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# ANALOGUE MODULATOR FOR PSYCHOACOUSTICAL PULSE MEASUREMENTS

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A general description and some diagrams of the three channel analogue modulator are given. Some more important details of the construction are discussed.

## 1. Introduction

In present day methods of psychoacoustical measurements, simple continuous signals often undergo processing in the time and amplitude domains to deliver the required time paradigms of pulses with suitable envelopes. Such pulse signals are commonly used in research pertaining to the perception of pitch, loudness, timbre, to direct and residual masking, to short term and long term memory, to localization of sound sources etc., to name only a few examples.

Periodically repeated paradigms of pulse signals are used frequently if the method of adjustments is applied in the measurements. In such a case the subjects have means to adjust the specified parameter in one of signals presented (variable), so as to match the corresponding sensation to the sensation developed by the standard signal. Often in such paradigms masking or disturbing signals are added to the standard and variable signals.

Stimuli of various types are used in the measurements i.e. sine signals, harmonic and inharmonic multitones, stochastic signals, such as white and filtered noise, various frequency or amplitude modulated signals, etc. Sometimes, periodic signals with a composite spectrum are also used in the form of suitable pulse trains. These incoming signals are usually continuous functions of time.

With respect to signal timing in these methods, operational times in the region from $10^{-4}$ up to $10^{2}$ s are most commonly used. This refers both to the duty times of the stimuli and to the time intervals between them. Amplitude or envelope processing should transform the rectangular signal pulses into pulses with the required envelope shape. Gaussian function or linear functions are used most often for pulse shaping, but $\sin^2$, cos or other simple functions are also used. It is necessary that the parameters of the envelope are adjustable. In general it means that the rise and decay slopes may be regulated. With linear functions the rise/decay slope is determined directly, whereas in case of Gaussian function it is expressed as the so-called «fuzziness» coefficient. With some other functions, e.g. $\sin^2$ and cos, it can be determined as a ratio of time intervals of the shaped fraction of the envelope to the whole duty time interval. It also is desirable that for each of the pulses in the paradigm, a different time-amplitude pattern can be chosen. In other words for each of the pulses in the paradigm a separate channel should be used for independent timing and envelope shaping. The number of separate pulses in the paradigms used in the majority of methods described is not greater than three.

## 2. General description

To meet the requirements discussed, a three channel analogue modulator has been designed. A block diagram of this modulator is given in Fig. 1.

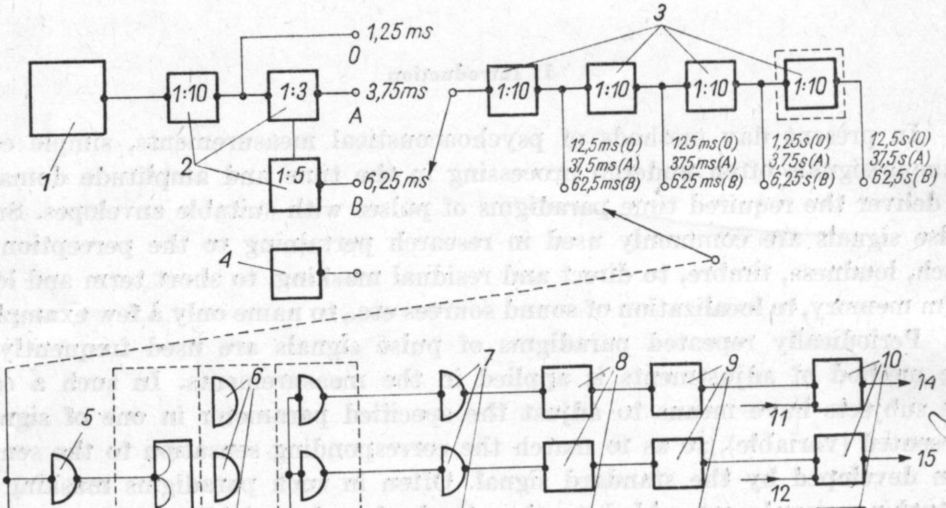


Fig. 1. Block diagram of the three channel analogue modulator

*1* – quartz oscillator 8 kHz, *2, 3* – frequency deviders, *4* – blocking oscillator, *5* – inverter, *6* – decoders, *7* – inverters, *8* – duty cycle adjustment circuits, *9* – rise/decay adjustment circuits, *10* – analogue gates, *11* – I signal input, *12* – II signal input, *13* – III signal input, *14* – I signal output, *15* – II signal output, *16* – III signal output

Three separate analogue gate circuits are used to perform the necessary processing of continuous signals into suitable pulses. The incoming continuous signals delivered to the inputs of these analogue gates obtain from them the required duty time, the suitable time location, and the envelope shape according to the chosen function.

Analogue gate circuits transmit the incoming continuous signals delivered to the inputs only in the presence of a keying signal. Thus, onset and cessation of the keying signal determine the onset and cessation of the incoming continuous signal, whereas the shape of the keying signal fix the shape of the envelope. Stimuli in the form of continuous signals thus processed constitute the required sequence of pulses (paradigm) which can be repeated over and over depending on the conditions of the experiment.

### 3. Timer

Keying signals are delivered from a quartz clock which consists of a conventional quartz stabilized oscillator operating at 8 kHz and a block of frequency dividers with division ratios 1 : 3, 1 : 5 and 1 : 10. With this clock, repetition periods within 1.25 ms to 62.5 s for a single channel can be obtained. The repetition period for the sequence of pulses from the three channels is three times greater than for a single channel because the repetition periods for the separate channels must be the same. Keying signals can also be delivered from the blocking oscillator in case a continuous adjustment of the repetition period is necessary. In that case, however, stability of the timer is lower than with the use of a quartz oscillator.

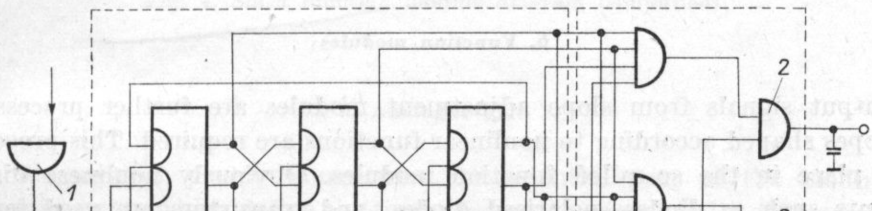


Fig. 2. Decoder logic diagram

*1* — clock input, *2*, *3*, *4* — keying signal outputs for channel I, II and III

The order of operation of analogue gates is fixed with the use of a decoder which delivers consecutive pulses from the timer to the corresponding channels in an orderly fashion, i.e. each third pulse to the same channel. A block diagram of the decoder used is presented in Fig. 2. A conventional circuit terminated at both sides by additional NAND gates is used.

### 4. Duty time adjustment

Output pulses from the decoder are used in each channel to trigger the duty time adjustment circuit (that is, the keying pulse width adjustment circuit). These circuits are operating on a monoflop principle and have an externally adjustable time constant. In the first version of the modulator discrete elements were used in these circuits. In the present version integrated monoflops 74121 are used.

### 5. Slope adjustment

Time-locked keying pulses are then fed to the slope adjustment circuits. In these circuits the onset and cessation of a pulse are processed according to linear functions so that rise and decay times are adjustable within a range from 1 ms to 500 ms. Rise and decay times are equal (symmetrical envelope) and are externally adjustable in steps. Simple manipulation of internal helipots, however, will result in asymmetrical envelopes if required.

Slope adjustment modules are regarded as linear function modules if envelopes of the more sophisticated type are not required. In that case output signals from these modules are used directly to key analogue gates.

### 6. Function modules

Output signals from slope adjustment modules are further processed if envelopes shaped according to nonlinear functions are required. This processing takes place in the so-called function modules. Obviously nonlinear discrete elements such as diodes, polarised diodes, and transistors are used for this purpose(1). A network of these elements is sometimes substantially complicated to suit the approximation of the amplitude modulation functions, and usually contains operational amplifiers.

In the first version of the analogue modulator for the approximation of a Gaussian function, a network consisting of over 80 discrete semiconductor elements and six controls for tuning was used. In the present version of the modulator a fairly simplified Gaussian function module network is utilized. It contains just a few semiconductor elements and six separate tuning controls. The schematic diagram of this network is presented in Fig. 3(2). A similar network for the approximation of a sine function is presented in Fig. 4.

With careful tuning the accuracy of approximation is about 3% to 5% which is sufficient for research practice.

(1) Digital circuits are not taken into account for the sake of simplicity of modulator circuits.

(2) Patent applied for.

Monopolar keying signals thus obtained, which present time locked analogues of the definite functions, are further transformed to bipolar signals and are used for keying linear analogue gates.

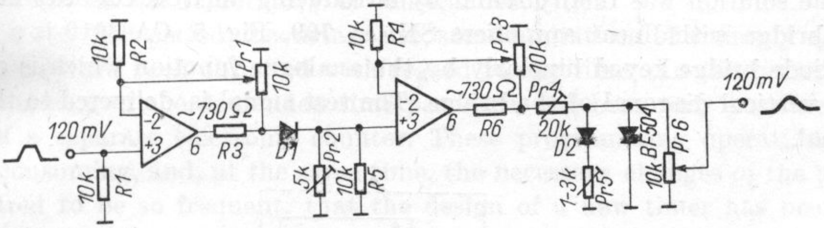


Fig. 3. Gaussian function module diagram (simplified)

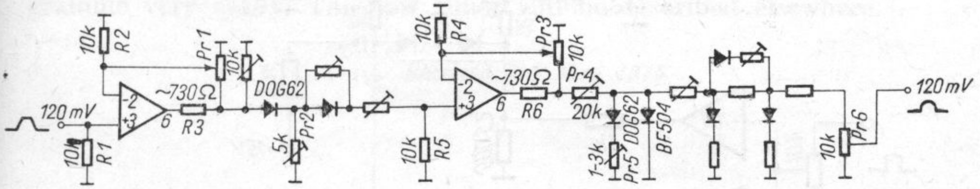


Fig. 4. Sin $at$ function module diagram (simplified)

### 7. Analogue gate

Analogue gate clearly constitutes the essential part of the modulator. The requirements which define the final product i.e. signal pulse characteristics, are not easy to achieve. Specification of these requirements is given in Table 1.

It seems next to impossible to organize a network of discrete semiconductor elements which meets these requirements. To achieve a keying cross-talk level lower than 30 dB in particular, it was necessary to check hundreds of

**Table 1.** Linear analogue gate – specification of requirements

| | |
|---|---|
| Test signal input-output level | 2 V eff |
| Frequency band | 0-20 kHz |
| Frequency response | ±0,1 dB |
| Noise level with gate closed | −90 dB |
| Test signal cross-talk | −80 dB |
| Nonlinear distortion with gate opened | 1 % |
| Dynamic characteristics linearity | 1 % |
| Keying singal cross-talk | −50 dB |
| Keying voltage (monopolar) | 100 mV |
| Operational times range | $10^{-5}$-$10^{2}$ s |

semiconductor elements to select just a few with close operating characteristics. The chances of arriving at sufficiently close characteristics are very thin indeed. 36 dB cross-talk of the keying signal was observed only in a constant ambient temperature with the use of extra resistor balance networks.

The solution was finally found by introducing an RCA CA 3019 integrated diode bridge with linear amplifiers SN μA 709, Fig. 5. CA 3019 is a resistive type diode bridge keyed bipolarly by the analogue function which is delivered to the vertical diagonal of the bridge. The test signal is delivered to the other diagonal.

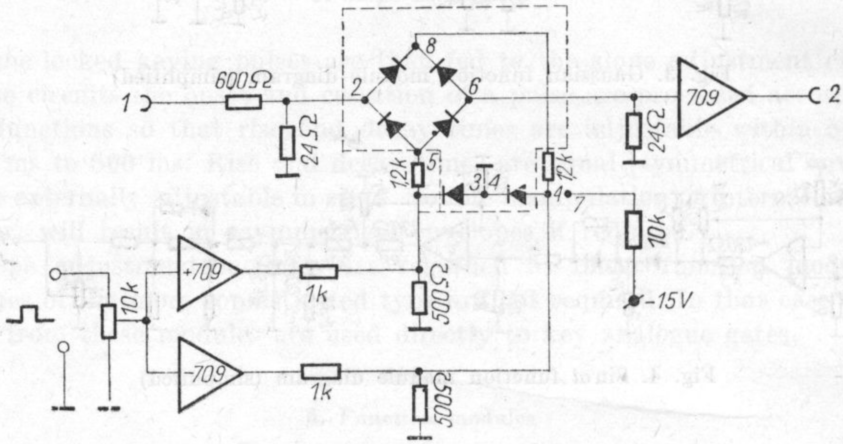


Fig. 5. Analogue gate module diagram (simplified)

1 – input, 2 – output

As all the diodes are on the same silica chip, their characteristics are fairly close, in fact much closer than it is possible to find in the discrete elements. To keep the keying cross talk at a level of – 50 dB, however, it is still necessary that the impedances at the test signal diagonal are low enough. In the present circuit this impedance should be 6 to 24 ohms. Also an accurate balance of the bipolar keying signals to 0.1% tolerance is needed.

To decrease nonlinear distortion of the test signal, its level should be low (of the order of few millivolts). Therefore amplification of the gate output to reach an overall gain of 0 dB, and an output level 2 V eff is necessary.

### 8. General remarks

It should be noted that for any chosen repetition period, the required duty time (or operational time) can be switched in by using duty time modules. In this way for repetition periods of the order of a few seconds, duty times can be of the order of 1 ms. Similarly it is possible that duty times overlap so that test signals are embedded in one another. To increase the possible range of this overlapping, two duty time modules connected in series are introduced in one channel.

The described analogue modulator has been used for over two years in the research work concerning pitch perception in direct and residual masking carried out at the Laboratory of Musical Acoustics.

During that period of constant use, some limitations of a mainly operational character have been observed with regard to the timer. In the present version programming of the demanded time paradigm has been only possible with the use of a separate electronic counter. These programming operations were so time consuming, and, at the same time, the necessary changes of the paradigms appeared to be so frequent, that the design of a new timer has been decided upon.

The new timer is designed in TTL technique. It enables digital programming of the paradigms with a direct display and makes it possible to change the programme very easily. The new timer will be described elsewhere.

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