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Automatic Drift Compensation in dc Amplifiers

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The application of an automatic circuit for the periodical compensation of drift in dc amplifiers is described. The circuit consists principally of a relay and memory condenser and is analogous to that described by Offner [Rev. Sci. Instr. **25**, 579 (1954)]. The difference is mainly in the application. Whereas Offner used the circuit to restore the balance in differential amplifiers, here it is applied to the drift compensation of an unbalanced straightforward or feedback dc amplifier.

INTRODUCTION

Several methods for the elimination of drift in dc amplifiers are in general use. They are:

(a) Introduction of a chopper amplifier.[1] The dc signal is converted into ac by means of a mechanical chopper. The amplified ac signal is later synchronously rectified.

The main disadvantage of this arrangement is its narrow band width limited by the relatively low sampling frequency.

(b) Addition of another chopper amplifier in a common feedback loop with the main dc amplifier.[2]

The disadvantage of this solution, apart from the use of two amplifiers instead of one, is the fact that it can be applied only to feedback amplifiers with a high loop gain.

(c) Use of a special servomechanism actuated by the drift voltage during the time when the input is zero.[3]

None of these methods affords a simple and generally applicable solution.

A circuit for the automatic restoring of balance in dc differential amplifiers has recently been described.[4] The authors of the present paper have independently used for some time the same circuit for drift compensation. It compares favorably with the other arrangements in many practical cases where a short interruption of the output voltage is admissible.

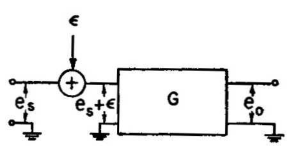

Fig. 1. Schematic diagram of uncompensated amplifier with drift represented by voltage ϵ at input.

PRINCIPLE OF STABILIZATION

Let e_s = input signal, e_c = output voltage, G = gain of the amplifier, ϵ = drift referred to the input, K = drift on the output terminals, and e_o = compensation voltage.

It is seen from Fig. 1 that

$$e_0 = e_sG + K = e_sG + \epsilon G. \quad (1)$$

Evidently the term $K=\epsilon G$ which appears in this expression is the unwanted drift component.

Referring now to Fig. 2, we see that the circuit of Fig. 1 is completed by adding the feedback loop and condenser C. Denoting the transfers from the input terminal 1 and condenser terminal 2 to the input of the amplifier 3, respectively, by G_1 and G_2, we have, for switch II open and switch I in position a,

$$e_o = [(e_s+\epsilon)G_1 + e_cG_2]G = e_sG_1G + e_cG_2G + K, \quad (2)$$

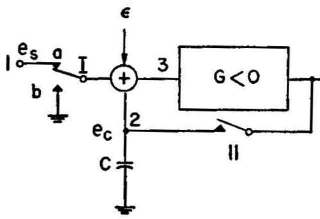

Fig. 2. Amplifier with addition of feedback loop, memory capacitor C, and switches, providing partial compensation of drift.

[1] Williams, Tarpley, and Clark, Trans. Am. Inst. Elec. Engrs. **67**, 47 (1948).
[2] E. A. Goldberg, RCA Rev. **11**, 296 (1950).
[3] S. Frost, Electronics **21**, 116–120 (July, 1948).
[4] F. F. Offner, Rev. Sci. Instr. **25**, 579 (1954).

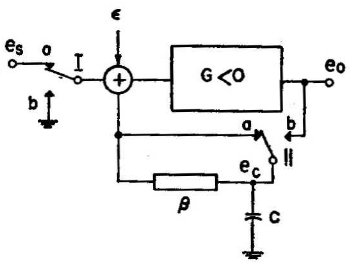

FIG. 3. Arrangement for full compensation of drift.

where $K=\epsilon G_1 G$ denotes the drift component in the output voltage.

Closing switch II and changing switch I to the position b will charge condenser C to the voltage

$$e_c=\frac{\epsilon G_1 G}{1-G_2 G}=\frac{K}{1-G_2 G}. \qquad (3)$$

Now, if we open II and change I to the position a, we get from Eqs. (2) and (3) the output voltage

$$e_o=e_s G_1 G+\frac{K G_2 G}{1-G_2 G}+K$$

or (4)

$$e_o=e_s G_1 G+\frac{K}{1-G_2 G}.$$

It is seen that the unwanted drift component $K/(1-G_2 G)$ is now $1-G_2 G$ times less than without the drift compensation.

The drift may be fully compensated by using the arrangement of Fig. 3. Here switch II of Fig. 2 has been replaced by a change-over switch, and an attenuator β inserted in the feedback loop.

When I is grounded and II is in the position b, the capacitor C is now loaded to a voltage

$$e_c=\epsilon G_1 G/(1-\beta G_2 G). \qquad (5)$$

Changing I to a and II to a results in the output voltage

$$e_o=(e_s+\epsilon)G_1 G+e_c G_2 G=e_s G_1 G+(\epsilon G_1+e_c G_2)G. \qquad (6)$$

For full compensation of the drift, the condition

$$\epsilon G_1+e_c G_2=0 \qquad (7)$$

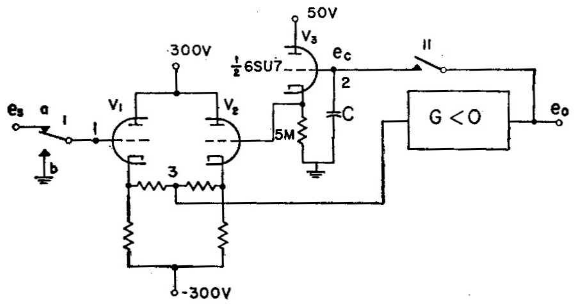

FIG. 4. Circuit employing scheme of Fig. 2.

must be fulfilled which, by taking Eq. (5) in account, gives

$$\beta=(1+G_2 G)/G_2 G. \qquad (8)$$

DESIGN CONSIDERATIONS

The circuit in Fig. 4 corresponds to the block diagram in Fig. 2. The input voltage e_s and the correcting voltage are applied to the grids of the two cathode followers V_1 and V_2. The weighted sum of both these voltages appears at point 3 and is applied to the input of the amplifier G.

The memory condenser C (Fig. 4) ought to have low dielectric absorption and high isolation resistance (e.g., polystyrene capacitor). This condenser is actually connected to the grid of an additional cathode follower V_3. This is done in order to decrease the charging effect of the grid current on the compensating voltage e_c.

The tube V_3 is of low grid current type (6SU7). Its anode voltage is chosen approximately 50 v and its cathode resistor is 5 meg. No current should be drawn from this cathode follower.[5]

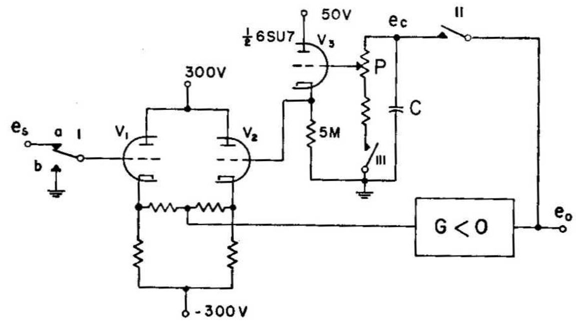

FIG. 5. Circuit giving full compensation of drift.

The circuit in Fig. 5 shows the refinements to be made for full compensation of drift. The attenuation factor β is adjusted to the value given by the formula (8) by means of the potentiometer P. Two switches II and III simultaneously closed or opened replace the change-over switch of Fig. 3.

A relay, not shown in the figures, is used to operate the switches. The relay may be energized both manually and automatically and special attention should be paid to minimize the interruption period.

The minimum interruption period is the time required for the charging of condenser C and depends both upon the output impedance of the amplifier and the value of the condenser used.

In a practical case, with C say 2 μf (large enough to minimize the charges caused by grid current) and a cathode follower output stage, this interruption can be limited to 3–4 msec.

In the cases discussed so far it was assumed that $G<0$ i.e., the output was assumed in phase opposition

[5] G. A. Korn and T. M. Korn, *Electronic Analog Computers* (McGraw-Hill Book Company, Inc., New York, 1952), p. 209.

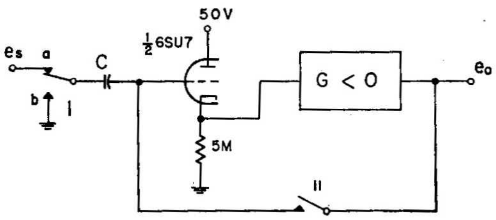

FIG. 6. Series compensation method.

with respect to the input. If on the contrary $G>0$ the tubes V_1 and V_2 may be connected as conventional amplifier stages in order to produce the needed over-all phase shift.

In a straightforward amplifier, a series compensation may be applied (Fig. 6). Grounding contact I and closing II causes the condenser to acquire the charge necessary for compensating the drift. The input tube must be a low-grid-current-type, e.g., 6SU7.

REMARKS

The method for drift compensation of dc amplifiers described in this paper has the following advantages:

(1) Between two consecutive interruption periods the compensated amplifier will reproduce a given wave form with the same fidelity as the uncompensated one.

(2) This method can be applied to both feedback and straightforward amplifiers.

(3) The additional apparatus needed for the automatic compensation is rather simple: it consists of relay, condenser, and timing device.

The drawbacks which might be mentioned are:

(1) The input must be periodically interrupted.

(2) The compensation is not continuous, thus only drift and noise with a large time constant may be eliminated.

The main applications of this method are: measuring and recording instruments, analog computers, and sampling amplifiers.

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Metal Foils as Filters in the Soft X-Ray Region*

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The paper describes the use of thin foils of Be, Mg, and Al as filters in the 50 to 500 A spectral region. Mention is made of various procedures for the preparation of plastic backing films. Included are illustrations which show how the metallic filters may be utilized to exclude visible light, to sort out overlapping orders, and to transmit narrow bands of radiation by reducing the intensity of undesirable portions of the spectrum. For each of the metals and for a plastic material (Zapon), plots showing the linear absorption coefficient as a function of wavelength are also given. The absorption curves facilitate the choice of the appropriate filter and its thickness.

INTRODUCTION

THIN deposits of Be, Mg, and Al may serve as filters in the soft x-ray region of the spectrum which extends from 50 A to 500 A. The authors have had occasion to use such foils in the study of solid state spectra and have found them to be convenient adjuncts in a variety of circumstances. These include: (1) the exclusion of visible light from the spectrograph, (2) the sorting out of higher-order overlapping spectra, (3) the reduction in intensity of undesirable spectral components such as impurity lines and the continuous background.

PREPARATION

Acceptable specimens of such filters may be prepared by the usual techniques of vacuum evaporation and procedural details need not be given here. These light metals are easily evaporated so that uniform deposits free from pinholes are obtainable if the usual precautions are observed. The coatings are not observed to deteriorate over a period of several months and are not excessively fragile. Metallic layers 500 A to 2000 A in thickness meet most requirements.

Generally the metal films require a backing layer for support. Certain plastic materials provide suitable substrates which are sufficiently strong yet tolerably transparent in the region of interest. Common substances[1] used for this purpose are; Zapon (cellulose acetate), Formvar (polyvinyl formal), Mylar (polyethylene tetra-

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[1] Zapon may be obtained from A. S. Lepine and Company, 6001 South Knox Avenue, Chicago 29, Illinois. Formvar is supplied by Shawinigan Resin Corporation, Springfield 2, Massachusetts. Sources for certain other plastics are listed in the *Handbook of Chemistry and Physics* (Chemical Rubber Publishing Company), thirty-sixth edition.