Response of Electromagnetic Deflection for CRT Display ★

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Synopsis

In the CRT display system of high-speed electromagnetic deflection, the tendency to amplifier saturation should not be neglected. We first show the limitation to the linear characteristics of input-output response and the response time under the saturation condition in this system. We try to improve the frequency-characteristics of the amplifier by making the load resistance constant and the feedback-paths partially positive, and reduce the L/R value of the load circuit by adopting the mutually-coupled yokecoils and the low-current amplifier. As the result, it is suggested that a low-power dissipation and high-speed response electromagnetic deflection system can be constructed.

1. Introduction

Nowadays, as the image display device in the information terminal equipment, the CRT is widely used in the almost cases, because of high quality and reliability attained through the inquiries for many years. Recently, from the requirements to use the solid-state device and project the image on a large screen or in a threedimension, the new devicesdifferent from the CRT have been produced in many laboratories by way of trial, but can be never found useful ones superior to the CRT in regard to the functions of response-time, brightness and resolution, etc. In this transition period of the display devices under development, it is significant for us to make clear the problems and the points to improve on the CRT system.

The type of the CRT used in the information terminal equipment is mostly the electromagnetic deflection type, so that the displacement linearity and spot-size stability may be required over a large display surface (1). In this case, however, the initial nonlinear response of the system tends to make the access-time extremely long. And it is said that the more quick response, the higher power dissipation required in the system (1).

In this paper, we analyzed the response process in the deflection system and suggest to be able to obtain the high-speed response with low-power dissipation.

2. The Signals in the Deflection System

In the CRT display system, figures or patterns are drawn by means of Rissajous lo'ci where $x=f_1(t)$ and $y=f_2(t)$ are curve components and $z=f_3(t)$ is brightness component. As the x and y signals, steps are usually adopted to explain positions and incremental curves, and ramps and sine-cosines, etc., to explain the specific continuous curves. To the z signal step is used. In the electromagnetic deflection, the step responses in the x or y route to the particular input-levels are likely to take the settling time extremely long as shown at

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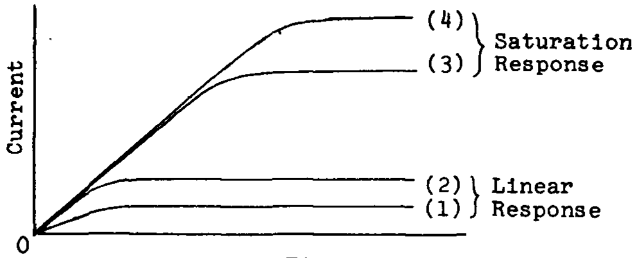
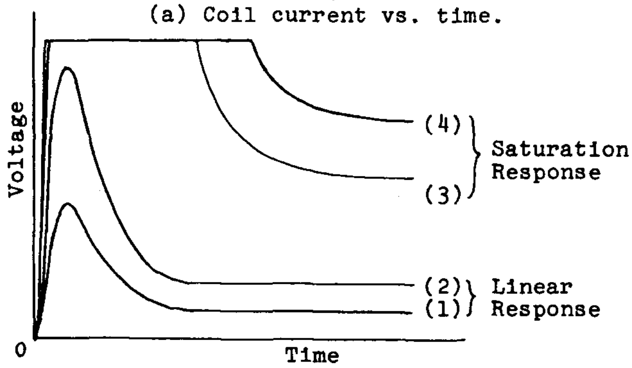
Fig. 1(a)-(3), (4) and 1(b)-(3), (4). They are the saturation responses in whose processes each output voltage Ldi/dt + Ri is clamped by the saturation voltage of the amplifier, and that is the cause to make the a access-time long. On the other hand, the linear responses uninfluenced by the saturation, as shown at Fig. 1(a)-(1), (2) and 1(b)-(1), (2), had better take the settling time short, so that the figure distortion based on time delay should be inconspicuous. The methods to improve these two responses are mentioned in the following sections.



(a) Coil current vs. time.



(b) Output voltage vs. time.

Fig.1—The step responses in the electromagnetic deflection to the several input-levels.

3. Analysis of the Deflection Circuit

The electromagnetic deflection circuit used in CRT display has generally the negative-feedback loop to keep the yokecoil current steady and the response time short, as shown at Fig. 2. Its response to the high-speed current is likely to be influenced by the amplifier saturation, since it forms a current amplifier with inductive load or a voltage amplifier with feedback loop of low-pass type. The summing amplifier may be composed of an operational amplifier, in which the characteristics of saturation and gain are roughly decided by ones of the first stage and the near, where the outline of the transient characteristics would be known. Further, on the yokecoil and the resistor R to keep its current steady, distributed resistance and inductance should be very small, respectively. Thus, the circuit of Fig. 2 can be rewritten as Fig. 3 explaining the above properties (3). In the linear range where the output voltage does not reach into the saturation level, that is $|v_0| < E_0$, a set of output response is represented by calculus operator p as follows:

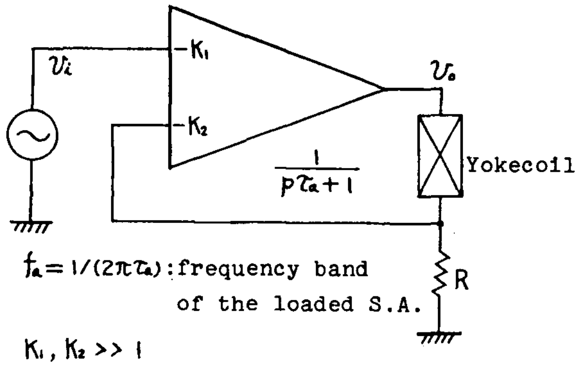


Fig.2— Electromagnetic deflection circuit.

$$V_0 \fallingdotseq F(p)\left\{-(p\tau+1)\frac{K_1}{K_2}V_i - p\tau R i_L(0) + p\tau_a(p\tau+1)\frac{v_0(0)}{K_2}\right\} \tag{1}$$

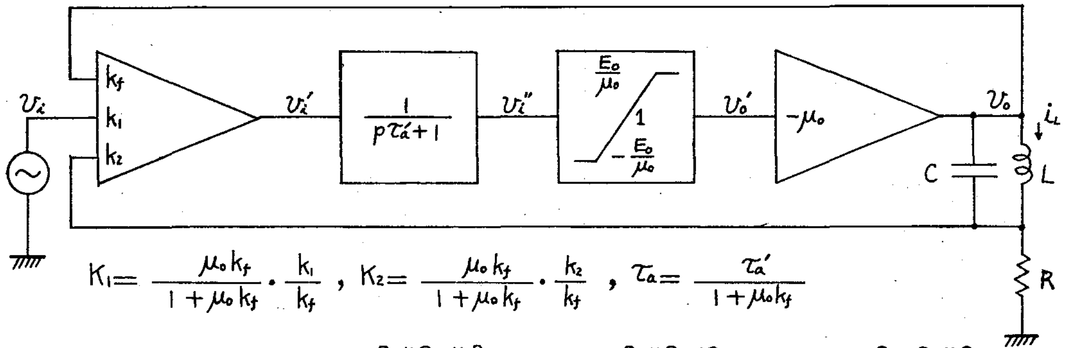
$$I_L \fallingdotseq F(p)\left\{-\frac{K_1}{K_2}\cdot\frac{V_i}{R} + p\tau(p\tau_a+1)\frac{i_L(0)}{K_2} + p\tau_a\cdot\frac{1}{K_2}\cdot\frac{v_0(0)}{R}\right\} \tag{2}$$

where the transfer coefficient

$$F(p) = \frac{A\beta}{1+A\beta} \tag{3}$$

and the loop gain

$$A\beta \fallingdotseq \frac{K_2}{(p\tau_a+1)}\cdot\frac{(p^2LC+1)}{(p\tau+1)(pCR+1)} \fallingdotseq \frac{K_2}{(p\tau_a+1)}\cdot\frac{1}{(p\tau+1)}\,. \tag{4}$$



$$K_1 = \frac{\mu_o k_f}{1+\mu_o k_f}\cdot\frac{k_1}{k_f}\ ,\quad K_2 = \frac{\mu_o k_f}{1+\mu_o k_f}\cdot\frac{k_2}{k_f}\ ,\quad \tau_a = \frac{\tau_a'}{1+\mu_o k_f}$$

$$k_1 + k_2 + k_f = 1\ ,\quad k_1 = \frac{R_1 /\!/ R_2 /\!/ R_f}{R_1}\ ,\quad k_2 = \frac{R_1 /\!/ R_2 /\!/ R_f}{R_2}\ ,\quad k_f = \frac{R_1 /\!/ R_2 /\!/ R_f}{R_f}$$

R_1, R_2 : summing resistance, R_f : feedback resistance

$$\tau = \frac{L}{R}\ ,\quad \tau >> \tau_a >> K_2 CR$$

Fig.3—The analytical model of the deflection circuit.

When the loop gain $A\beta$ satisfys the critical condition in the linear response to the step input as $v_i = E_i - E_s u(t)$, the settling time is minimum and the peak value of the output voltage, maximum. That is, when

$$K_2\tau_a = \tau/4 \quad \text{or} \quad K_2/f_a = (\pi/2)\tau\ , \tag{5}$$

the time

$$t_{st} = 2\tau_a x \tag{6}$$

where the settling error-rate of the current $\rho = (1+x)\exp(-x)$, and the peak

$$|v_o|_{max} \fallingdotseq |2\varepsilon^{-1}K_2E_s - E_i|\frac{K_1}{K_2}\ . \tag{7}$$

If the peak value calculated goes over the output saturation voltage, that is $|v_o|_{max} \geqq E_o$, the saturation response occurs. In the instant of saturation, the forward path is stopped up, the voltage E_o transmitted into the input side through the backward path, and the voltage summed there reaches the threshold level of the saturation voltage $\pm E_o/\mu_o$, until the loop is closed again and the output v_o and i_L gain rapid access to each steady-state value. This duration of the saturation is represented, to neglect the very short time till the start of the saturation, as follows:

$$t_{sat} = \tau \ln \frac{1 + \frac{E_i}{E_o}\cdot\frac{K_1}{K_2}}{1 + \frac{(E_i - E_s)}{E_o}\cdot\frac{K_1}{K_2}}\ . \tag{8}$$

In the saturation response, the time t_{sat} occupys so many a part of the access-time between the starting and settling points of the output response to step-input, that it ought to be reduced.

4. Some Methods to Get the Better Response

Even if the linear response takes, as mentioned previously, the minimum access-time under the critical condition, it should be rather damped with a view of stabilizing the system. Thus, here fits the equation with margin

$$K_2\tau_a \leqq \tau/4 \quad \text{or} \quad K_2/f_a \leqq (\pi/2)\tau \tag{9}$$

for Eq.(5). The more quick response is obtained by increasing the gain-band product $K_2 f_a$ satisfied with Eq.(9). There is the limitation in increasing K_2, because it means to increase the peak $|v_o|_{max}$ and decrease the linearity margin according to Eq. (7). The increase of the frequency band f_a can be carried out as the circuit of Fig.4 shows, in which the amplifier load with the distributed capacitance C of the yokecoil is constant resistance R and the positive feedback contradicts the part of the phase lead by LC. The loop gain considered to high frequency in this circuit is as follows:

$$A\beta \fallingdotseq \frac{K_2}{(p\tau_a+1)}\cdot\frac{1}{(p\tau+1)(pCR+1)} \quad (10)$$

The shorter time t_{sat} in the saturation response is surely obtained by reducing τ or the rate of the available voltage in the output

$$\alpha = \frac{E_{imax}}{E_o}\cdot\frac{K_1}{K_2} = \frac{|v_R|_{max}}{E_o} \quad (11)$$

as found from Eq.(8). The decrease of α means to expand the operating region of the current amplifier. Both the linear response and the saturation response can be made more quick by reducing τ. The relation between t_{sat} and τ is linear and t_{sat} is influenced very effectively by it.

The decrease of τ can be carried out by adopting the parallel common or serial differential method in Fig.5(a) or 5(b), respectively, where both methods take τ one half and the power dissipation two times. The more power margin allows to decrease τ by combination of parallel and series.

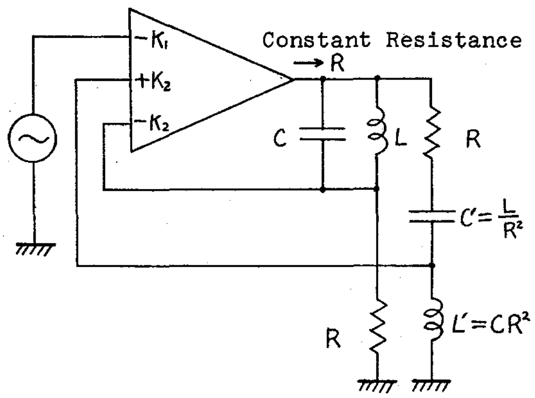
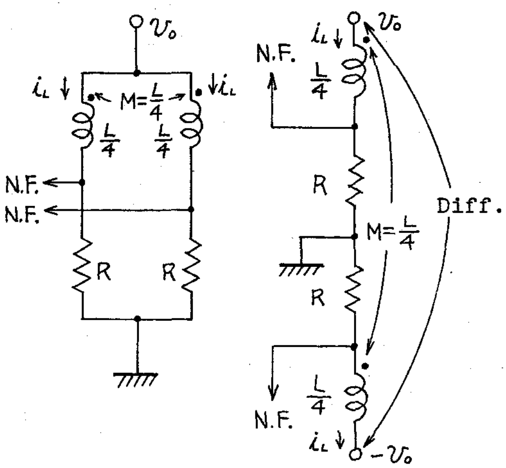


Fig.4—A band-compensated circuit.

Now, standing on a different viewpoint, take notice that a settled deflection is given not by electromagnetic energy, but by magnetic flux. Considering it, the time-constant is transformed into

$$\tau = \frac{L}{R} = \frac{L|i_L|}{R|i_L|} = \frac{|\Phi|}{|v_R|} \quad (12)$$

Therefore, under a settled distance of deflection, the response becomes more quick as the voltage $|v_R|$ dropped in R increases. This may be realized by adopting the condition that the voltage of the circuit and the power supply is taken higher and the current lower so as to save the power dissipation. Thereby it is neccesary to increase $L = |\Phi|/|i_L|$ and $R = |v_R|/|i_L| = P_R/|i_L|^2$, where the increment of L is less than of R. The capacitance C, however, increases with the inductance L in the yokecoil, and so the lower limitation of $|i_L|$ should be set in the range where CR does not influence the stability of the system. The time-constant τ can be much decreased by the above-mentioned methods.



(a) Parallel common. (b) Serial diff.
Fig.5—Time-constant reduction by mutually-coupled yokecoils.

By the way, under the condition $E_i = E_s = E_{imax}$ of the edge-to-center deflection by step input, the critical response is not influenced by the saturation voltage, if the equation (13) derived from Eq.(7) and (11) is satisfied, that is

$$2\varepsilon^{-1}K_2\alpha < 1, \quad (13)$$

and then the time-constant of the response

$$\tau_r > \frac{|\Phi|_{max}}{\varepsilon E_o} = \tau_{ro} \quad (14)$$

is derived from Eq.(4), (12) and (13). If in the response to the low-level input here is desired the shorter time-constant by increasing K_2 than τ_{ro}, then the saturation of the response to the high-level input could not be avoided. Where given the values of $|\Phi|_{max}$ = 120 μH·A and E_o=100V, the time-constant is 0.44 μsec. without dividing the yokecoil, and 0.22 μsec. with dividing it into two parts.

5. Conclusion

In the electromagnetic deflection on CRT display, the response to the step input for indicating the position is subject to be influenced by step levels and the incorrect estimation of this time brings unexpected distortion on a figure drawn from a certain point. And it is said that the more quick response requires the higher power dissipation.

In this paper these two problems are dealt with, that is, the response process is made clear by a concise model representative of the system with a saturating element, and the possibility of the system for a low-power dissipation and a high-speed response by some measures to improve is suggested. The problems concerning the saturation are to be seen in the other general amplifiers, to which such an inner model of amplifier as Fig.3 will be able to be diverted. Further, it is added that some problems with regard to the response of the deflection system are dealt with in relation to the analog generators for display.

6. References

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