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Control of Activators of Mechatronic Devices by Real Time Information Transfer

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Introduction

Numerical control device's usage is problematic by complicated information transfers between control object and control device. Because of this reason it is normal to have a simple feedback device and information transferring modes problems. The way analyzed at work – simple device forms impulse, which duration τ is feedback function and in real time transferred to the microcontroller where it is changed to numerical code. Model application limits, centre of oscillation, effect of stability on effectiveness, increase of effectiveness limit, measurement errors are defined. Promoters control algorithm and promoters control modeling results that prove theoretical conclusions are presented.

Problem and Calculating Method

Numerical control devices, compared to analogical, have many advantages. Despite that their usage is complicated by intricate information transfers between controls object and control device. This is especially seen when to realize control algorithm microcontrollers are used. Creating numerical feedback signal using traditional models (numerical devices or analogical and analogical–numerical converter) increasing systems coverage and cost. So simple feedback signal's sensor and information transfer channel problem is urgent. One of this problem's solution methods in this work is provided. It is based on the idea of part of feedback signal formatting functions, which are usually performed by the sensor and signal processing and transforming controller, moving of microcontroller, that's why sensor and signal transferring channel becomes simpler. The idea is realized by formation impulse, which term τ fits feedback signal amplitude's value, and this impulse's term in real-time is transferred to microcontroller, which provides to this signal numerical form which is needed for future transformations.

Given feedback signal formatting method can be used only when a signal is a periodical one argument's time function.

$$y = f(t),\ \ f(t) = f(t+T), \tag{1}$$

here y – measured variable, t – argument (time), T – function $f(t)$ period.

During the formation of impulse τ it could be used various simple formatting devices: for example comparator, which when moment signal's value is equal and higher than reference y_r, forms impulse (Fig. 1). If function (1) whole half-period stays prominent, then in comparator's exit could be received only one impulse that lasts till the inequality is confirmed

$$y_r \le f(t). \tag{2}$$

When impulse's duration is function of signal magnitude Y_m may be written

$$\tau = \varphi(y_r, Y_m). \tag{3}$$

Reference variables value y_r, is usually constant, and then impulse duration is variables amplitude's function. Impulse's duration τ in real time transferring to microcontroller where it is measured and during calculations (3) could be found variable's amplitude Y_m.

In case when variable is harmony function

$$y = Y_m \sin \omega t, \tag{4}$$

here ω – angular frequency.

When variable y reaches reference value y_r feedback signal formation device forms impulse that continues term τ. Putting in these values into (4) and calculating it is received impulse duration's (in radians) dependence on signal's amplitude

$$\omega\tau = \pi - 2\arcsin\frac{y_r}{Y_m}, \qquad (5)$$

here y_r – reference variable's value $y_r < Y_m$.

The argument of function (4) is composite, and in general case both values can be variables, because of that the requirement for function (1) is not satisfied. Required argument of function (4) is if one of the values will be a constant. After accepting ω is const impulse duration's dependence is received

$$\tau = \frac{1}{\omega}\left(\pi - 2\arcsin\frac{y_r}{Y_m}\right). \qquad (6)$$

When signal is frequency modulation: Y_m – const, ω – var., then (6) could be used for oscillation period measurement.

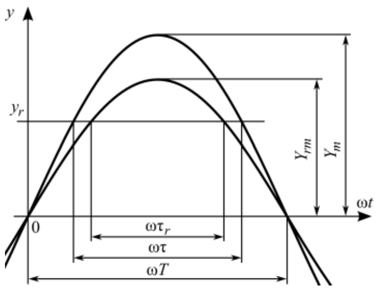

Fig. 1. Feedback signals formation process

From all possible variable amplitude's values choosing reference value Y_{rm}, the according impulse's duration to this value is τ_r:

$$\tau_r = \frac{1}{\omega}\left(\pi - 2\arcsin\frac{y_r}{Y_{rm}}\right). \qquad (7)$$

If control's goal is to keep variable's amplitude equal Y_{rm}, instead of control error $\varepsilon = Y_{rm} - Y_m$ it is expedient to use error

$$\varepsilon = \tau_r - \tau. \qquad (8)$$

In this case calculation's volume could be diminished which is very important while calculating control's equations with low speed microcontrollers in real time.

Information forming and transferring channel characteristics

When chosen variable is harmony condition (4) the reference value y_r must be $y_r < Y_m$. While signal's amplitude is changing from $Y_m = y_r$ to $Y_m \to \infty$, impulse τ duration is changing in interval $[0, \pi/\omega]$.

Putting the values τ and τ_r calculating using (6) and (7) into (8) could be written

$$\varepsilon = \frac{2}{\omega}\left(\arcsin\frac{y_r}{Y_m} - \arcsin\frac{y_r}{Y_{rm}}\right). \qquad (9)$$

In this equation Y_m is variable, Y_{rm} is fixed value of this variable. So, while projecting feedback signal channel only one parameter y_r could be freely chosen. Dependency (9) is non-linear so this parameter has to be in interval which error's changing is the fastest

$$\frac{d\varepsilon}{dy_r} = \frac{2}{\omega}\left(\frac{1}{Y_m\sqrt{1-\left(\frac{y_r}{Y_m}\right)^2}} - \frac{1}{Y_{rm}\sqrt{1-\left(\frac{y_r}{Y_{rm}}\right)^2}}\right). \qquad (10)$$

It is obviously, that $\frac{d\varepsilon}{dy_r} \to \infty$, when $y_r \to Y_m$ or when $y_r \to Y_{rm}$. According to all this we find value y_r. If the controlled variables' Y_m maximum dynamic deviation ± ΔY_m, then reference value y_r is

$$y_r = Y_{rm} - k\Delta Y_m, \qquad (11)$$

here k – emergency coefficient ($k > 1$), which value depends on oscillating centre's stability and on minimal calculated impulse τ_{min} duration.

There are some cases when oscillating centre during the work could move, Fig. 2, *a*. If control system doesn't receive any information on oscillating centre situation change, then it defines oscillating amplitude that impulse τ_r duration would be equal to written down in control's program, because of that displacement the amplitude is different from the defined value Y_{rm}.

Let oscillating centre displacement is $\pm\Delta y_0$. Then, when the oscillating centre moves, feedback is

$$y = Y_m \sin\omega t + \Delta y_0. \qquad (12)$$

Control system minimizing the error (8) sets new oscillating amplitude $Y_m = Y'_{rm}$, that in signal's fixed level y_r, impulse's duration τ_r would be equal to the previous set one. Putting this into (12) the changed defined oscillating amplitude could be written

$$Y'_{rm} = \frac{y_r - \Delta y_0}{\cos\frac{\omega\tau_r}{2}}. \qquad (13)$$

If before the displacement of oscillating centre, amplitude was equal to $Y_m = Y_{rm}$, and after the displacement of oscillating centre amplitude should change as well it's control doesn't have any effect on oscillating centre displacement, then amplitudes error $\Delta Y_{rm} = Y_{rm} - Y'_{rm}$. Equation (13) using in the event when $\Delta y_0 = 0$ could be found reference oscillating amplitude Y_{rm}. Then amplitude's error after oscillating centre moved

$$\Delta Y_{rm} = \frac{\Delta y_0}{\cos\frac{\omega\tau_r}{2}}. \qquad (14)$$

Cosine is smaller than one, so $\Delta y_0 < \Delta Y_{rm}$. Amplitude's error is set opposite: when oscillating centre displacement $\Delta y_0 > 0$ oscillating amplitude decreases and when $\Delta y_0 < 0$ – increases.

If amplitude's error doesn't comply with requirements set to achieve control's effectiveness then it is needed to use extra means, Fig. 2, *b*. When feedback signal is electrical this problem is solved using high frequency filter, which separates variable signal's constituent. Linear signal distortions in the filter are compensated changing impulse's duration τ_r.

When feedback signal is mechanical one, problem's solution is complicated. To eliminate the displacement of oscillating centre it is needed to move sensor exactly Δy_0 the same direction that oscillating centre moved. Then there is unnecessary to change control programme, but realizing of this method is complicated.

Impulse's duration oscillating centre displacement two variables' function

$$\tau = \frac{1}{\omega}\left(\pi - 2\arcsin\frac{y_r - \Delta y_0}{Y_m}\right) \qquad (15)$$

not compiling condition (1). Because of this first we have to measure oscillating centre displacement. After the oscillating centre moved the asymmetry of a signal in primary coordinates system may be used for searching displacement centre.

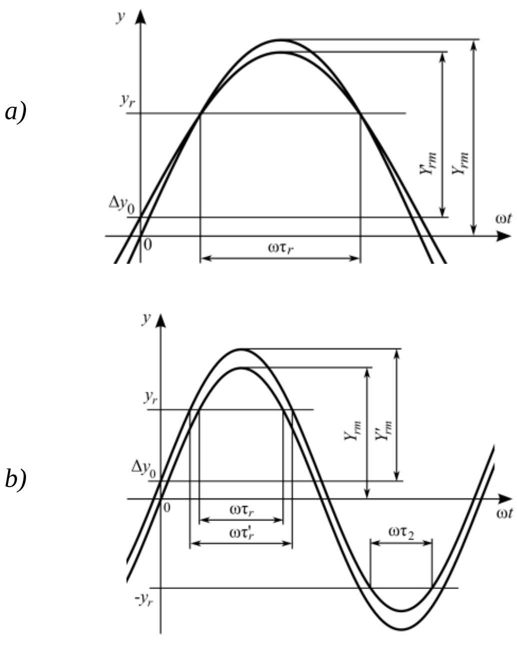

Fig. 2. Graphs to analyze the effect of oscillating centre displacement: *a)* – amplitude's error, *b)* – amplitude error's adjustment

So in signal's level $y = -y_r$ could be formed second duration τ_2 impulse. When the oscillating centre has not moved, impulse's duration is equal to τ, and after it gets displaced $\tau \neq \tau_2$. It could be written this equation system

$$\begin{cases} y_r = Y_m \sin\frac{1}{2}(\pi - \omega\tau) + \Delta y_0, \\ -y_r = Y_m \sin\frac{1}{2}(\pi - \omega\tau_2) + \Delta y_0. \end{cases} \qquad (16)$$

After solving this one could be received

$$\Delta y_0 = \frac{1-\vartheta}{1+\vartheta} y_r, \qquad (17)$$

here ϑ– variable's τ and τ_2 function:

$$\vartheta = \frac{\sin\frac{1}{2}(\pi - \omega\tau)}{\sin\frac{1}{2}(\pi - \omega\tau_2)}. \qquad (18)$$

For a new oscillating centre value new reference impulse's duration could be found using (15)

$$\tau'_r = \frac{1}{\omega}\left(\pi - 2\arcsin\frac{y_r - \Delta y_0}{Y_{rm}}\right). \qquad (19)$$

Measured signal may be different from harmony then expressions (4) right side is written using FURJE series. For this case dependencies (5)–(19) are got analogically. If signals harmonics coefficients are constant, then measuring principal difference signal and transfer is not present. When during the work harmonics coefficients change it is needed to analyze how it affects amplitudes measuring accuracy.

Impulse's duration τ is measured using measuring processes' sampled step, which could be equal few microcontrollers command cycle T_{CY}.

$$h = nT_{\text{CY}}, \quad n = 1,\ 2, \ldots \qquad (20)$$

Because impulse's front and back front are in asynchrony to sampled step *h*, maximum absolute measuring error could be close to *2h*. Then static interval's τ measuring error

$$\delta = \frac{2h}{\tau_r} 100\%. \qquad (21)$$

Choosing the defined impulse's duration and sampled step could be found for compatible error of calculation. While impulse's duration is getting smaller, relative error of calculation is getting bigger.

Microcontroller timer's functioning specific doesn't allow measuring few sampled steps duration impulses. Timer's measured impulse's duration consists of three values

$$\tau = t_{ON} + t_{CNT} - t_{OFF}, \quad (22)$$

here t_{ON} = const – timer's start time (time from impulse's front till moment since which timer starts calculating the time), t_{CNT} = var. – timer's calculated time, t_{OFF} = const – time spent to stop the timer.

Let's assume, that $t_{ON} < \tau$, then after time t_{ON} passed from impulses front timer starts calculating time, but after impulse's τ time calculations still continues interval t_{OFF}, till timer is stopped. In this case this equation could be written

$$t_{OFF} < t_{CNT}. \quad (23)$$

If $\tau < t_{ON}$ then before the start of calculating interval τ the timer will be stopped. This condition could be used to check if impulse's duration fits into calculated values diapason

$$\tau_{min} \le \tau, \text{ when } t_{OFF} < t_{CNT}. \quad (24)$$

here $\tau_{min} = t_{ON} + h$ – minimal calculated impulse duration.

Relative measurement's error in this point could reach 100%. Besides that doesn't have any effect on control efficiency, because when approaching the systems halfway state's measuring error is decreasing getting closer to (21).

Control Algorithm of Activators

Control algorithm (Fig. 3) composed of mechatronic devices' oscillating activators' controlled companies microchip microcontrollers' to control oscillating amplitude. Control asynchronous – control amplitude measuring and motor's control signal u_d transfer to promoter neither with feeding frequency, nor with other variable synchronization. So, to avoid unwanted case, when before starting to measure time interval τ this interval already started, algorithm defines delay till sensor sending impulse's end, when RB0=0. After that outside interrupts are permitted and whole period T is waiting till control size value would fit into condition $y \ge y_r$. If this condition the whole period is not satisfied, performing control algorithm CONTROL 1, in the other case, when it is being fixed, that case would be satisfied (INT RB0=YES) measured τ and performed control algorithm CONTROL 2.

Control algorithm CONTROL 1 controls promoter start or returns into main control process (algorithm CONTROL 2) if disturbances turned out ($Y_m < y_r$) of control process.

If oscillating centre displacement emerges the deflection check-up and corrugation procedure should be performed. In other cases this algorithm's part is not necessary. This procedure continues quite lot time, so it is performed not during every control cycle, but every N control cycle.

Note: Markups, in control algorithm's graph and in some formulas affiliated with it, taken from microcontrollers making companies microchip sources [2].

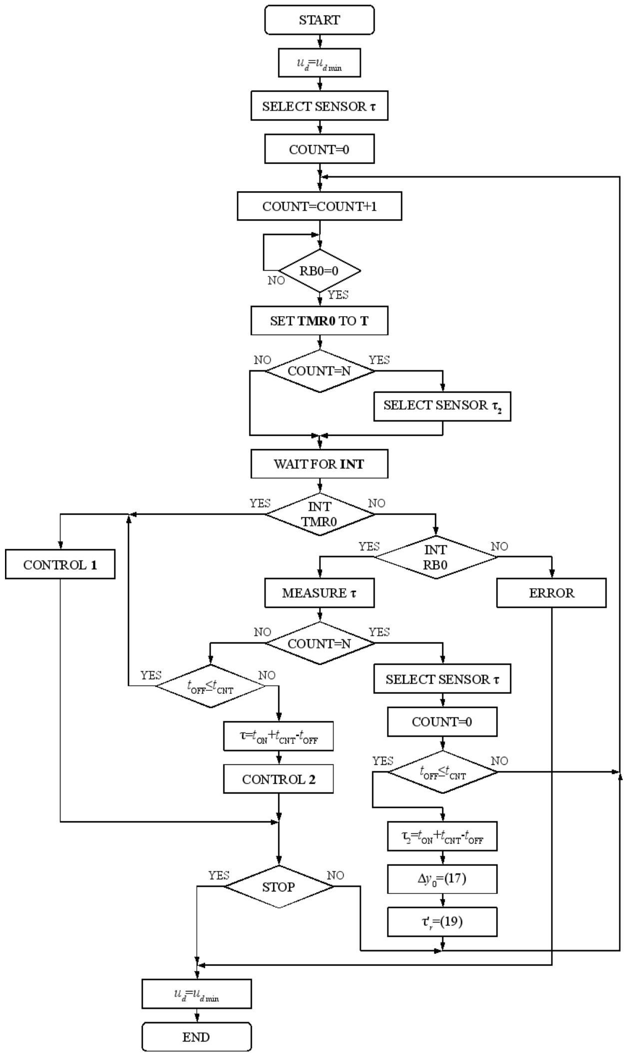

Fig. 3. Flow chart of the activators control algorithm

Modeling of Control Process of Actyvators's

Mechatronic device activator system function's scheme is shown in Fig. 4. It contains these elements: 1 – microcontroller, 2 – controlled feeding source, 3 – activator (oscillating engine), 4 – feedback sensor signal changer, 5, 6 – oscillating amplitude signal τ sensors. Microcontroller's entrance and exit (they are not connected) are intended for turning on activators' control system into general mechatronic device control system.

Activators and its control system modeling programme is created using functional scheme Fig. 4 and control algorithm Fig. 3. In model's algorithm could be simplified feedback signal measuring modeling, but controlled feeding source and promoters models are needed extra to be created [8].

While using rectangular voltage feeding source, then its mathematical model for one side of the motor and for one period is

$$u_d(t)=\begin{cases}U_m, & \text{when } 0\le t\le\lambda,\\ -U_m, & \text{when } \lambda<t<T.\end{cases} \quad (25)$$

here λ – feeding voltage positive impulse spread, U_m – feeding voltage impulses' amplitude.

Controlled feeding source voltage amplitude's model is constant, and controlled is voltage impulse spread. Positive impulse spread is λ seconds, and negative – the rest of period. Because, while λ is changing, the voltage's constant outgoing is changing too, but this doesn't have any effect on motor's work, because the diode is turned on in the current's circuit. The mathematical model of other side of engine differs with delay half of period. Control system λ transfer from microcontroller's feeding source could be realized with impulse in real time. Then source's control system becomes simpler.

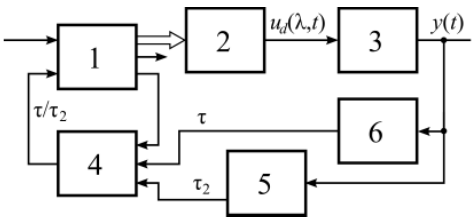

Fig. 4. Block diagram of activator's control system of mechatronic device

Creating modeling program for control algorithm CONTROL 1 was used integration of constant speed, and for algorithm CONTROL 2- PI regulation case

$$W(p)=\frac{\Lambda(p)}{\mathrm{E}(p)}=K_p+\frac{K_i}{p},\quad K_p=2{,}3,\quad K_i=0{,}5. \quad (26)$$

For control moving from CONTROL 1 into CONTROL 2, to avoid feeding source's control signal λ jump, programming algorithm CONTROL 2 speed algorithm was used. Reference oscillating parameter: $Y_{rm}=5{,}00$ mm, $y_r=3{,}50$ mm, $\tau_r=5{,}0637$ ms.

While modeling control process modeling time is taken 1.5 s and time sampled step is $h=0{,}1$ ms. Release's transitional process finishes after 0,4 s, then to receive system's reaction into interference, for moment t=0,8 s the load was increased 50%. Modeling results can be seen in Fig. 5. After the transferring process, that was created by interference, ended, directly controlled size τ error Fig. 5, *a*) and *d*) $\varepsilon<2h$ didn't go over regular numerical controlled error, and oscillating amplitude Fig. 5, *e)* after transferring process reaches initial value. In real system control accuracy could be increased, while increasing τ measuring accuracy, for example, sampled step should be decreases ten and more times. To achieve that while modeling it is complicated because most part of modeling time is taken by calculations of model of the motor. In real system there is no such problem.

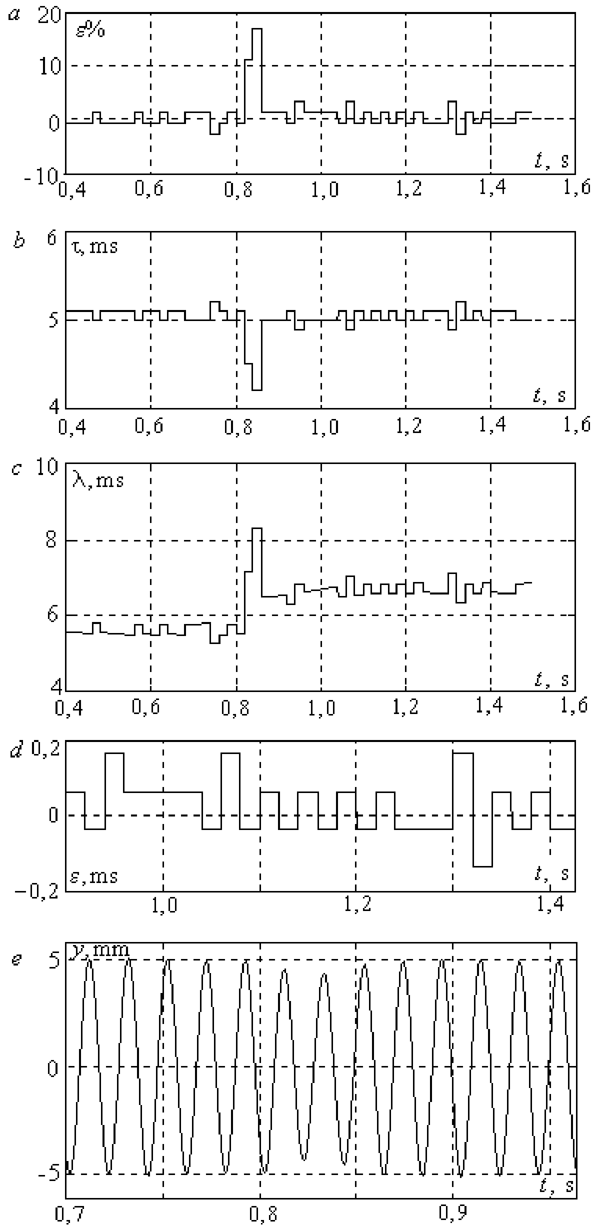

Fig. 5. Promoter's control process modeling results

Conclusions

1. Simple periodical signal measuring method and real time information transfer by one bit channel in this work is analyzed.

2. Effect is received using simple sensor which forming voltage impulse's duration is measuring variable function. Analogical sensor signal at real time is transferred to promoter control's microcontroller, where analogical signal is changed in numerical one and used in control process.

3. It is established that after the movement of oscillating centre, because of indirect oscillating amplitude's measuring, we get amplitudes measuring error. It is offered oscillating centre movement measuring way and, how to use measuring results to eliminate oscillating amplitude error.

4. The algorithm for activator control system working, which involves feedback signal and calculating of control effect to the promoter, is created (Fig. 3).

5. Results, received while modeling promoter's control system (including source and promoter), prove information forming and transferring method and theory, which approves it, effectiveness.

6. Real time information transfer can be used not just when the transferring signal is impulse's duration, but also when it is the voltage, current or other variable (in case when it is non periodical function), before transferring it must be changed to time interval.

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Numerical device's control usage is problematic by complicated information transfers between control object and control device. Because of this reason it is normal to have a simple feedback device and information transferring channel. The way analyzed at work - simple device forms impulse, which duration τ is function of measuring variable, in real time transferred to the microcontroller, where it is changed in numerical code. Model application limits, centre of oscillation, effect of stability on effectiveness, increase of effectiveness limit, measurement errors are defined. Promoters control algorithm as well promoters and control model's results proving theoretical conclusions are presented. Ill. 5, bibl. 8 (in English; summaries in English, Russian and Lithuanian).

А. Бразаитис, Э. Гусейновене. Управление активаторами мехатронных устройств, передавая информацию сигналом реального времени // Электроника и электротехника. – Каунас: Технология, 2009. – № 2(90). – С. 89–94.

Использование цифровых устройств осложнено сложным обменом информацией между управляющим устройством и объектом управления. Поэтому актуальной является проблема поиска путей передачи информации по возможности простыми способами. В статье рассматривается способ – простой датчик формирует импульс, интервал времени τ которого является функцией измеряемой величины и реальным временем передается микроконтролеру, в котором преобразуется в цифровой код. Определены области применения метода, влияние стабильности центра колебаний на точность, возможности увеличения точности, а также погрешности измерения. Представлен алгоритм управления активатором и результаты моделирования управления, которые подтверждают теоретические выводы.Ил. 5, библ. 8 (на английском языке, рефераты на английском, русском и литовском яз.).

A. Brazaitis, E. Guseinovienė. Mechatroninių įtaisų aktyvatorių valdymas, informaciją perduodant realaus laiko signalu // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – Nr. 2(90). – P. 89–94.

Naudoti skaitinius valdymo įtaisus apsunkina gerokai sudėtingesni informacijos mainai tarp valdymo objekto ir valdymo įtaiso. Todėl aktuali paprastų grįžtamojo ryšio jutiklių ir informacijos perdavimo būdų problema. Darbe analizuojamas toks būdas: paprastas jutiklis formuoja impulsą, kurio trukmė τ yra matuojamo dydžio funkcija, realiu laiku perduota mikrovaldikliui, keičiama skaitiniu kodu. Nustatytos metodo taikymo ribos, švytavimų centro stabilumo įtaka tikslumui, tikslumo didinimo galimybės, matavimo paklaidos. Pateikiamas aktyvatoriaus valdymo algoritmas ir aktyvatoriaus ir valdymo modeliavimo rezultatai, kurie patvirtina teorines išvadas. Il. 5, bibl. 8 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).