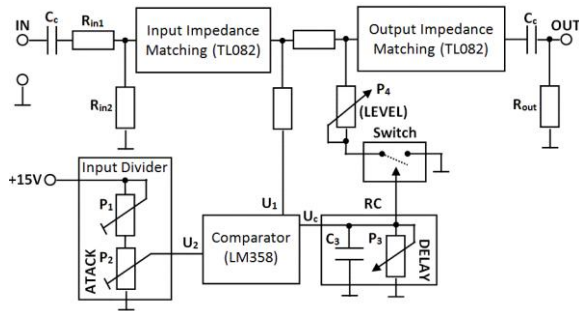

Fig. 3:   Block diagram of realized signal gate

Final signal gate solution is shown in Fig.4. The transistor of type BF245 [12], labeled T1 in the schema, works in switch mode. In the quiescent mode, transistor is switched on and it is connected to the ground to noise do not come to signal gate output.

However, if the comparator will overturn, then negative voltage will come to terminal G. This voltage causes a change of transistor state from switched on to switched off. The signal gate output reaches a minimum voltage value defined by threshold level, which is set by voltage divider. Tunable RC circuit, consisting of potentiometer P3 (delay) and capacitor C3, allows continuous change of time constant that determines, how long the

transistor T1 will be in open state after the decline of the signal, when the comparator is already closed. The open state means state, when signal is at the signal gate output. Signal gate is opened for the time of discharging the capacitor. Properly set of time constant (release time) can causes the elimination of unwanted acoustic phenomena that may occur in the time of main signal subsiding. Switch Pr1 is the main switch, which activates or inactivates signal gate respectively. LED D3 indicates the current status of signal gate. Potentiometer P4 (level) allows the control of signal gate use ratio in complex signal path. LED D2 indicates the presence of signal. No signal on LED indicates throughput of signal gate. These states are controlled by the second comparator, which operates by the same way as first comparator [12].

The basic parameters of particular signal gate are power supply ±15V, current consumption 16mA.

Characteristic parameters of signal gate circuit solution have been calculated according to the following equations. The value of signal gate input resistance is given by equation (1). The resulting value of the input resistance was determined Rin = 233kΩ.

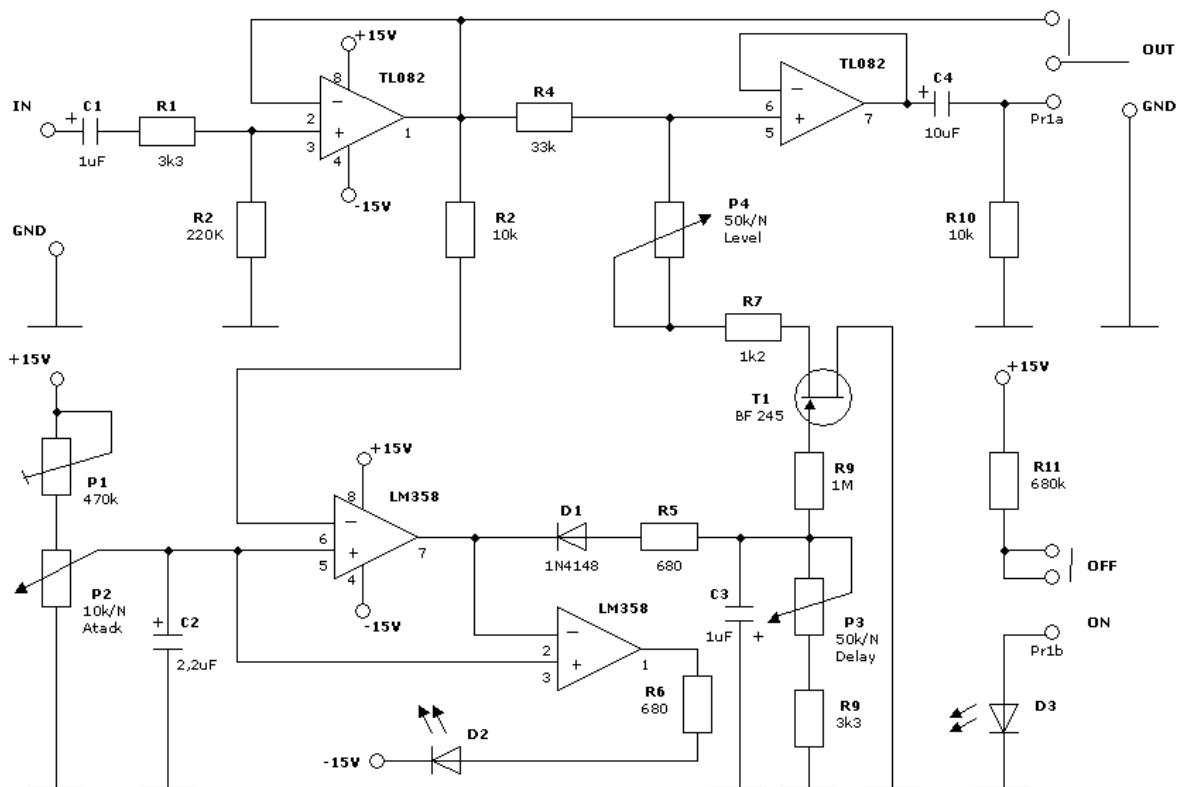$$R_{in} = R_{in1} + R_{in2} = R_1 + R_2 \qquad (1)$$

Fig. 4:   Electronic diagram of realized signal gate

The total output resistance of signal gate is determined by the resistor R10. The value of the output resistance is Rout = 10kΩ.

$$R_{out} = R_{10} \qquad (2)$$

Resistive voltage divider parameters were defined specifically according to equation (3), where U2 represents the value of comparator input voltage. Ucc is value of active elements supply voltage. P2 and P1 represent the maximum resistance values for each potentiometer [12].

$$U_2 = \frac{P_2}{P_1 + P_2} \cdot U_{cc} \qquad (3)$$

The resulting values of passive elements were determined P1 = 470kΩ, P2 = 10kΩ. The supply voltage is Ucc=15V. The resulting value of U2= 0.3125V. The signal gate use ratio in complex signal path with zero resistance of potentiometer P4 is determined by equation (4). R7 and R4 represent the values of individual resistors, Uin is value of the input voltage signal.

$$U_{out} = \frac{R_7}{R_7 + R_4} \cdot U_{in} \qquad (4)$$

The resulting values of passive elements were determined R7 = 1.2kΩ, R4 = 33kΩ. If the value of the input signal Uin= 1.5V, then the resulting value of output voltage is Uout = 0.0544V.
The signal gate use ratio in complex signal path with maximum resistance of potentiometer P4 is determined by equation (5). P4 is the maximum value of resistance of potentiometer P4. Other parameters are the same equation (4).

$$U_{out} = \frac{R_7 + P_4}{R_7 + P_4 + R_4} \cdot U_{in} \qquad (5)$$

The maximum resistance value of potentiometer was determined P4 = 50kΩ. Resulting value of Uout = 0.9425V. Time constant of RC circuit consisting of potentiometer P3 and capacitor C3 is defined by equation (6), where P3 is the maximum resistance value of potentiometer P3. C3 is capacitance value of capacitor C3.

$$\tau = P_3 \cdot C_3 \qquad (6)$$

Values of passive elements were determined P3 = 50kΩ and C3 = 4.7μF. The resulting value of time constant τ = 235ms.

CONCLUSION

The presented paper describes in particular the basic theory of signal gates, briefly summarizes the purpose and function of these circuits. Finally, the simple signal gate solution is introduced. The presented signal gate is suitable for use in the recording technology field. This signal gate combines several advantages. It is a very simple circuit solution that employs commercially available building blocks, especially classical operational amplifiers. Despite of it, the realized device achieves quite good results. One of the most important advantages is relatively low price of the circuit solution compared to commercially available professional signal gates. The resulting price of realized signal gate remains low despite the fact that finally there were realized four signal gates. These four signal gates were placed in the comprehensive box to find wider application use and offer more options in the field of audio and recording technologies. Final signal gate solution is shown in Fig. 5.
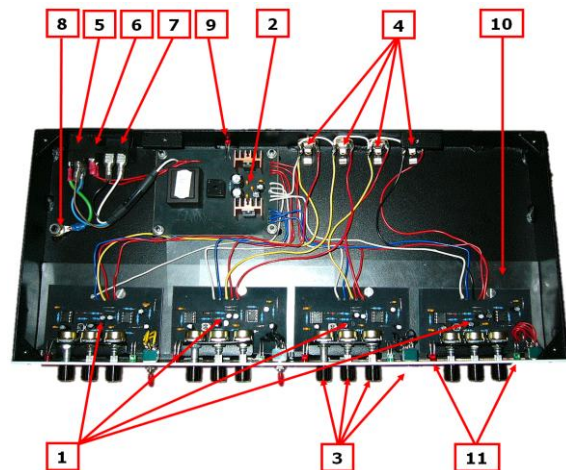

Fig. 5:   Four solution of signal gate in complex box

Fig. 5 description: 1 – four signal gates, 2 – DC power supply ±15V, 3 – signal gate controls, 4 –four JACK connectors (stereo, 6.3mm) serving as inputs and outputs of signal gate, 5 – Supply connector of EURO type 230V, 6 – electrical fuse box, 7 – power switch, – ground pin, 9 – red LED signaling device is switched on, 10 – isulating film, 11 – signaling LED of signal gate (red, green).
Fig. 6 describes comprehensive function of signal gate. There is a rule of set the threshold level as low as possible to cut out noises. It also causes signal gate is not opened by unwanted signals. Then the reaction times are set. Attack time should be as fast as possible without causing noise in the initial phase. Release time (or hold) should be set to resonate sound naturally.
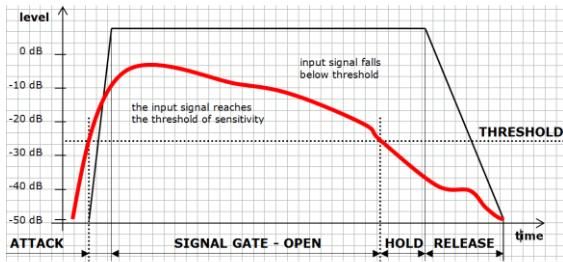
Fig. 6: Signal gate function

Price range of realized signal gate is about 70€. The device is primarily suitable for the drum kits [1], [10]. This sophisticated four signal gates solution is not available in the commercial market. For sounding or recording drum kit several microphones are needed (multiple signal gates) [3]. This device is usually part of comprehensive systems performing many functions. Their price range is from hundreds to thousands €. Parameters of the proposed device can be considered equivalent to parametres of these systems (see Tab. 1).

Tab.1: Technical parameters of realized signal gate.

Input voltage	1.2V p-p
Power Requirements	±15V DC
Power consumption (maximum)	50mA
Frequency	50Hz to 10kHz
Atack	10us to 1s
Hold	2ms to 4s
Range	0dB to 90dB
Threshold	-40dBu to +20dBu
Release	2ms to 2s

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