Mean and RMS value converters

Mean and RMS value converters errors calculations

Exercise program:

1. Wire circuit with mean value converter, which properly calibrated will allow RMS value measurement (e.g. sinusoidal waveform).
2. Calibrate circuit for sinusoidal waveform (e.g. for U=5V). Reference meter is a digital voltmeter which measure RMS value.
3. Do measurements by changes sinusoidal input voltage from 0.2 V to 1.0 V of every 0.2 V and from 1 V to *U*MAX of waveform generator changing by 1 V.
4. Analogous measurements performed for triangle and square waveform.
5. Calculate processing errors and present it in graphical form.
6. Wire circuit with RMS value converter described by implicit function.

Calibration and measurements do by the same way as it is shown above.

Mean value circuit



RMS value circuit



A. Mean value converter

For this class of converters the converter shown in Fig. 1 has a very good parameters.



Fig. 1. Mean value converter

The converter due to its good metrological parameters is also called a linear charger. In the properly built converter the processing error caused by amplifier parameters is greater than the error caused by the diodes parameters. Converter principle of operation illustrate the voltage and current curves shown in Fig. 2.

Voltage *u*1 behind diode *D*1 is a inversion of positive half-wave voltage *e*1. Diode *D*1 junction voltage drop doesn’t affect the processing signal *u*1 because the amplifier *W*1 forces current, which flows through the diode *D*1, resistor R to the inverting input of amplifier *W*1. This current is equal to the voltage source *e*1 current which flows through a resistor R to the inverting input of the amplifier. The input voltage *e*1 and received voltage *u*1 are summed at the non-inverting amplifier *W*2 input, and its output when the capacitor C is not connected, you get a rectified voltage *eo*. Connection of capacitor C, with sufficiently large values of capacitance causes averaging *eo* (no pulse), so that the amplifier *W*2 output the voltage  is obtained.



Fig. 2. Voltages and currents waveforms of the mean value converter

B. RMS value converters

Analog RMS converters are divided into two classes. One comprises non-feedback RMS converters and because of the function which describes them they are referred to as converters described by the explicit function. The other class includes feedback converters described by the implicit function.

**RMS converter described by explicit function**

The function circuit of an non-feedback RMS converter described by the explicit function is shown in Fig. 3.



Fig. 3. The functional circuit of a RMS converter described by the explicit function

The converter consists of a squaring circuit, integrating circuit and square rooter. Metrological parameters are characterized by

* a squaring circuit described by the equation

, (1)

* an integrating circuit described by the relation

, (2)

and a square rooter performing the operation

, (3)

where:

*e* - the processed input signal;

 - signals at the outputs of respectively the squaring circuit and the integrating circuit;

 - the signal at the square rooter circuit output, whose average value is proportional to the RMS value of input signal *u*;

 - the processing constants of respectively the squaring, integrating and rooter circuits;

 - processing constant errors of the circuits (multiplicative errors);

 - input offset voltages of the circuits (additive errors).

The processing constants, processing errors of the circuits and input offset voltages of above circuits are presented in section 4.7. Multiplicative errors causes processing constant value change - changing the gradient of the processing characteristics. Additive errors add up to the input signal - causing a parallel shift of processing characteristics.

Relations (1) and (2) were substituted into expression (3) and the following equation describing the processing by the RMS converter described by the explicit function was obtained

. (4)

Assuming that multiplicative and additive errors are time-independent and that *e* is a AC signal, after simplifications was obtained

, (5)

where  stands for the convertor error given by the relation

. (6)

Assuming that processing constants , one gets

, (7)

. (8)

The last relation indicates that the processing error for low RMS values depends on the input offset voltages, offset voltages of integrating circuit and squaring circuit (*Y*, *Z*).

**RMS CONVERTER DESCRIBED BY IMPLICIT FUNCTION**

The function circuit of a feedback RMS converter described by the implicit function is shown in Fig. 4.



Fig. 4. The function circuit of a RMS converter described by the implicit function.

The converter consists of an absolute value circuit, a multiplier-divider and an integrating circuit.

General principle of converter operation is as following. The multiplier-divider output voltage described by the equation

, (9)

which after integrating, one gets

 (10)

And is described by implicit function (unknown appears on both sides of the equation). Since the voltage *E* is a fixed value, the converter output voltage is equal

. (11)

Below the metrological analysis of converter is presented.

Metological parameters are characterized by relations:

* an absolute value circuit described by the equation

, (12)

* a multiplier-divider performing mathematical operations in the first quadrant of a rectangular coordinate system

, (13)

* an integrating circuit described by the equation

, (14)

where:

 - the processed input signal;

 - signals at the outputs of respectively the absolute value circuit and the multiplier/divider;

 - the signal at the output of the rooter, whose average value is proportional to the RMS value of input signal *u*;

 - the processing constants of respectively the absolute value circuit, the integrating circuit and the multiplier/divider;

 - circuit processing constant errors (multiplicative errors);

 - input circuit offset voltages (additive errors).

Having substituted relations (12) and (13) into expression (14) and after simple transformation the following was obtained

(15)

After transformations, assuming that the voltage e is a sine wave and processing constants , the following is obtained

, (16)

where processing error  is given by

. (17)

The analyzed converter for signals with small values processing the additive errors have a lesser affect on the processing error, rather than in the converter described by explicit function because additive errors occurring in the counters have the same exponent as the output voltage *E* in the denominators.

**Example**

Determine processing error of RMS converters described by explicit and implicit functions for sinusoidal signals with values ranging from 0.01 V to 10 V.

Processing constant errors and output offset voltages are equal





Equations (4.118), (4.127) for data presented in this example gets

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For large values of *E*=10 V the processing errors depends on multiplicative processing errors

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However, for small values of *E* at the processing errors affects only the input offset voltage (an additive error). Converters errors curves is shown in Fig. 5.

Carried out a comparative metrological analysis indicates that, for signals with smaller values of these parameters incomparably better are a RMS converters described by implicit functions, because mathematical operations performed inside the converters are done on the much larger values of the signals.

Previously was built converters described by explicit function. For large voltages have processing errors at 0.5% or even 0.05%. Significant developments in technology enabled the realization of mathematical operations using logarithmic and exponential functions. In these circuits is a natural process carried out in accordance with the description of the implicit function.



Fig. 5. Errors of RMS converters described by explicit and implicit function   
determined for *δk* = ±0.1 % and *X* = ± 0.5 mV

Dynamical properties of RMS converters : errors for low and high frequencies, slew rates is presented in [17].