



Universal filter

For filters of every type, especially active filters such as low-pass, high-pass, band-pass, band-stop (trap filter), all-pass etc., it is known to assign special circuits which are as simple as possible. Sometimes however, there occurs a demand for the implementation of all of the above mentioned types of filter using a single circuit and also for even more general kinds of filter functions in accordance with the transfer function of a filter block of second order having the general form

$$A(P) = \frac{d_0 + d_1P + d_2P^2}{c_0 + c_1P + c_2P^2} \quad \text{Gl.1.1.1}$$

using arbitrary filter coefficients d_0 , d_1 , d_2 , c_0 , c_1 and c_2 . Such filters are called universal filters and represent active filters.

One implementation of a circuit for a universal filter is known from the ninth revised and expanded edition of, "Halbleiterschaltungstechnik", U. Tietze, Ch. Schenk, Springer-Verlag 1989, page 444 in the illustration 14.42 found there. In the case of a circuit of this type, the individual coefficients can be set independently of each other since each coefficient is dependent on only one component.

Moreover, filters having adjustable parameters are shown in the circuit in the above mentioned source, wherein the resonant frequency, the Q factor and the amplification at the resonant frequency can be adjusted independently of one another.

The advantage of such a universal filter consists, in particular, in that it simultaneously works as a selective filter, a stop filter or trap filter, as a low pass and/or a high pass or as a high pass in dependence on which output one is using. A type of filter can be specified and, in addition, the filter characteristics can be altered in dependence on the way in which the individual components are dimensioned. Moreover, in



respect of the type of filter specified, the boundary frequency and the degree of amplification can be continuously tuned independently of one another.

In addition, when operating as a band-pass or band-stop filter, the resonant frequency, the amplification and the Q factor can be varied without any mutual interaction.

Universal filters can be obtained as integrated circuits in which one only has to externally connect up a couple of resistors for the purposes of defining the type of filter and the boundary frequency.

The circuits known from the above mentioned source do however have the disadvantage that they are constructed from a relatively large number of components which makes any integration into a semiconductor circuit expensive and hence costly.

Thus, the object of the invention is to develop a universal filter which has a simple and or a very small circuit arrangement.

This object is achieved in accordance with the invention by a universal filter having the features in accordance with claim 1. Advantageous developments are specified in the appendant claims.

Whilst 10 resistors, 2 capacitors and 4 operational amplifiers are needed for an active universal filter according to Tietze-Schenk, page 444 (Fig. 1), only 2 conductance amplifiers, 4 capacitors, 1 voltage following means and 1 amplifier K having an amplification factor k are needed in the circuit in accordance with the invention. The outlay for the circuit is thus considerably reduced.

In particular and in an outstanding manner, a band-pass filter or a band-stop filter can be constructed by using the universal filter arrangement in accordance with the invention and it can be continuously tuned in dependence on the wanted centre

frequency, the Q-factor, the steepness of the edges and the amplification etc.

The invention will be explained in more detail hereinafter by means of a plurality of graphically illustrated embodiments. In the drawings:

Fig. 1 illustrates a universal filter of second order having independently adjustable coefficients (known),

Fig. 2 a universal filter in accordance with the invention,

Fig. 3a the universal filter in accordance with Fig. 2 connected up as a band-stop or trap filter,

Fig. 3b the frequency responses of the band-stop filter in accordance with Fig. 3a when varying the values m and k ,

Fig. 4a the universal filter in accordance with Fig. 2 connected up as a band-pass filter,

Fig. 4b the frequency responses of a band-pass filter in accordance with Fig. 4a in the case where m and the ratio of g_{m1} to g_{m2} are varied,

Fig. 5 a universal filter in accordance with Fig. 2 connected up as a low-pass filter,

Fig. 6 a universal filter in accordance with Fig. 2 connected up as a high-pass filter,

Fig. 7 a universal filter in accordance with Fig. 2 connected up as an all-pass filter,

Fig. 8 a universal filter having independently adjustable parameters (known).

Fig. 1 shows a universal filter of second order having independently adjustable coefficients as well as the





appertaining transfer function $A(P)$ such as is known from the book, "Halbleiter-Schaltungstechnik", in its ninth revised and expanded edition, U. Tietze, Ch. Schenk; Springer-Verlag Berlin 1989, pages 444 - 447. This universal filter has a relatively complicated and expensive construction. Moreover, four operational amplifiers, ten resistors and two capacitors are needed for the implementation of this universal filter. Such a filter can be adjusted for producing a particular type of filter in dependence on the way in which the coefficients k_0 , k_1 , k_2 , l_0 , l_1 and l_2 are varied. Low-pass, high-pass, band-pass, all-pass filters or band-stop filters are mentioned in particular, as being such types of filter. A universal filter of second order having independently adjustable parameters (see the book "Halbleiter-Schaltungstechnik", page 446) is illustrated in fig. 8 in respect of the setting up of the different kinds of filter and the simultaneous variation of the filter parameters or characteristics. This filter comprises 4 operational amplifiers, four fixed and four adjustable resistors and two capacitors as well as four outputs (on a chip having four pins) and an input. Each output represents a tapping point for a particular type of filter. In the case of this universal filter too, the outlay on the circuitry, and hence the overhead, for a circuit that is capable of being integrated is relatively high.

Fig. 2 shows the basic arrangement of a universal filter in the form of a biquad filter structure in accordance with the invention. The universal filter comprises two conductance amplifiers GM_1 and GM_2 as well as four capacitors (condensers) mCO , $(1-m)CO$, CO and $1CO$ as well as an amplifier K and a voltage following means SP in addition to having three inputs V_h , V_b and V_l as well as an output V_{out} . The voltage following means SP has a high resistance input and is implemented in practice as an impedance converter having the amplification factor 1. The input V_l is connected to the non-inverting input of the trans-conductance amplifier GM_1 having the amplification factor gm_1 . The input V_b is connected via the capacitor mCO to the output of the trans-conductance amplifier GM_1 , to the non-inverting input of the 2nd trans-conductance amplifier GM_2 having the amplification factor gm_2 as well as to the capacitor $(1-m)CO$.

The input V_h is connected via the capacitor C_0 to the output of the trans-conductance amplifier GM_2 , to the input of the voltage following means having a high resistance input and to the feedback capacitor $1C_0$. The output V_{out} is connected to the output of the voltage following means, to the inverting inputs of the two trans-conductance amplifiers GM_1 and GM_2 , to the capacitor $(1-m)C_0$ as well as to the input of the amplifier K having the amplification factor k . The output of the amplifier K is connected to the capacitor $1C_0$. Each of the connections is formed so as to be electrically conductive.

Following the form for the formula G1. 1.1, there arises for the voltage V_{out} :

$$V_{out} = \frac{V_1 + m \cdot (p/p_0) \cdot V_b + (p^2/p_0^2) \cdot (gm_1/gm_2) \cdot V_h}{1 + m \cdot (p/p_0) + (p^2/p_0^2) \cdot (gm_1/gm_2) \cdot (1 + 1 - 1 \cdot k)} \quad G1.2.1$$

The universal filter is formed either as a high-pass filter or a low-pass filter or a band-pass filter or an all-pass filter or a band-stop (trap) filter or some other sort of active filter in dependence on the input loading of the three inputs V_1 , V_b and V_h . The different filter characteristics such as the Q-factor, the amplification, the centre frequency, the steepness of the edges, etc can be set in dependence on the dimensioning of the parameters gm_1 , gm_2 , m , l , k .

Fig. 3a shows the universal filter in accordance with Fig. 2 connected up as a trap filter or band-stop filter. The inputs V_1 and V_h are connected together. These two inputs form the common input for the circuit. The input V_b is connected to earth. There thereby arises for V_{out}

$$V_{out} = \frac{V_{in1} (1 + (p^2/p_0^2))}{1 + m \cdot (p/p_0) + (p^2/p_0^2) (1 + 1 - 1 \cdot k)} \quad G1.2.1.A$$



wherein the quotient of gm_1/gm_2 of the equation 2.1 is set = one and there is $V_1 = V_h = V_{in}$.

Fig. 3b shows the frequency responses of the trap filter in one case where $l = \text{zero}$ and when varying m and in another case where $l = \text{four}$, $m = \text{three}$ and when varying k , in addition to the transfer function for the circuit in accordance with Fig. 3a. The larger m is, the steeper the fall of the level at the centre frequency of the trap filter. In the case of a variation in k , the frequency response of the trap filter shows: The larger k is, the greater the falling away of the slopes of the curve at the centre frequency and the steeper the drop in level.

In Fig. 4a, the universal filter in accordance with Fig. 2 is connected up as a band-pass filter. V_h and V_1 are again connected together and are now at earth potential. The parameter l is set to zero. There then arises for the output voltage V_{out} :

$$V_{out} = \frac{m \cdot (P/P_0)V_{in}}{1 + m \cdot (p/p_0) + (p^2/p_0^2) \cdot (gm_1/gm_2)} \quad G1.2.1.B$$

wherein $V_b = V_{in}$ applies.

In Fig. 4b, the frequency responses of the band-pass filter are shown once in the case where m is varied and then in the case where gm_1/gm_2 is varied, and there is also shown the transfer function of the band-pass filter. In the case where m is varied, $gm_1 = gm_2$. In the case where gm_1/gm_2 is varied, $m = \text{three}$. The larger m is, the flatter the waveform of the transfer function in the vicinity of the centre frequency. The larger the ratio gm_1/gm_2 , the steeper the drop of the transfer function at the edges.

In Fig. 5, the universal filter in accordance with Fig. 2 is connected up as a low-pass filter. The inputs V_h and V_b are connected together and are at earth potential. l is set to zero. There then arises for V_{out} :

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V1

$$V_{out} = \frac{V_1}{1 + m \cdot (p/p_0) + (p^2/p_0^2) \cdot (gm_1/gm_2)} \quad G1.2.1.C$$

In Fig. 6, the universal filter in accordance with Fig. 2 is connected up as a high-pass filter. The input V1 is connected to the input Vb and is at earth potential. 1 is set to zero. There then arises for Vout:

$$V_{out} = \frac{(p^2/p_0^2) \cdot (gm_1/gm_2) \cdot V_h}{1 + m \cdot (p/p_0) + (p^2/p_0^2) \cdot (gm_1/gm_2)} \quad G1.2.1.D$$

In Fig. 7, the universal filter in accordance with Fig. 2 is connected up as an all-pass filter. 1 is again set to zero. The two inputs VH and V1 are connected together. The relationship: $V_b = -V_1 = -V_h$ applies for the inputs. There then arises for Vout:

$$V_{out} = \frac{V_1 - m \cdot (p/p_0) \cdot V_b + (p^2/p_0^2) \cdot (gm_1/gm_2) \cdot V_h}{1 + m \cdot (p/p_0) + (p^2/p_0^2) \cdot (gm_1/gm_2)} \quad G1.2.1.E$$

The relationship: $p_0 = gm_1/C_0$ applies for all of the formulae. The difference between an operational amplifier and a (operational) trans-conductance amplifier (OTA) is that, in an operational amplifier, the voltage difference (differential voltage) at the input is amplified up to 100000 times and this amplified voltage is made available at its output, whereas, for the OTA, although it also amplifies the differential voltage at the input, the "amplification factor" is adjustable and a current appears at the output instead of a voltage. The amplification factor of the OTA is expressed in mA/V and is referred to as a mutual conductance. As integrated semiconductor modules, the types LM 13600 and LM 13800 from RCA are known.

The respective centre frequency or boundary frequency of the filter can be altered via the ratio P/PO in each of the circuits

in Figs. 2 - 7. The Q factor of the band-pass filter can be continuously adjusted by means of the ratio $1 : m$.

Circuits of the type mentioned hereinabove can be used, in particular, in television receivers, in multi-norm television receivers, radio receivers and test equipment. They are to be used, in appropriate manner, in multi-norm television receivers because at one frequency in one case there is a wanted signal, where in the case of another norm an interference signal turns up. Thus, by virtue of the invention, a signal may be variously suppressed or let through as and when necessary. These circuits can therefore be usefully used for processing analogue signals in a flexible manner.

Due to their simplicity in respect of the circuit structure, the layout on circuitry - the so-called overhead - is kept low and the whole process of integration is made simpler.

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Claims

1. Universal filter in the form of a biquad filter structure having three inputs V_h , V_b and V_l as well as an output V_{out} , characterised by the following features:

- the input V_l is connected to the non-inverting input of a first trans-conductance amplifier G_{m1} having the amplification factor g_{m1} ;
- the input V_b is connected via a capacitor mC_0 to the output of the trans-conductance amplifier G_{m1} , to the non-inverting input of a second trans-conductance amplifier G_{m2} having the amplification factor g_{m2} as well as to a capacitor $(1-m)C_0$;
- the input V_h is connected via a capacitor C_0 to the output of the trans-conductance amplifier G_{m2} , to the input of a voltage following means having a high resistance input and to a feedback capacitor $1C_0$;

the output V_{out} is connected to the output of the voltage following means, to the inverting inputs of the two trans-conductance amplifiers G_{m1} and G_{m2} , to the capacitor $(1-m)C_0$ as well as to the input of an amplifier K having the amplification factor k whose output is connected to the capacitor $1C_0$;

- the universal filter is formed either as a high-pass filter or a low-pass filter or a band-pass filter or a band-stop (trap filter) or as an all-pass filter or some other sort of active filter in dependence on the input loading of the inputs V_h , V_b and V_l ;

- different filter characteristics such as the Q -factor, the steepness of the edges, the centre frequency, the amplification etc can be set in dependence on the dimensioning of the parameters g_{m1} , g_{m2} , m , 1 and k .





2. Universal filter in accordance with Claim 1, characterised in that, in general, the following applies for the output of the universal filter:

$$V_{out} = \frac{V_1 + m \cdot (p/p_0) \cdot V_b + (p^2/p_0^2) \cdot (gm_1/gm_2) \cdot V_h}{1 + m \cdot (p/p_0) + (p^2/p_0^2) \cdot (gm_1/gm_2) \cdot (1 + 1 - 1 \cdot k)}$$

wherein the following applies: $PO = gm_1/CO$.

3. Universal filter in accordance with Claim 1, characterised in that, the universal filter is constructed as an integrated circuit.

