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A DEVICE FOR AUTOMATIC TUNING OF CONTROL SYSTEMS.(U)
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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

A DEVICE FOR AUTOMATIC TUNING OF CONTROL SYSTEMS

by

B.V. Novoselov and A.A. Kobzev

FOREIGN TECHNOLOGY DIVISION

[illegible] 1982

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82 04 22 077

EDITED TRANSLATION

FTD-ID(RS)T-0066-82 18 March 1982

MICROFICHE NR: FTD-82-C-000324

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English pages: 7

Source: USSR Patent Nr. 297032, 2 March 1971,
pp. 1-4

Country of origin: USSR
Translated by: Victor Mesenzeff
Requester: USAMICOM
Approved for public release; distribution unlimited.

	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*<u>ye</u> initially, after vowels, and after ъ, ь; <u>e</u> elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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A DEVICE FOR AUTOMATIC TUNING OF CONTROL SYSTEMS

B. V. Novoselov and A. A. Kobzev.

This invention is intended for tuning the automatic control and regulation systems.

High-quality tuning is required in the operation of the automatic control systems and, in particular, servomechanisms, which, as a rule, is accomplished by an operator. However, in a whole series of cases (for example, in mass production of systems, when high-qulity tuning is required), it is more expedient to perform an automatic adjustment of the system's parameters.

In addition to the amplifiers, servomotors, and comparison circuits, the unit being proposed contains two squaring devices connected to the output of their comparison circuit, an adder whose inputs are connected to the outputs of both squaring devices, two relay units, and also two units connected to output of the system - one for measuring frequency and another for measuring and registering amplitude, the output of the first one is connected to a servomotor for adjusting the amplification factor via the corresponding comparison circuit and one of the relay units, while the output of the other unit, via its comparison circuit and second relay unit, is connected to the motor for adjusting the rate-feedback transmission coefficient; moreover, the outputs of the adder are connected to the inputs of both amplifiers.

This type of coupling for the units in the device makes it possible to use it for adjusting the amplification factor and the transmission factor of the rate-feedback of the high-order linear systems and nonlinear systems.

The amplitude-frequency characteristic of a closed system is determined by its parameters. Both in a linear system of any order and in a nonlinear system, there is always a resonance frequency and a fully defined amplitude of induced oscillations at this frequency with a certain input action. The resonance frequency and the amplitude of induced oscillations at this frequency can be determined experimentally or analytically. For the servo systems, the values are determined relatively simply by means of an experiment. Basically, the resonance frequency is determined by the amplification factor, while the amplitude of induced oscillations - by the damping factor. Consequently, the adjustment of the amplification factor can be conducted as a function of deviation of the resonance frequency of the system from the standard frequency, while the adjustment of the rate-feedback transmission factor - as a function of deviation of the amplitude of induced oscillations from the standard value of the amplitide of induced oscillations at a resonance frequency, for which it is necessary to control the resonance frequency and the amplitudes of induced oscillations at this frequency.

The following performance evaluation criterion is used to construct the automatic-tuning device:

$$I = [(M_{\text{э}} - M)^2 + (\omega_{\text{э}} - \omega_p)^2]^2,$$

where $M_{\text{э}}$ is the standard amplitude of induced oscillations at a resonance frequency;

M - actual amplitude value of induced oscillations;

$\omega_{\text{э}}$ - standard resonance frequency;

ω_p - actual resonance frequency.

In the case of the minimization of this criterion using the gradient method, the tuning algorithm will be as follows:

for the amplification factor

$$K_{\text{у}} = -\int \{[M_{\text{э}} - M(t)]^2 + [\omega_{\text{э}} - \omega_p(t)]^2\} [\omega_{\text{э}} - \omega_p(t)]\,dt,$$

for the damping factor

$$K_{\text{д}} = -\int \{[M_{\text{э}} - M(t)]^2 + [\omega_{\text{э}} - \omega_p(t)]^2\} [\omega_{\text{э}} - \omega_p(t)]\,dt.$$

To simplify the realization of the systems, this algorithm can be changed without diminishing the quality of tuning:

for the amplification factor

$$K_y = -\int \{[M_э - M(t)]^2 + [\omega_э - \omega_p(t)]^2\} \operatorname{sign} [\omega_э - \omega_p(t)] dt,$$

for the damping factor

$$K_д = -\int \{[M_э - M(t)]^2 + [\omega_э - \omega_p(t)]^2\} \operatorname{sign} [\omega_э - \omega_p(t)] dt.$$

To perform adjustment, it is necessary to supply a test harmonic action with the standard resonance frequency and defined amplitude to the input or the internal circuit. In the case where $\omega_p < \omega_э$, the amplification factor K_y will increase and when $\omega_p > \omega_э$ it will decrease; in this case, its rate of change, in both instances, will be proportional to $[M_э - M(t)]^2 + [\omega_э - \omega_p(t)^2]$. The rate-feedback transmission factor $K_д$ will increase when $M > M_э$, and decrease when $M < M_э$.

Fig. 1 shows a block-diagram of the servo system and the device for an automatic adjustment of its parameters, where X_1 is the input value; X_2 - output value; X - system's error; $A_э \sin \omega_э t$ - test harmonic action; $M_э$ - standard amplitude of induced oscillations at the resonance frequency $\omega_э$ during the test $A_э \sin \omega_э t$.

Fig. 2 shows the amplitude-frequency characteristics of a closed system, where M is the amplitude of oscillations and ω is the frequency of oscillations.

The servo system is presented in the form of a main control loop 1, adjustable amplification factor 2 (K_y), feed back circuit differentiator 3, and adjustable rate-feedback transmission factor ($K_д$). Loop 5 of the automatic tuning of the coefficients K_y and $K_д$ consists of the amplitude measuring and registering unit 6 and the frequency measurement unit 7, whose input is connected to the output of the system. The output of the amplitude measuring and registering unit 6 is connected to the comparison circuit 8, fed to which is the standard amplitude of induced oscillations $M_э$ at the resonance frequency $\omega_э$ and its output is connected to the relay unit 9 and to adder 11 through the squaring device 10. The output of the frequency measuring unit 7, just as the amplitude measuring and registering unit 6, is connected to the comparison circuit 12, fed to which is the standard frequency $\omega_э$, and the output of the comparison circuit 12 is connected to the relay unit 13 and to adder 11 through the squaring device 14. Through amplifier 15 the output of adder 11 is connected to servomotor 16 for adjusting the amplification factor and through amplifier 17 to servomotor 18 for adjusting the rate-feedback transmission factor. Servomotor 16 is also connected to the relay unit 13, while servomotor 18 is connected to the relay unit 9. The output shaft of motor 16 is connected to the adjsutable coefficient K_y (it can be, in particular, a potentiometer) and the output shaft of motor 18 - to the adjustable coefficient $K_д$ (it can be, in particular, a potentiometer).

Fig. 2 shows the amplitude-frequency characteristics of the tuned system 19 and untuned system 20, 21.

The amplification coefficient K_y and the rate-feedback transmission coefficient $K_д$ are tuned as follows. Test harmonic oscillations $A_э \sin \omega_э t$ with the standard frequency (which is equal to the resonance frequency of the system) $\omega_э$ and certain amplitude $A_э$ are fed to the input or the internal circuit of the system. At the output of the tuned system there will appear oscillations with the same resonance frequency $\omega_э$ and defined amplitude $M_э$ (which is different from that of the test action) - curve 19 in Fig. 2. In the untuned system, the amplitude and resonance frequency will be different from the standard $\omega_э$ and $M_э$ - curves 20 and 21 in Fig. 2.

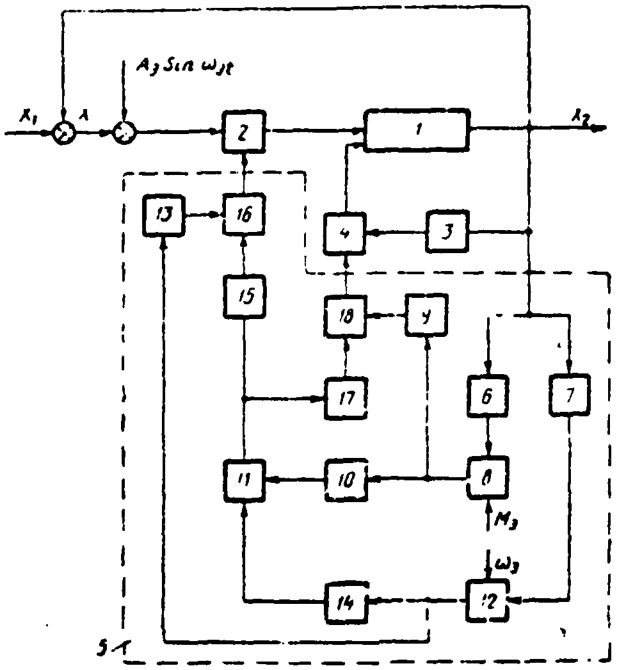
For example, let us assume that the tunable system has a resonance frequency $\omega_{р1}$ and amplitude M_1. The output signal of the system enters the amplitude measuring and registering unit 6 and frequency measuring unit 7, whose output puts out the amplitude and frequency of induced oscillations, respectively. A signal, which is proportional to the amplitude of the oscillations, is sent from the output of the measuring and registering unit 6 to the comparison circuit 8, which also receives a signal, which is proportional to the standard amplitude $M_э$, as a result of which a signal is formed at the output of the comparison circuit 8 which is proportional to the algebraic difference of the standard and actual value of the amplitude $M_э - M_1$. In this case this quantity has a negative value. From the output of the comparison circuit 8 the signal enters the relay unit 9 and then, through the squaring device 10, adder 11. The relay unit 9 operates and activates motor 18 (it switches on the input signal or supplies voltage to the excitation coil); in this case, the rotation direction of motor 18 is determined by the difference sign $M_э - M_1$. In this case, $M_э - M_1 < 0$ and the rate-feedback transmission coefficient $K_д$ increases. A signal, which is proportional to the resonance frequency of induced oasillations ω_{p1}, is sent from the output of the measuring unit 7 to the comparison circuit 12, which also receives a signal which is proportional to the standard value of frequency $\omega_э$, as a result of which a signal, which is proportional to the algebraic difference of the standard and actual values of resonance frequencies $\omega_э - \omega_{p1}$, is formed at the input of the comparison circuit 12.

From the output of the comparison circuit 12 the signal proceeds to the relay unit 13 and, via the squaring device 14, to adder 11. The relay unit 13 operates and turns on motor 16 (it switches on the input signal or supplies voltage to the excitation coil); the rotation direction of motor 16 is determined by the difference sign $\omega_э - \omega_{p1}$. In this case, $\omega_э - \omega_{p1} > 0$ and K_y increases. The speeds of servomotors 16 and 18 are determined by the magnitude of the output signal from adder 11, which is proportional to $(M_э - M)^2 + (\omega_э - \omega_{p1})^2$, and which is fed to motor 16 through amplifier 15 and to motor 18 through amplifier 17. Amplifiers 15 and 17 serve to amplify the output signal from adder 11 with respect to power.

Then the value of $M_э - M_1 = 0$, which is determined by the sensitivity of the system, the relay unit 9 will shut off motor 18, despite the fact that the controlling signal from adder 11 may not equal zero, since, at this moment, $\omega_э - \omega_{p1}$ may not equal zero. The tuning process for the rate-feedback transmission coefficient $K_д$ is finished. When the value of $\omega_э - \omega_p = 0$, which is determined by the sensitivity of the system, the relay unit 13 will shut off motor 16, despite the fact that the controlling signal from adder 11 may equal zero, since, at this moment, $M_э - M_1$ may not equal zero. The tuning process for the amplification factor K_y is finished.

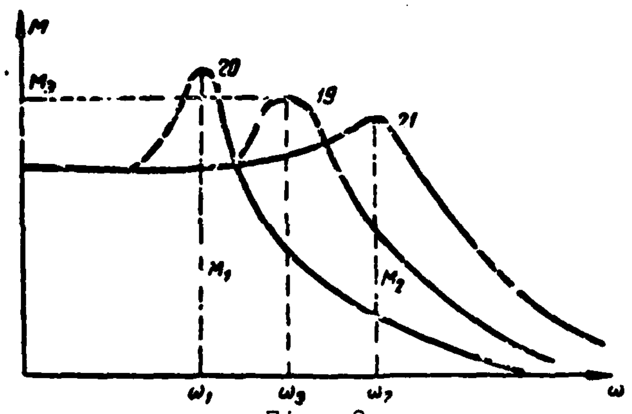
Patent Claims

The device for an automatic tuning of the control systems, which contains two amplifiers connected to the servomotors and the comparison circuits, is **distinguished** by the fact that in order to broaden its functional capabilities, it has been provided with two squaring devices connected to the output of its comparison circuit, an adder whose inputs are connected to the outputs of both squaring devices, two relay units, and also two units connected to the output of the system - one for measuring frequency and one for measuring and registering amplitude. The output of the first one is connected via the corresponding comparison circuit and one of the relay units to the servomotor for adjusting the amplification factor and the output of the second one is connected via its comparison circuit and the second relay unit to the servomotor for adjusting the rate-feedback transmission factor, while the outputs of the adder are connected to the inputs of both amplifiers.



A3 Sin ω3t
X1
X
X2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
M3
ω3

Fig. 1



M
M3
20
19
21
M1
M2
ω1
ω3
ω2
ω

Fig. 2

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