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**Method and circuit for automatic, high-precision
fine frequency tuning**

The invention relates to a method and a circuit for automatic, high-precision fine frequency tuning with the aid of a frequency-trimmable analogue circuit in an integrated circuit.

Prior art

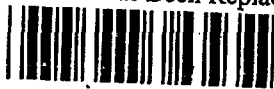
In the field of electronic signal processing, it is often necessary to trim precisely frequencies or frequency-dependent circuits, for example for the tuning of tuners or the trimming of frequency generators.

Appropriate AFT methods (automatic fine tune) are known, for example, from "Television Engineering Handbook", page 13.117, K. Blair Benson, McGraw-Hill Book Company. In this case, the phase shift on a parallel tuned circuit is evaluated.

Fig. 1 shows a corresponding block diagram. An output signal 10 which is influenced by tuning, for example a television audio signal, is supplied to a tuned circuit 11 and to a first input of a phase detector 12. The tuned circuit is tuned to a required frequency. The output signal from the tuned circuit 11 is supplied to a second input of the phase detector. The output signal from the phase detector is filtered in a low-pass filter 13 and is used as the control variable 14 for tuning the input signal 10. A circuit which is suitable for this purpose is, for example, an FM demodulator 15 which can be tuned by a control variable and to which the control variable 14 and a signal 16 to be demodulated are supplied.

However, using the prior art, a tuning accuracy of only about 150 kHz can be achieved in this application. In addition, such known AFT circuits cannot be completely integrated. Two connections on an integrated circuit are required, for example, for an external tuned circuit.

A further known solution comprises the frequency to be tuned being counted digitally and being appropri-



ately readjusted. The circuit complexity required for this purpose and a corresponding chip area in an integrated circuit are, however, high. The current consumption of such a digital AFT circuit is likewise comparatively high.

Invention

The invention is based on the object of specifying a method for automatic, high-precision fine frequency tuning with little circuit complexity and low current consumption in integrated circuits.

In principle, the method according to the invention consists in that, for the purpose of automatic, high-precision fine frequency tuning, for example to a specific television channel, at least one control variable for the frequency-trimmable analogue circuit is formed and stored for a frequency-trimmable analogue circuit in an integrated circuit as a function of a high-precision reference frequency, the value of which control variable is likewise influenced by a reference circuit section in the integrated circuit, and in that various operating modes are switched on successively for fine tuning.

Advantageous developments of the method according to the invention result from subclaims 2 to 7.

The invention is based on the further object of specifying a circuit for the method according to the invention.

In principle, the circuit according to the invention is provided with an analogue circuit 23, 33 whose frequency can be trimmed by means of a control variable, said analogue_circuit 23, 33 having a supply point for a high-precision reference frequency f_{ch} , having a first, a second and a third changeover switch, having a first T1, a second T2 and a third T3 control amplifier, having a first CL and a second CH comparator, having an adder 21 and having an internal capacitor C_{int} , the following voltages being supplied:

- an output voltage V_1 from the analogue circuit 23 being

supplied to second inputs of the first T1 and of the second T2 control amplifier and of the first CL and of the second CH comparator;

- a reference voltage V_{ref} being supplied to a first input 5 251 of the first control amplifier T1 in a normal mode;
- a combined voltage formed from the reference voltage V_{ref} and a compensation voltage V_{of} being supplied to a first input 252 of the second control amplifier T2 in a calibration mode;
- 10 - a difference voltage formed from the reference voltage V_{ref} and a threshold voltage V_{th} being supplied to a first input 254 of the first comparator CL, and a sum voltage formed from the reference voltage V_{ref} and the threshold voltage V_{th} being supplied to a first input 253 of the 15 second comparator CH in a measurement mode;
- an output signal from the first control amplifier T1 being supplied to a first input N of the third change-over switch in the normal mode;
- an output signal from the second control amplifier T2 20 being supplied to a third input C of the third change-over switch in the calibration mode;
- an output signal from the third changeover switch being supplied to an input of the third T3 control amplifier;
- an output signal from the third T3 control amplifier 25 being supplied to a first input of the adder 21;
- a signal which is derived from the magnitude of the internal capacitor C_{int} and is reformed using a factor k being supplied to a second input of the adder 21;
- an output signal from the adder 21 being supplied to a 30 control input of the analogue circuit 23;
- a wanted signal which is to be processed in the analogue circuit 23 being supplied to a first input N of the first changeover switch in the normal mode;
- an additional signal frequency being supplied to a 35 second input C, M of the first changeover switch in the calibration mode and in the measurement mode;
- the high-precision reference frequency f_{ch} or a frequency derived from it being supplied to a first input C of the second changeover switch in the calibration



mode;

- a signal frequency which is derived from the output signal from the first changeover switch being supplied to a second input N, M of the second changeover switch;
- 5 - an output signal from the second changeover switch being supplied to the analogue circuit 23.

The output signals from the first and the second comparator can then be used, for example, for tuning an oscillator in a television set tuner.

- 10 Advantageous developments of the circuit according to the invention result from subclaims 9 to 11.

The method is suitable for integrated circuits and enables automatic fine frequency tuning using frequency-trimmable analogue circuits, for example FM
15 demodulators or frequency generators. The AFT circuit according to the invention contains an automatically operating control loop having a control variable formed therein. This control variable is additionally influenced by a reference component, for example a reference capacitance, on the substrate of the integrated circuit,
20 manufacturing tolerances during the production of the integrated circuit manifesting themselves in a respective value of this reference component. A reference frequency having the required accuracy is supplied as reference to
25 the AFT circuit in a calibration mode. Three operating modes are provided in this case in order to be able to carry out the AFT function:

- a) Normal mode,
- b) Calibration mode,
- 30 c) Measurement mode.

In the calibration mode, the frequency of the analogue circuit is initially trimmed. This trimming is then maintained until the calibration mode is switched on again. After this, in the measurement mode, a present
35 value of a frequency which is to be finely tuned is determined with the aid of the previously trimmed analogue circuit. Appropriate fine tuning is then carried out depending on whether this determined value is less than, equal to or greater than a required value for the



frequency which is to be finely tuned. Subsequently, the normal mode is switched on, in which the analogue circuit is used for its actual task.

The trimming and the fine tuning are advantageously carried out in a current-controlled manner, using an energy storage capacitor and transductance amplifiers.

Drawings

Exemplary embodiments of the invention are described with reference to the drawings, in which:

- 10 Fig. 1 shows a known AFT circuit;
Fig. 2 shows an AFT circuit according to the invention;
Fig. 3 shows the application of the AFT circuit according to the invention in an enlarged integrated circuit for television sets.

15 Exemplary embodiments

First of all, three operating modes of the AFT circuit for trimming an FM demodulator and for the generation of signals for fine tuning are described in the following text. If, for example, a television set is switched on or the reception channel in this television set is changed, the calibration mode is initially briefly selected (this selection and the selection of the other operating modes is advantageously carried out automatically). In this case, the FM demodulator is finely trimmed with the aid of a precise reference frequency, for example the colour sub-carrier frequency, by means of a control variable, and a measure for this control variable is stored.

After this, the measurement mode is briefly selected. Using the output voltage from the previously trimmed FM demodulator, two comparators detect whether the IF frequency and thus the frequency of the tuner oscillator must be maintained, reduced or increased.

Once the tuner oscillator has been trimmed, the normal mode is switched on.

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1. Normal mode

In Fig. 2, switch position "N" corresponds to this operating mode. The entire circuit operates as an FM demodulator with automatic trimming of the mid-frequency.

5 The IF output audio signal 20 of a 4.5 MHz band-pass filter is used, for example, as the signal source. This output signal is converted to 920 kHz in a mixer 221, to which the frequency $f_{ch} = 3.579545$ MHz of a colour sub-carrier oscillator is likewise supplied, is band-pass-
10 filtered in a filter 222 having the quality factor $Q = 3$, and then forms the input signal f_s which is demodulated in an FM demodulator 23.

The FM demodulator 23 contains an internal, current-controlled oscillator (not illustrated) with a free-
15 running frequency

$$f_1 = k_d \cdot I_{con} / C_{int}, \quad (1)$$

k_d being a first constant, I_{con} being the control current for the FM demodulator 23, and

$$C_{int} = C_{nom} \pm \Delta C \quad (2)$$

20 being an internal capacitor (not illustrated) which is integrated on the circuit and has a nominal value of C_{nom} and an absolute manufacturing tolerance of $\pm \Delta C$.

The free-running frequency of the oscillator and thus the tuning of the FM demodulator can be synchronized to the
25 frequency of the input signal f_s if

$$|f_s - f_1| \leq \Delta f_1, \quad (3)$$

where $\Delta f_1 =$ synchronization range.

If the input signal f_s is frequency-modulated, then

$$30 \quad f_s = f_c + \Delta f_s(t), \quad (4)$$

f_c being the mid-frequency and Δf_s being the shift. Frequency f'_1 of the synchronized oscillator is given by $f'_1 = f_s$, as long as $\Delta f_s \leq \Delta f_1$. The low-pass-filtered output voltage V_1 then represents the demodulated audio
35 signal,

$$V_1 = -k_f \cdot (f_1 - f_c) + V_{ref}, \quad (5)$$

k_f being the gradient of the demodulator characteristic and V_{ref} being a reference voltage.

To simplify understanding, it is assumed



initially that no IF output audio signal 20 is present in the AFT circuit in Fig. 2. A first transductance amplifier T_1 , an energy-storage capacitor C_{stor} , a third transductance amplifier T_3 and the FM demodulator 23 form a trimming loop. The reference voltage V_{ref} is supplied to the input 251 of the first transductance amplifier. If a frequency difference in the range

$$0 \leq |f_1 - f_c| \leq \Delta f_1 \quad (6)$$

occurs between the mid-frequency f_c and the free-running frequency f_1 , the automatic trimming loop corrects the free-running frequency f_1 to $f_1 = f_c$ in the following manner:

If the output voltage V_1 changes in accordance with equation (5), the first transductance amplifier T_1 (which has a transductance k_1) charges an external energy-storage capacitor 26 (C_{stor}) at a maximum output current of, for example, $\pm 0.5 \mu A$ to a storage voltage of

$$V_c = (V_1 - V_{ref}) * k_1 / (p * C_{stor}) \quad (7)$$

p being the complex frequency. The third transductance amplifier T_3 (which has a transductance k_3) produces, in accordance with storage voltage V_c , a correction current

$$I_{cor} = k_3 * V_c, \quad (8)$$

which is added in an adder 21 to a control current I_{con0} , which takes account, for example, of manufacturing tolerances, and then forms the demodulator control current

$$I_{con} = k * I_{con0} + I_{cor}. \quad (9)$$

The control current I_{con0} can also be used for trimming the filter 222. In this case, a first multiplier 241 and a second multiplier 242 multiply the control current I_{con0} in the normal mode by a factor $k = 1$.

The corrected free-running frequency is obtained by appropriate reforming from the equations (1), (2), (5) and (7) to (9) as follows:

$$f_{1c} = k_d / (C_{nom} \pm \Delta C) * [I_{con0} - k_3 * k_1 * k_f * (f_1 - f_c) / (p * C_{stor})]. \quad (10)$$

Typical values are $k_d = 1$, $f_s = 920 \text{ kHz}$, $C_{int} = C_{nom} = 10 \text{ pF}$, $I_{con} = I_{con0}$, $f_1 = f_s$, $V_1 = V_{ref}$ and $C_{stor} = 1 \text{ nF}$.

The cut-off frequency in the trimming loop is



20 Hz in order to avoid audio signal components producing distortion in the correction current I_{cor} .

The correction current I_{cor} can advantageously also be used to tune the filter 222, for example by using a second adder or by supplying the demodulator control current I_{con} directly to this filter (not illustrated).

The signal to noise ratio of the FM demodulator 23 is roughly inversely proportional to the synchronization range Δf_1 . For this reason, Δf_1 should be made as small as possible.

If the automatic trimming loop is not used and, instead of being the correction current I_{cor} , I_{cor0} is a constant current irrespective of the absolute value of the internal capacitor C_{int} , it can be seen from equations (1) and (2) that the free-running frequency f_1 depends on the absolute tolerance ΔC . This tolerance has a magnitude of about $\pm 15\%$. Under these conditions and in order still to ensure good synchronization, Δf_1 should not fall below a minimum value of

$$\Delta f_1 = \Delta f_s + (\Delta C / C_{nom}) * f_c. \quad (11)$$

An advantageous value for Δf_1 results using the corresponding numerical values

$$\Delta f_1 = 70 \text{ kHz} + 0.15 * 920 \text{ kHz} = 208 \text{ kHz}.$$

It is now assumed that the demodulator control current I_{con} is proportional to the internal capacitor C_{int} . In consequence, the second term on the right-hand side of equation (11) changes and the synchronization range Δf_1 becomes

$$\Delta f_1 \leq \Delta f_s + df_1 * f_c, \quad (11a)$$

df_1 representing a frequency offset which is caused by the different behaviour between the FM demodulator 23 and the components which produce the demodulator control current I_{con} , relating to thermal drift and parasitic effects. The maximum value of df_1 is about 5 %. The numerical values mentioned above then change to

$$\Delta f_1 = 70 \text{ kHz} + 0.05 * 920 \text{ kHz} = 116 \text{ kHz}.$$

If the automatic trimming loop is now additionally operating, df_1 loses its significance and tends to zero in equation (11a), the numerical value of Δf_1



changing to $\Delta f_1 = 70$ kHz.

2. Calibration mode

The AFT circuit can be calibrated. In Fig. 2, switch position "C" corresponds to this operating mode. A precise, known frequency is used for this purpose. For example, the crystal-stabilized frequency $f_{ch} = 3.579545$ MHz of a colour oscillator is reduced in a first divider 22 to one fifth. This results in the calibration frequency $f_{cal} = 715.909$ kHz. The demodulator control current I_{con} is reduced, for example, in the first multiplier 241 and the second multiplier 242 by the factor $k = 0.78$. In consequence, the calibrated free-running frequency becomes

$$f_{1cal} = 0.78 * f_1 = 717 \text{ kHz.} \quad (12)$$

Because of the frequency offset

$$\Delta F = f_{mea} - f_{cal} \quad (13)$$

between the calibration frequency f_{cal} (715.909 kHz) and an AFT measurement frequency f_{mea} , a compensation voltage $V_{ref} - V_{of}$ is supplied to the input 252 of a second transductance amplifier T2. In accordance with equation (5), V_{of} becomes

$$V_{of} = \Delta F * k_f. \quad (14)$$

The second transductance amplifier T2 supplies a maximum output current of, for example, $\pm 300 \mu A$ if the transductance is k_2 and charges the energy-storage capacitor 26 (C_{stor}) such that the corrected, calibrated free-running frequency is given by:

$$f'_{1cal} = f_{1cal} + V_{of} * k_f. \quad (15)$$

Then, in a similar manner to equation (10),

$$f'_{1cal} = k_d / (C_{nom} \pm \Delta C) * [I_{con0} - k_3 * k_2 * [k_f * (f_{1cal} - f_{cal}) - V_{of}] / (p * C_{stor})]. \quad (16)$$

The theoretical frequency trimming error resulting from the different behaviour between the FM demodulator 23 and the components which produce the demodulator control current I_{con} becomes

$$f_{1cal} + \Delta F - f_{cal} = df_{1cal} * f_{cal} \quad (17)$$

$= 0.05 * 717 \text{ kHz} = 35.9 \text{ kHz}$ and is advantageously eliminated, as in the normal mode, by automatic tuning. An



intermediate frequency $f_{IF} = 45.75$ MHz, which is reduced, for example, by the factor $n = 16$ in a downstream second divider 223, is supplied to an intermediate frequency input 24. This reduced frequency is mixed in the mixer 221 with the colour oscillator frequency f_{ch} , as a result of which a measurement frequency

$$f_{mea} = f_{IF}/16 - f_{ch} \quad (18)$$

is present at the input of the FM demodulator 23. If, for example, $f_{mea} = 45.75 \text{ MHz}/16 - 3.579545 \text{ MHz} = 720.17 \text{ kHz}$ and $k_f = 20 \text{ mV/kHz}$, then $\Delta F = 4.261 \text{ kHz}$ and $V_{of} = 85 \text{ mV}$.

The cut-off frequency of the trimming loop is higher than in the normal mode by the factor $k_2/k_1 = 300 \mu\text{A}/0.5 \mu\text{A} = 600$ times, and thus becomes approximately 10 kHz. This allows an advantageously short calibration time of $t_{cal} < 10/f_{1cal} = 1 \text{ ms}$.

3. Measurement mode

Before the AFT circuit can operate in the measurement mode, it must be calibrated as described in 2.).

In Fig. 2, the switch position "M" corresponds to the "measurement mode" operating mode. The signal source in the measurement mode is either an intermediate frequency VCO (voltage controlled oscillator) or an amplified and limited intermediate frequency signal at the intermediate frequency input 24. The frequency f_{IF} of this intermediate frequency signal is reduced in the second divider 223 by the division factor n , for example $n = 16$, and is mixed in the mixer 221 with the colour oscillator frequency f_{ch} , as a result of which, as in the calibration mode, a measurement frequency of $f_{mea} = f_{IF}/16 - f_{ch}$ is present at the input of the FM demodulator 23.

If $f_{IF} = 45.75 \text{ MHz}$, $n = 16$ and $f_{ch} = 3.579545 \text{ MHz}$, then $f_{mea} = 720.17 \text{ kHz}$ again.

The control current I_{con0} and thus the free-running frequency f_{1mea} of the internal oscillator of the FM demodulator 23 are multiplied by $k = 0.78$, as in the calibration mode.

Because the automatic trimming loop is open in the



measurement mode, the storage voltage V_c remains constant and $f_{1\text{mea}}$ is equal to $f'_{1\text{cal}}$, for example as in equation (16). The compensation voltage V_{of} mentioned in section 2.) was selected such that, in the measurement mode, the nominal measurement frequency f_{meanom} from the signal derived from the intermediate frequency f_{IF} is equal to $f_{1\text{cal}}$. In addition, the output voltage V_1 is supplied to a first comparator CL and a second comparator CH. The first comparator additionally receives at its input 254 the voltage $V_{\text{ref}} - V_{\text{th}}$, and the second comparator receives the voltage $V_{\text{ref}} + V_{\text{th}}$ at its input 253, V_{th} being a threshold voltage. The two comparators CL and CH, with the threshold voltage V_{th} detect whether f_{mea} is at the correct value ($f_{\text{mea}} = f_{\text{meanom}}$) or is too high or too low.

If, as in the calibration mode, the gradient of the demodulator characteristic is $k_f = 20 \text{ mV/kHz}$, then $V_{\text{th}} = k_f \cdot 1\text{kHz} = 20 \text{ mV}$ is advantageously chosen as the threshold voltage.

This results in a level change in the output signals from the comparators if $|f_{\text{meanom}} - f_{\text{mea}}| \geq 1 \text{ kHz}$. The tuning error of the intermediate frequency resulting from this is $\Delta f_{\text{IF}} = n \cdot V_{\text{th}} / k_f$, which gives $\Delta f_{\text{IF}} = 16 \text{ kHz}$ in the example mentioned above.

If the FM demodulator 23 is designed for a synchronization range of magnitude Δf_1 , the AFT circuit can compensate for an IF tuning error up to $n \cdot \Delta f_1$. For example, if $n = 16$, $\Delta f_1 = 100 \text{ kHz}$ is an advantageous value.

In Fig. 2, the value of the reference voltage V_{ref} is advantageously half that of the operating voltage V_{cc} of the integrated circuit.

Frequencies from another crystal-stabilized source can also be used instead of the frequency f_{ch} supplied to the mixer 221 and to the first divider 22, which frequencies are supplied to the mixer and replace the output signal of the first divider.

Other input frequencies at the inputs 20 and 24 result in correspondingly changed frequencies at the output from the filter 222 and from the first divider 22,



a correspondingly changed value for the factor k and a changed division factor for the first divider 22. For example, the following values result for a television standard using the CCIR standard B/G:

- 5 Frequency at the input 223 of the mixer 221: 5.875 MHz
- $f_{IF} = 38.9 \text{ MHz}$
- $f_{\text{meanom}} = 38.9 \text{ MHz}/16 - 2.9375 \text{ MHz} = 560 \text{ kHz}$
- $f_{\text{cal}} = 500 \text{ kHz}$
- $\Delta F = 6 \text{ kHz}$
- 10 $V_{\text{of}} = 6 \text{ kHz} \cdot K_f = 120 \text{ mV}$
- k in the normal mode : 1.00
- k otherwise : 1.01

Fig. 3 shows a detail of an integrated circuit in which audio demodulation is represented (only the normal mode) with the aid of the AFT circuit according to the invention.

A converter 38 receives an IF signal at its input and supplies the filtered output signal, for example a 4.5/5.5/6.0 MHz or 6.5 MHz audio IF signal, to a first input of a first mixer 321. This mixer may correspond to the mixer 221 in Fig. 2. At its second input, the first mixer 321 receives the output signal from a VCO circuit 372, which provides a suitable mixing frequency. This output signal is passed on via a frequency divider 373 to a first input of a second mixer 374 which receives, at its second input, a signal from a reference oscillator 371. The output signal from the second mixer 374 is supplied via a loop filter 375 to the VCO circuit 372, as a result of which a control loop is closed. This control loop carries out the function of the automatic trimming loop described in Fig. 2. The output signal for the first mixer 321 passes to a filter 322, whose function corresponds to that of the filter 222 in Fig. 2. The filtered signal is then supplied via a limiter 391 to an FM demodulator 33. This FM demodulator corresponds to the FM demodulator 23 in Fig. 2. The output signals from the FM demodulator 33 are subsequently band-limited in a first low-pass filter 393 and in a second low-pass filter 392. An audio signal can be picked off at the output from the



first low-pass filter, and a control voltage, which is supplied for fine tuning to the FM demodulator 33 and to the filter 322, can be picked off at the output from the second low-pass filter. The cut-off frequency in the
5 first low-pass filter is, for example, 100 kHz, and that in the second low-pass filter is, for example, 20 Hz. A capacitor which belongs to the second low-pass filter 392 can also be externally connectable to the integrated circuit.

10 In the case of stereo or dual-tone audio signals, for example in the case of the dual-tone carrier method, the filter 322, the limiter 391, the FM demodulator 33, the first low-pass filter 393 and the second low-pass filter 392 are present in a correspondingly duplicated
15 manner.

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Patent Claims

1. Method for automatic, high-precision fine frequency tuning, characterized in that at least one control variable (I_{con}) is formed and stored for trimming of a frequency-trimmable analogue circuit (23, 33) in an integrated circuit as a function of a high-precision reference frequency (f_{ch}), the value of which control variable (I_{con}) is likewise influenced by a reference circuit section (C_{int}) in the integrated circuit, and in that various operating modes (C, M, N) are switched on successively for fine tuning.
2. Method according to Claim 1, characterized in that three operating modes (C, M, N) are provided.
3. Method according to Claim 2, characterized in that the operating modes calibration mode (C), measurement mode (M) and normal mode (N) are provided, the reference frequency (f_{ch}) or a frequency (f_{cal}) derived from the reference frequency being used in the calibration mode for trimming the analogue circuit (23, 33) and, while maintaining this trimming, the fine tuning in the measurement mode being carried out using the previously trimmed analogue circuit, and the analogue circuit being used in accordance with its known object in the normal mode.
4. Method according to one or more of Claims 1 to 3, characterized in that the calibration mode (C), measurement mode (M) and normal mode (N) are switched on successively at least once during initial tuning to the frequency which is to be finely tuned or during tuning to a different frequency which is to be finely tuned.
5. Method according to one or more of Claims 1 to 4, characterized in that the control variables are control currents (I_{con0} , I_{cor} , I_{con}).
6. Method according to one or more of Claims 1 to 5, characterized in that the reference circuit section is a capacitor (C_{int}).
7. Method according to one or more of Claims 1 to 6, characterized in that the frequency-trimmable analogue circuit is an FM demodulator (23, 33) having an internal



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current-controlled oscillator or a current-controlled frequency generator.

8. Circuit for a method according to one or more of Claims 1 to 7 provided with an analogue circuit (23, 33) whose frequency can be trimmed by means of a control variable (I_{con}), said analogue circuit (23, 33) having a supply point for a high-precision reference frequency (f_{ch}), having a first, a second and a third changeover switch, having a first (T1), a second (T2) and a third (T3) control amplifier, having a first (CL) and a second (CH) comparator, having an adder (21) and having an internal capacitor (C_{int}), the following voltages being supplied:
- an output voltage (V_1) from the analogue circuit (23) being supplied to second inputs of the first (T1) and of the second (T2) control amplifier and of the first (CL) and of the second (CH) comparator;
 - a reference voltage (V_{ref}) being supplied to a first input (251) of the first control amplifier (T1) in a normal mode;
 - a combined voltage formed from the reference voltage (V_{ref}) and a compensation voltage (V_{of}) being supplied to a first input (252) of the second control amplifier (T2) in a calibration mode;
 - a difference voltage formed from the reference voltage (V_{ref}) and a threshold voltage (V_{th}) being supplied to a first input (254) of the first comparator (CL), and a sum voltage formed from the reference voltage (V_{ref}) and the threshold voltage (V_{th}) being supplied to a first input (253) of the second comparator (CH) in a measurement mode;
 - an output signal from the first control amplifier (T1) being supplied to a first input (N) of the third changeover switch in the normal mode;
 - an output signal from the second control amplifier (T2) being supplied to a third input (C) of the third changeover switch in the calibration mode;
 - an output signal from the third changeover switch being supplied to an input of the third (T3) control amplifier;



- an output signal from the third (T3) control amplifier being supplied to a first input of the adder (21);
 - a signal which is derived from the magnitude of the internal capacitor (C_{int}) and is reformed using a factor (k) being supplied to a second input of the adder (21);
 - an output signal from the adder (21) being supplied to a control input of the analogue circuit (23);
 - a wanted signal which is to be processed in the analogue circuit (23) being supplied to a first input (N) of the first changeover switch in the normal mode;
 - an additional signal frequency being supplied to a second input (C, M) of the first changeover switch in the calibration mode and in the measurement mode;
 - the reference frequency (f_{ch}) or a frequency (f_{cal}) derived from it being supplied to a first input (C) of the second changeover switch in the calibration mode;
 - a signal frequency (f_g) which is derived from the output signal from the first changeover switch being supplied to a second input (N, M) of the second changeover switch;
 - an output signal from the second changeover switch being supplied to the analogue circuit (23).
9. Circuit according to Claim 8, characterized in that the first, the second and the third control amplifiers are transductance amplifiers, and in that the output signals from these transductance amplifiers and the signals at the first input and the second input of the adder (21) and the output signal from the adder are currents.
10. Circuit according to Claim 8 or 9, characterized in that the combined voltage is a difference voltage.
11. Circuit according to one or more of Claims 8 to 10, characterized in that the signal which is reformed using a factor (k) is a signal which is multiplied by the factor (k) in a multiplier (241).



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