AN AMORPHOUS MAGNETIC CORE MULTIVIBRATOR FOR TENSILE-STRESS TRANSDUCERS

by
Kaneo MOHRI*
Shigeru KOREKODA**
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Abstract

A new amorphous magnetic core multivibrator applied to tensile-stress transducers is presented.

This "differential-type multivibrator" has two kinds of transducing behaviors : (i) analog-type (or linear-type) transducer with no zero output, good linearity and high sensitivity, and no hysteresis for tensile-stress variations, and (ii) threshold-type transducer with adjustable threshold σ_{th}, of tensile stress, zero output for tensile stress under σ_{th} while maximum output for over σ_{th}, and no hysteresis at small σ_{th}. Both transducers have dc output, and portablity due to dc voltage source. This multivibrator is simple, stable, and reliable, and is possible to transduce the tensile stress with the values from zero to $8n$ kg. by using amorphous ribbon-wound cores with $4n$ layers ($n = 1, 2, \cdots$).

INTRODUCTION

Recently, special interest has been put to amorphous magnetic alloys, named Metglas*** ribbons [1] made by Allied Chemical Corp., Morristown, N. J., because of its outstandingly good dc magnetic properties under tensile stress [2],[3]. However, few applications of amorphous magnetic alloys have been reported [4]. This is probably due to difficulty to treat tensile stresses successfully. The remarkable sensitivity in magnetic properties with tensile stress is one of the most inherent qualities of amorphous magnetic alloys.

So, we present, in this paper, a new multivibrator (temporarily named 'differential type multivibrator') with two amorphous magnetic cores and two switching transistors applied to tensile-stress transducers. This differential-type multivibrator has dc output as same as magnetic mixing amplifiers [5], and has two kinds of transducing behaviors : (i) an analog-type transducer with no zero output, good linearity and sensitivity, no hysteresis for tensile-stress variations, and (ii) an threshold-type transducer with zero output for tensile stress under threshold, σ_{th}, maximum output for tensile stress over σ_{th}, no hysteresis for tensile-stress variations at small σ_{th}. Both the transducers have dc output and portability due to dc voltage source.

This multivibrator is simple, stable, and reliable, and is possible to transduce the tensile stresses up to $8n$ kilograms by using amorphous ribbon-wound cores with $4n$ layers ($n = 1, 2, \cdots$)

* Associate Professor at the Department of Electrical Engineeing. Kyushu Institute of Technology, Tobata, Kitakyushu 804.

** Graduate Student.

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AMORPHOUS MAGNETIC CORES

Metglas amorphous magnetic ribbons (2826) [1] have magnetic properties under tensile stress similar to Supermalloy regarding maximum permeability μ_m, saturation flux density B_s, and coercive force H_c, and similar to 50% Ni–Fe in regard to squareness B_r/B_s, as shown in Table 1. The resistivity ρ is about three times that of Supermalloy.

Table 1. The characteristic values of Metglas 2826 amorphous ribbon with applied tension of over 10 kg/mm²

	Metglas 2826 ($Fe_{40}Ni_{40}P_{12}B_8$)	
μ_m	4×10^5	with tension of 10 kg/mm².
H_c	0.03 oe	
B_s	8000 gauss	
B_r/B_s	0.95	
ρ	180 $\mu\Omega$-cm	
tensile strength	230 kg/mm²	
width	2.1 mm	
thickness	0.05 mm	

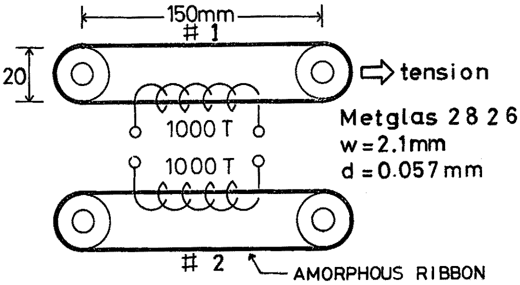


Fig. 1. Amorphous magnetic cores with 4 layers.

Fig.1 illustrates two amorphous ribbon-wound cores, used for tensile-stress transducers, consists of 4 layers around two bakelite bobbins and a winding with 1000 turns, respectively. Tension is applied to one of the cores, while the other core is reference one. We now investigate the characteristics of one of the cores (# 1) against tensions in Fig. 2 and 3.

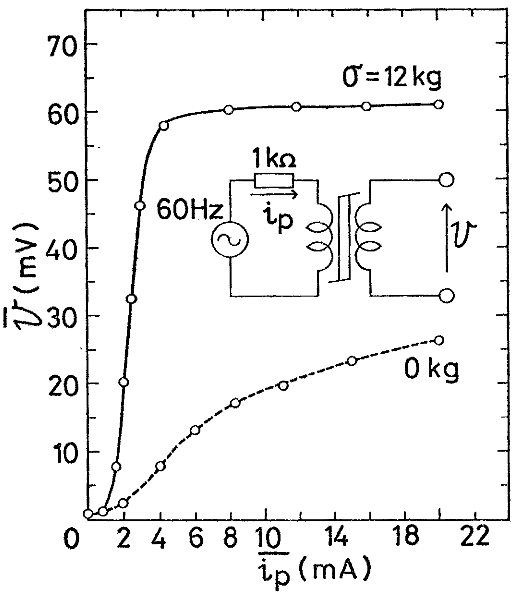


Fig. 2(a). Experimental results of induced voltage $\bar{v}$ versus magnetizing current $\bar{i}_p$ with and without tension σ.

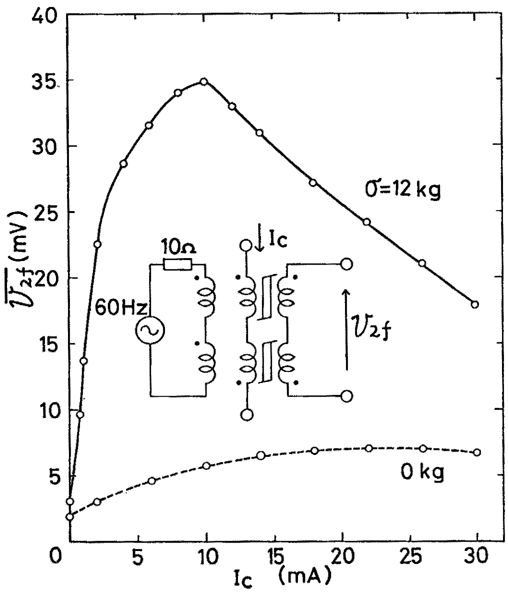


Fig. 2(b). Experimental results of induced second harmonic voltage $\bar{v}_{2f}$ versus input dc current I_c with and without σ in a modulator circuit.

Fig2(a) shows the experimental results of induced voltage $\bar{v}$ (r.m.s. value) of winding versus sinusoidal magnetizing current i_p (r.m.s. value) with frequency of 60 Hz. Maximum gradient from the origin of the curve at tension σ of 12 kg is about seven times that of one at $\sigma = 0$. Fig.2(b) is the experimental results of output voltage $\bar{v}_{2f}$, versus input dc current I_c, of a magnetic modulator circuit whose winding are set on two legs of the core (not shown in Fig. 1). Maximum gradient from the origin of the curve at $\sigma = 12$ kg is about twenty-two times that of one at $\sigma=0$.

Fig.3(a) shows the measured values of magnetizing current $\bar{i}_p$ (r.m.s. value) of the core versus σ under "voltage excitation" : solid lines are at sinusoidal voltage, while broken lines are at rectagular voltage. All curves reveal fairly good linearity. But these lines no longer show linearity at higher frequencies over 1 kHz, while all lines are still in good linearty under "rectified sinusoidal and rectagular voltage excitation" as shown in Fig.3(b). This is considered due to that saturation regions of BH loop are less-influenced with frequency. This is the origin of good linearity in differential-type mutivibrator. These curves in both (a) and (b) have almost no hysteresis for variation of σ. This is considered due to small coercive force of amorphous alloys.

These experimental results suggest the probability of realizing tensile-stress transducers with good linearity and no hysteresis.

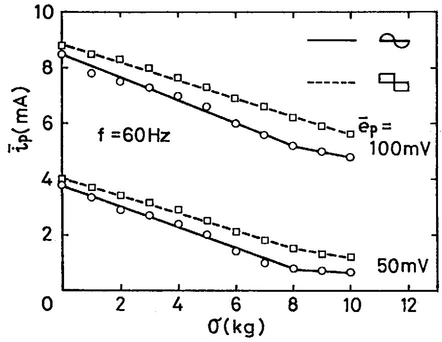


Fig. 3(a). Measured values of magnetizing current $\bar{i}_p$ versus σ under "voltage excitation" by sinusoidal (solid line) and rectangular (broken line) ac voltages with 60 Hz respectively.

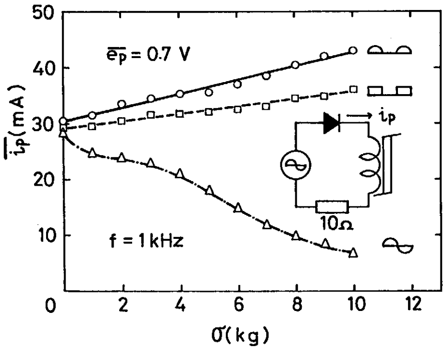


Fig. 3(b). Measured values of magnetizing current $\bar{i}_p$ versus σ under "voltage excitation" by rectified sinusoidal (solid line) and rectangular (broken line) ac voltages with 1 kHz respectively.

DIFFERENTIAL-TYPE MULTIVIBRATOR

We newly present an amorphous core multivibrator for tensile-stress transducers as shown in Fig.4. Two amorphous cores are as same as that illustrated in Fig.1, and tensile stress is applied to one of the cores, so that no zero output reveals at no tension. R_L and C_L are load resistance and filtering capacitance respectively , and variable resistance VR is for complete zero output adjustment. C_B and R_B are for commutation. We can obtain two kinds of dc voltage outputs corresponding to the difference flux behaviors in the two cores : (i) analog output proportional to applied tension at output terminals 1-2. This proportionality is predicted by Fig.3(a), because that two cores is magnetized by rectangular voltage (amplitude E) under near "voltage excitation" due to small R_L. And (ii) digital output with variable threshold of tension at terminals 1′–2, obtained by only adjusting the value of *R* and by using a diode. The method for detecting dc output in a multivibrator is developed at "magnetic mixing amplifier" [5].

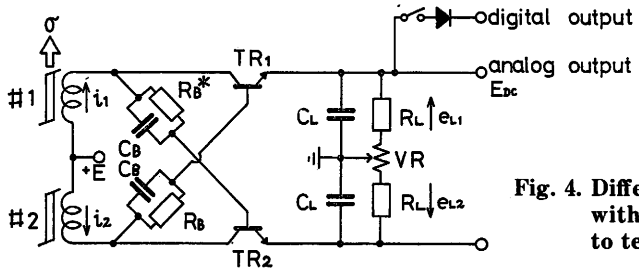


Fig. 4. Differential-type multivibrator with two amorphous cores applied to tensile-stress transducers.

EXPERIMENTAL RESULTS OF TENSILE-STRESS TRANSDUCERS

ANALOG-TYPE TRANSDUCER

Fig.5 represents the experimental results for the characteristics of dc output voltage at terminals 1–2 as shown in Fig.4 versus applied tension with parameter amplitude of dc voltage source *E*. Good lineariry with accuracy less than 2% was obtained for all curves in the range of tensions 0 – 7 kg (0 – 10 kg in the case of $E=8$V).

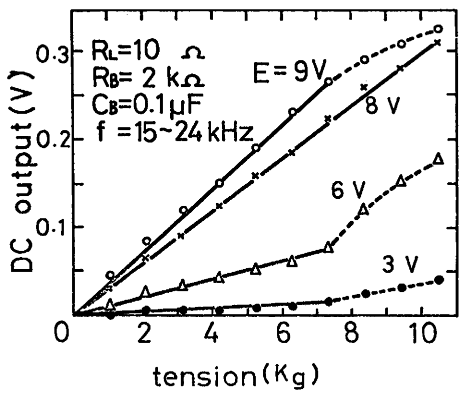


Fig. 5. Experimental results of E_{dc} versus σ with parameter E in the analog-type transducer.

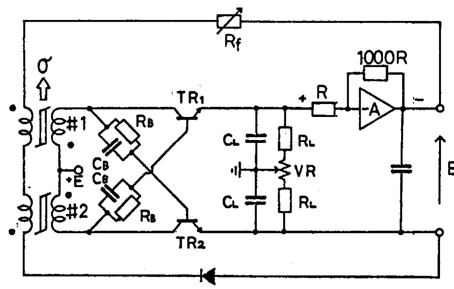


Fig. 6(a). A negative feedback system with IC operational amplifier and feedback windings.

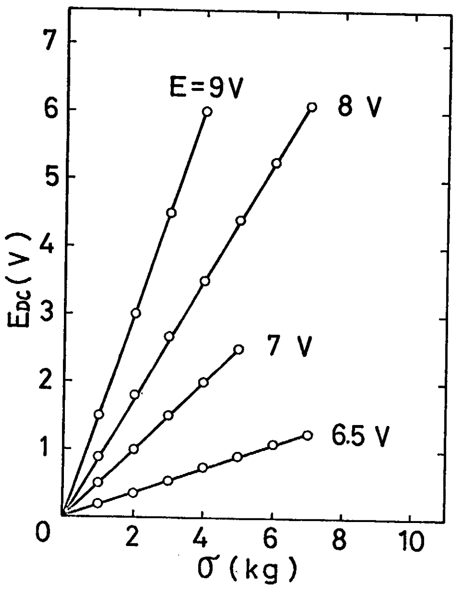


Fig. 6(b). Improved characteristic of E_{dc} versus σ with parameter *E*.

The oscillation frequencies of the multivibrator are 15 - 24 KHz depend on tensions. Optimal values of C_L for linearity were 0.47, 10, 1, and 50 μF for $E=3$, 6, 8, and 9 V respectively. The linearity is improved by using a negative feedback system with a operational amplifier and feedback windings as shown in Fig. 6 (a). The experimental result of E_{dc} versus σ is illustrated in Fig. 6 (b). That is, the linearity was very improved to less than 0.2 % of full scale and the maximum output is simultaneously increased about twenty times because of small amount of negative feedback. Zero output is completely removed by adjusting VR. These lines has almost no hysteresis. This analog-type transducers are stable, reliable, and portable due to dc voltage source. The mechanism of the circuit behavior will be discussed later.

THRESHOLD-TYPE TRANSDUCER

Threshold-type transducers are available for detecting the critical or limited physical quantity. The differential-type multivibrator, as shown in Fig. 4, behaves not only as a analog-type transducer but also as a digital-type one by only setting the value of R_B to a proper one. Digital output is obtained at the terminals 1'-2 in Fig. 4. A diode is used in order to set the output at zero for tensions under threshold σ_{th}.

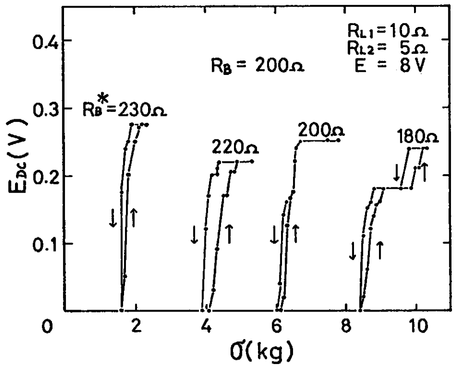


Fig. 7. Experimental results of E_{dc} versus σ with parameter R_B in digital-type transducer.

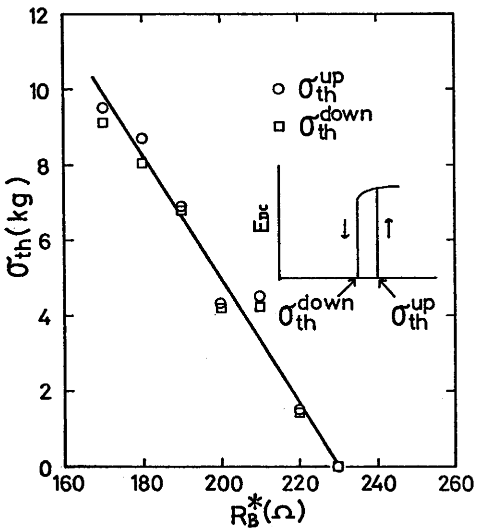


Fig. 8. Measured values of σ_{th} versus R_B.

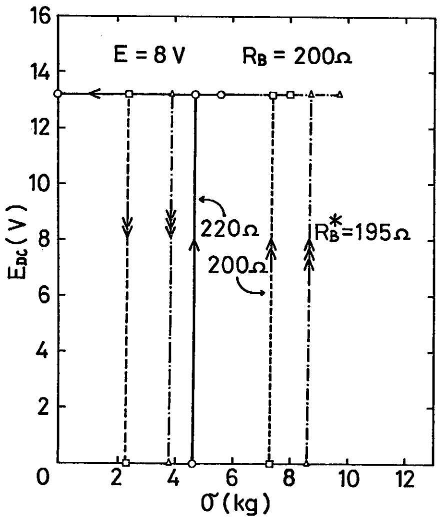


Fig. 9. Improved characteristic of E_{dc} versus σ.

Fig. 7 shows the measured values of dc output voltage E_{dc}, versus tension with the values of R_B^* (one of the two R_B) as the parameter. The characteristic of E_{dc} versus tension at small σ_{th} is almost ideal because of no hysteresis, and almost infinite gain near σ_{th}. The value of σ_{th} is easily changed by adjusting the value of R_B^* as shown in Fig. 8. The jumping behavior becomes nonideal with increasing σ_{th}. The value of σ_{th} is also changed due to R_L, C_L, and C_B.

These jumping properties are improved by constructing a positive feedback system with IC operational amplifer and feedback windings in the same manner as one shown in Fig. 6 (a). The experimental results are represented in Fig. 9: ascending and descending lines of E_{dc} versus σ are vertical, the value of E_{dc} is constant over descending threshold, and the value of E_{dc} is over 12 volts.

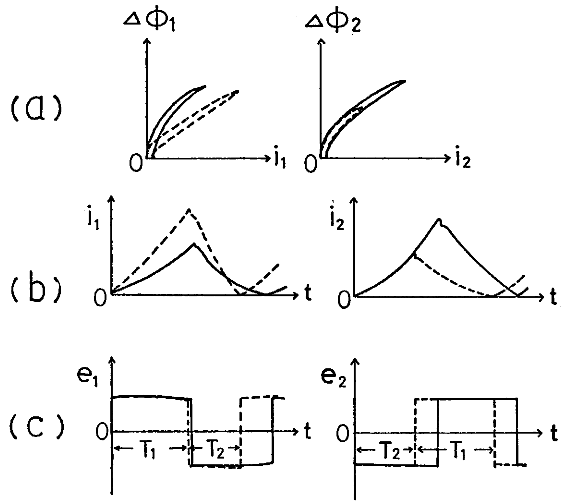
DISCUSSIONS

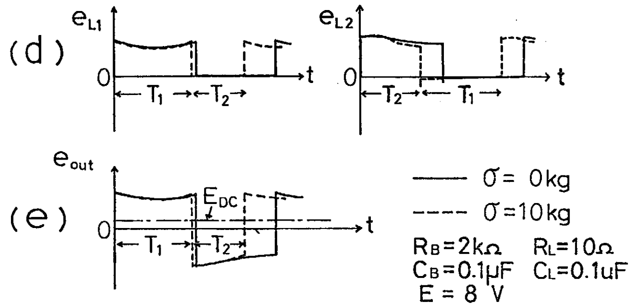
We simply express the phenomena of the relation of E_{dc} and σ in these transducers. Fig. 10 illustrates measured dynamic BH loops and voltage- and current-wave shapes in analog-type transducer. The solid lines are without σ, while the broken lines are with σ. In dynamic BH loops, as shown in (a), the maximum value of flux variation $\Delta\phi_{1m}$, in #1 core is almost constant, while $\Delta\phi_{2m}$, in #2 core decreases with increasing σ. That is, the maximum value of magnetizing current i_{1m} of #1 core increases with increasing σ because of decreasing permeability. On the contrary i_{2m} in #2 core decreases with σ due to the interaction between i_1 and i_2 at R_L through R_B and C_B. The periods T_1 (TR_1 is saturated, and TR_2 is off) and T_2 (TR_1 is off, and TR_2 is saturated) are expressed for small R as follows,

$$T_1 = N\Delta\phi_{1m}/E$$
$$T_2 = N\Delta\phi_{2m}/E \qquad (1)$$

where N and E are the number of core winding and the value of dc source voltage, respectively.

Fig. 10. Dynamic BH loops and current- and voltage- wave shapes in analog-type transducer.





Then $T_2 < T_1$ for σ, while $T_1 = T_2$ for $\sigma = 0$ as shown in (b), (c), and (d). In (c) e_1 and e_2 are induced voltages of windings, and e_{L1} and e_{L2} are voltage drops at both R_L in (d). Therefore, dc output voltage E_{dc} reveals in output voltage with σ due to the differences of T_1 and T_2, and of i_{1m} and i_{2m} in (e).

Fig. 11 represents dynamic BH loops and voltage–wave shapes in digital-type transducer with an output diode and small R_B. Solid lines are for $\sigma = 0$, while broken lines are for σ. Since the dc output is obtained through the diode, the values of both R_L are chosen in different ones ($R_{L1} = 10\ \Omega$, $R_{L2} = 5\ \Omega$) in order to set $E_{dc} = 0$ at $\sigma = 0$. That is, $i_{1m} < i_{2m}$ and $\Delta\phi_{1m} <$ $\sigma = 0$ in (a) ; $T_1 < T_2$ as shown in (b). When we apply σ over σ_{th}, the amount of $\Delta\phi_{2m}$ $\Delta\phi_{2m}$ for suddenly decreases and becomes $\Delta\phi_{1m} = \phi_{2m}$, and $i_{2m} < i_{1m}$. So, E_{dc} suddenly reveals due to that e_{L1} becomes greater than e_{L2} as shown in (c) and (d).

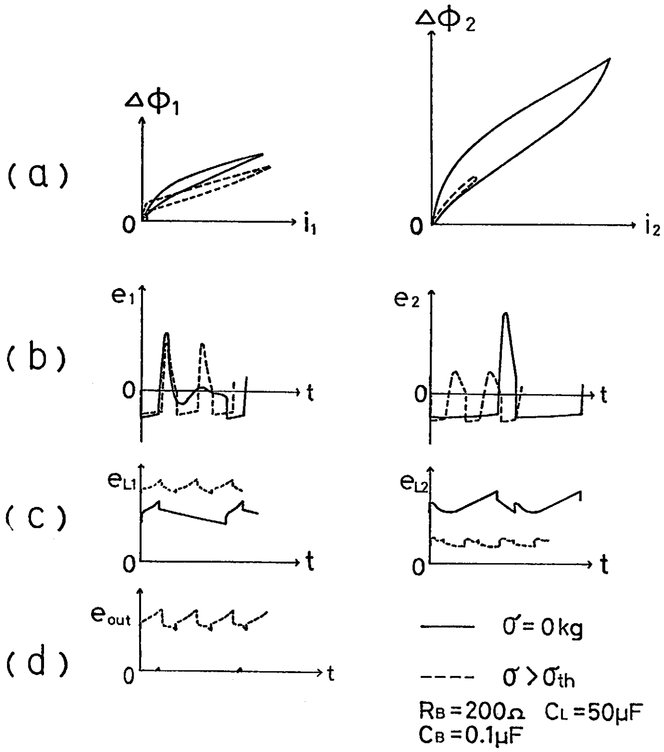


Fig. 11. Dynamic BH loops and voltage-wave shapes in digital-type transducer.

CONCLUSIONS

Amorphous magnetic alloys have inherent advantageous points over crystalline materials such as high tensile–strength and anti–corrosiveness due to its homogenity. So,application for high sensitive tensile–stress transducers is one of the most available ones of amorphous alloys.

New results obtained in this paper are as follows :

(i) New tensile-stress transducer using amorphous magnetic ribbon cores is presented. This transducer consists of "differencial–type" multivibrator with amorphous cores and two switching transistors, and has two kinds of transducing behaviors of "analog(linear)–type" and "digitel (threshold)–type" by adjusting the value of circuit parameters.

(ii) The properties of analog–type transducer are : good linearity, no zero output, no hysteresis, and dc output. The linearity of less than 2% is obtained in only this multivibrator for tensions under 7 kg. This linearity is improved to less than 0.2 % and the sensitivity to more than ten times by constructing a negative feedback system using an IC operational amplifier and feedback windings.

(iii) The properties of digital–type transducer are : $E_{dc} = 0$ for σ under σ_{th} ; E_{dc} jumps to its maximum value for over σ_{th}, and no hysteresis near small σ_{th}.

These jumping behaviors are emphasized by constituting a positive feedback system using a IC operational amplifier and feedback windings. That is, jumping lines are vertical and maximum value of E_{dc} becomes over 12 volts, and E_{dc} is constant for σ over descending threshold.

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