Accuracy increase of self-compensator

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Abstract. In this paper, the authors consider a self-compensation system and a method for increasing its accuracy, without compromising the condition of the information theory of measuring devices. The result can be achieved using the pulse control of the tracking system in the dead zone (the zone of the proportional section of the amplifier’s characteristic). Pulse control allows one to increase the control power, but the input signal of the amplifier is infinitesimal. To do this, the authors use the conversion scheme for the input quantity. It is also possible to reduce the dead band, but the system becomes unstable. The amount of information received from the instrument, correcting circuits complicates the system, and, reducing the feedback coefficient dramatically, reduces the speed. Thanks to this, without compromising the measurement condition, the authors increase the accuracy of the self-compensation system. The implementation technique allows increasing the power of the input signal by many orders of magnitude.

1. Introduction

In all areas of human activities, people use different measuring systems; they are ubiquitous and can be found in everyday life, in industry, in scientific activity, etc. Many technical installations, automated systems require constant measurement control. The problem of increasing accuracy has always been and will be relevant because the question of improving the accuracy of measuring systems enhances competitiveness. For example, let us consider the oil industry with the production and transportation of petroleum products, which at each stage requires accurate quality control and accounting for the amount of oil. The accuracy of measuring systems directly depends on the profit of the enterprise. How to improve accuracy, there are many different ways [1, 2, 3]. One of them is the use of follow systems [4, 5].

Follow systems solve the problem of controlling various systems, such as radar stations, information-measuring systems, etc. The principle of operation differs from software control systems since it is equipped with a device for monitoring changes in external influences. In measurement theory it has long been a postulate to consider without fail the accuracy, sensitivity, speed and power consumption. And all four characteristics are not only important - it is mandatory to jointly consider them (additive). Information theory of measuring devices says that:

\[ \gamma^2 \cdot \eta_p \cdot P_t = 3.5 \cdot 10^{-20} \, [J] \]  

\( \gamma \) - relative measurement error, \( \eta_p \) - power efficiency, \( P \) - capability, \( P_t \) – energy consumed by the device in exchange for information.
2. The self-compensator
The self-compensator in the simplest image has the structure shown in Fig. 1. The circuit consists of the following elements:
- the comparison element (CE);
- the error amplifier (EA);
- the executive power element (EPE);
- the compensating element (CE).

From the point of view of information theory, information efficiency is \( \eta_q \approx 16\% \), while a direct measurement system has only \( \eta_q \approx 5.8\% \). The advantage is obvious, and engineers know this well, applying it in response systems. It is used in self-recording instruments [6].

If one is very picky from the view point of obtaining high accuracy, then according to the structural scheme of the self-compensator, one can see that the follow-up system has a dead band and it is always working. With small input signals, its transmission characteristic has the character of proportional dependence, and only somewhere at the level of 0.2% of the dynamic range it has saturation, and the engine begins to work out value \( x \). It is possible to reduce the deadband, but the system becomes unstable. The amount of information (\( q \)) received from device (2) [7], correcting circuits, complicates the system, and a decrease in the feedback coefficient sharply reduces the speed.

\[
q = 9.3 + \frac{1}{2} \log Pt
\]  

(2)

3. Method of increasing accuracy
In this paper, let us propose, without prejudice to condition (1), improving the accuracy of the self-compensation system.

Any expert knows that the greatest error in measuring systems is inherent in small input signals - at the beginning of the scale, and the self-compensation system works in the normal mode always at the beginning of its dynamic range, i.e. under additive and multiplicative errors. At it is seen from Fig. 1, this is the second-order astatic system and its dynamic error is 0 when tracking. But in the mode of small signals, it is in the normal operation of the self-compensation system that the engine can not track the signal due to the "proportional" section of the amplifier’s characteristic. This zone of data system insensitivity is usually (0.2-0.5)% of dynamic range.

The essence of the authors’ proposal is as follows: in the dead zone (the zone of the proportional part of the characteristic of the amplifier), one applies the impulse control of the servo system. Pulse control allows one to increase the power of control, according to theoretical studies, \( 10^{14} \) times. This is a fantastic value, but one does not need this. The authors have the difficulty of another plan - an infinitesimal signal at the input of the amplifier. The way out is here. Let us apply the scheme for converting the input quantity, as shown in Fig. 2.

The difference of the solution from all others is the following: a small value of \( x \) is converted by
bridge $M1$ into a small voltage, under which equalizing current $I_e$ flows between bridges, the direction of which is determined by the sign of potential difference $Y_{AB} - Y_{CD}$; this potential difference is amplified by statistical amplifier, $R_p$ to the value in the circuit in Fig. 3 (Conversion of voltage into pulses.).

![Figure 2. Conversion scheme for x value](image)

![Figure 3. Current-versus-voltage characteristic (Vac) of a tunnel diode](image)

![Figure 4. The electrical circuit of the input signal](image)

When the voltage on the tunnel diode increases, then value $M$, at point $E$ in the Vac jumps to $F$ point of the characteristic; the current also changes abruptly on resistor $R_b$ from the value of $N$ to $L$. The signal at the input of amplifier $D$ (Fig. 2) changes abruptly to the saturation level, engine runs $R_k$ to zero level $F_{TD}$, point $M$ (Fig. 3) goes down, the current jumps from point $L$ to point $N$, and so on. Let us get the diode voltage on $R_b$.

In Fig. 5 $T$ - period, $t_U$ - duration of control pulses, $t_{U}/T$ - reliability. The power of the incoming electrical signal is increased by a factor of $T/t_{U}$, by many orders because the jump of points $E$ to point $F$ of the Vac of the diode will be determined by the speed of the follow-up system.
The complexity of the implementation is as follows: in the dead zone it is difficult to create $U_{TD}=U_M$ on the diode's current-voltage characteristic. Here $M2$ comes to the rescue, with resistor $R0$ of which one creates a countercurrent on $Rb$ in such way that, at the required value of $x$ (zero of our scale), the operating point on the current-voltage characteristic of the diode is close to point $M$ [8, 9]. This adjustment of the zero on the device is also a tuning of the sensitivity - it is fitted with resistor $R_k$ and divider $R_b$.

The threshold of energy sensitivity ($C_e$) is equal to [10]:

$$C_e = \gamma^2 \eta_p Pt$$  \hspace{1cm} (3)

It is adjusted with the help of $R_b$ and the corresponding characteristic of the tunnel diode (the duty-characteristic can be widely varied by period $T$) to point 0.

4. Conclusion

For small input signals, the energy threshold of the sensitivity of the devices, determined by relation (2), becomes less than the level of thermodynamic noise, and here such measurements are impossible with any devices. The use of pulse control and the method of its implementation allows one to increase the power of the input signal by many orders, providing condition 2 and ensuring the level of the energy threshold of sensitivity.

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