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Conversion-Type D.C. Amplifiers

By the Engineering Department, Aerovox Corporation

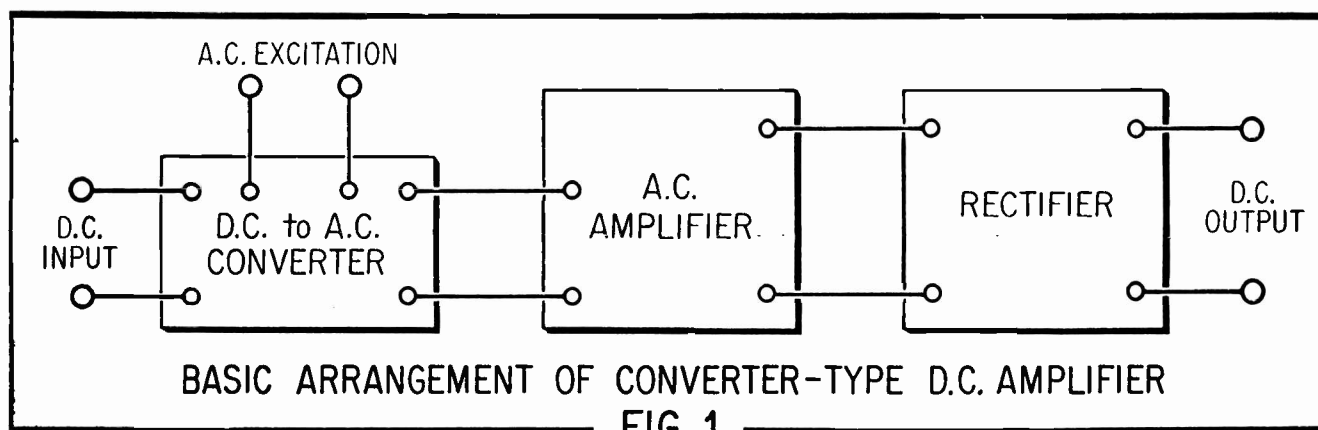
IN an effort to escape the instability and drift of conventional, direct-coupled d. c. amplifiers, various conversion-type amplifier circuits have been developed.

In these arrangements, illustrated by the block diagram of Figure 1, the d. c. to be amplified is applied first to a d. c. — a. c. converter. An a. c. excitation voltage also is

applied to the converter. The converter output is an a. c. having the same frequency as that of the excitation voltage but with an amplitude which is proportional to that of the applied d. c.

This output signal from the converter then is applied to a conventional a. c. amplifier which can be made quite stable by conventional

techniques. Both voltage gain and power gain may be provided by this amplifier. The voltage gain is chosen to give the desired signal set-up ratio, and the output power is selected for efficient driving of the output device. Rectification of the amplifier output recovers the d. c. Thus, the d. c. input signal effectively is amplified by a system which partakes

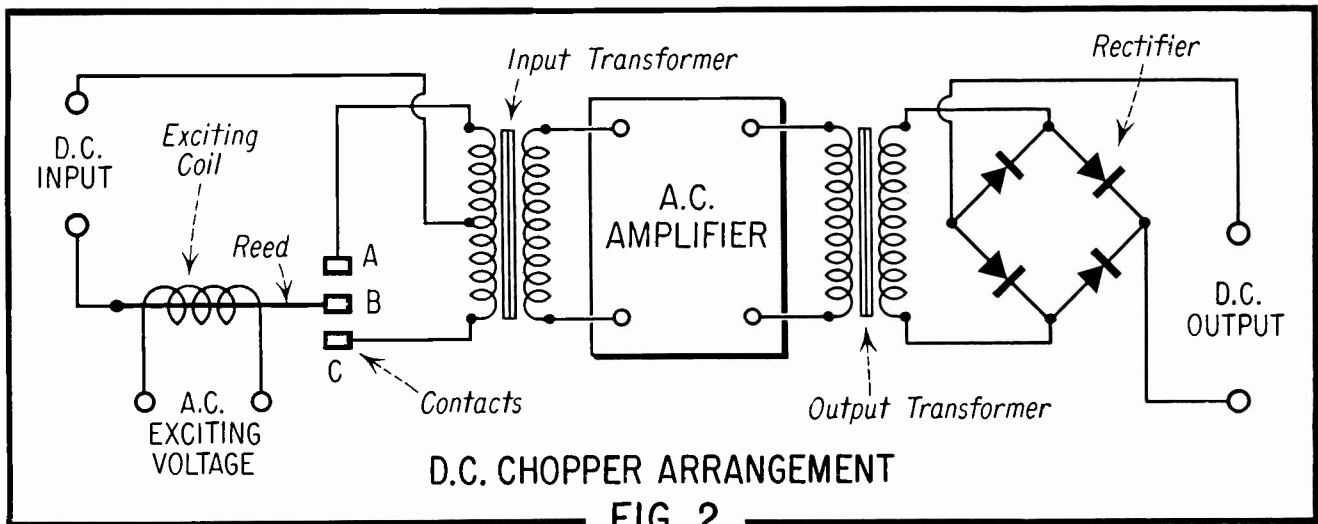


BASIC ARRANGEMENT OF CONVERTER-TYPE D.C. AMPLIFIER

FIG. 1

CORRECTION: Despite careful fact-findings, writing and editing, two errors crept into the December 1954 issue, entitled "Elementary Binary Arithmetic". In the table on page two, column three, $+ 0 \times 2^{-1} = 0$ making the correct total $100101.01 = 37.25$. In the table on page three, column two, $+ 1 \times 2^{-2} = 0.25$ making the correct total $10.01 = 2.25$.

Additional references on Binary Arithmetic are as follows: *High Speed Computing Devices* — by the Engineering Staff of Engineering Research Associates, (McGraw-Hill, N. Y.); *Calculating Instruments and Machines* — by D. R. Hartree (University of Illinois Press); *Number, the Language of Science* — by Tobias Dantzig (McMillan, N. Y.); *Introduction to the Foundations of Mathematics* — by Raymond L. Wilder (Wiley, N. Y.); and *New Numbers* — by F. Emerson Andrews (Essential Books, N. Y.).



of the high stability of the a. c. amplifier.

Conversion-type d. c. amplifiers presently are in use in science and industry to amplify the tiny d. c. output of such devices as strain gages, thermocouples, self-generating photocells, accelerometers, Ph meters, and moisture sensors. These amplifiers may be employed to actuate either recording or indicating instruments or electromechanical control devices.

Details of Operation

Various types of d. c. - a. c. converters are employed in conjunction with conventional a. c. amplifiers. The representative ones are described in this article.

The a. c. excitation voltage may be derived from the tube-filament circuit of the amplifier section or may be supplied from a separate source.

The excitation frequency sets the minimum transient response time of the system. For this reason, the filament-source frequency often is too low to be useful, and excitation must be obtained from some higher-frequency source. Response time also depends upon the time constants of the various coupling networks within the system.

The amplifier section may utilize a standard audio circuit (either RC- or transformer-coupled) for use at excitation frequencies between 20 and 20,000 cycles, but must be a radio-frequency amplifier when extremely rapid d. c. fluctuations must be accommodated and the excitation frequency accordingly must be extended into the kilocycle or megacycle region. The amplifier design is simplified, however, by the fact that this unit is essentially single-frequency in operation.

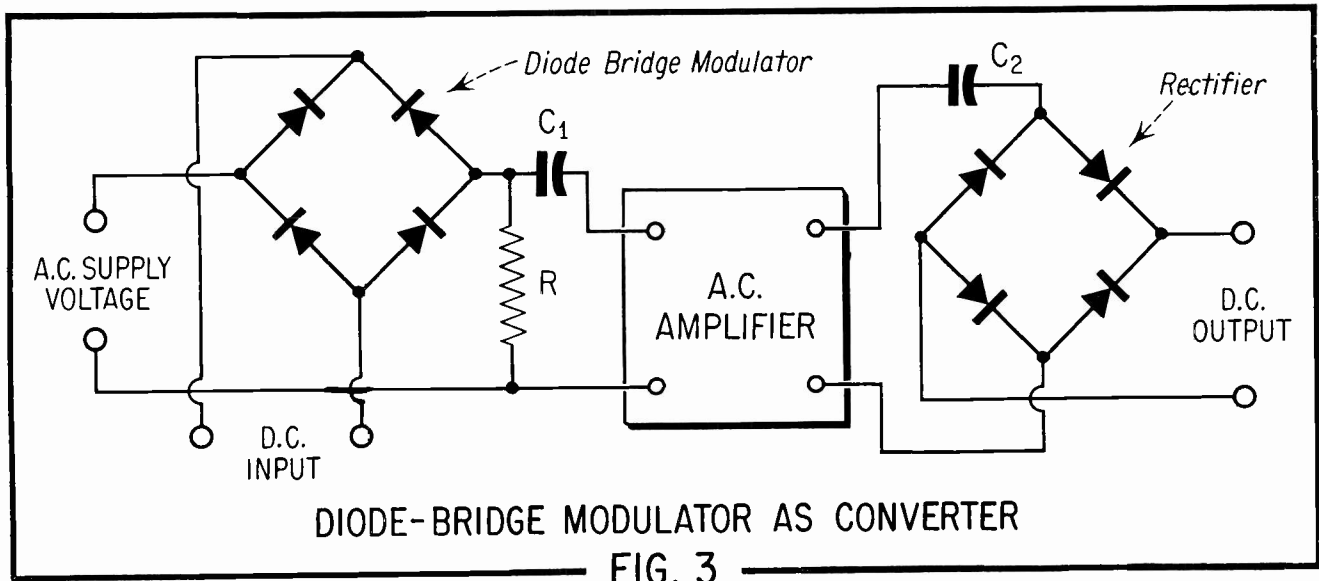
After a. c. amplification, the signal is rectified. The rectified section may take any one of the several conventional forms — from simple half-wave to voltage multiplication. Also, the rectifier may be transformer-coupled or capacitance-coupled to the amplifier output. Figures 2 to 7 show full-wave bridge rectifiers for illustration. When non-pulsating d. c. output is desired, the rectifier output may be filtered with either RC or LC networks.

Configurations of Systems

Figures 2 to 7 show various arrangements for conversion-type amplifiers. These will be described separately.

D. C. Chopper Converter. Figure 2 shows the arrangement which perhaps is in widest use at the time of this writing.

The converter is a "full-wave" vi-



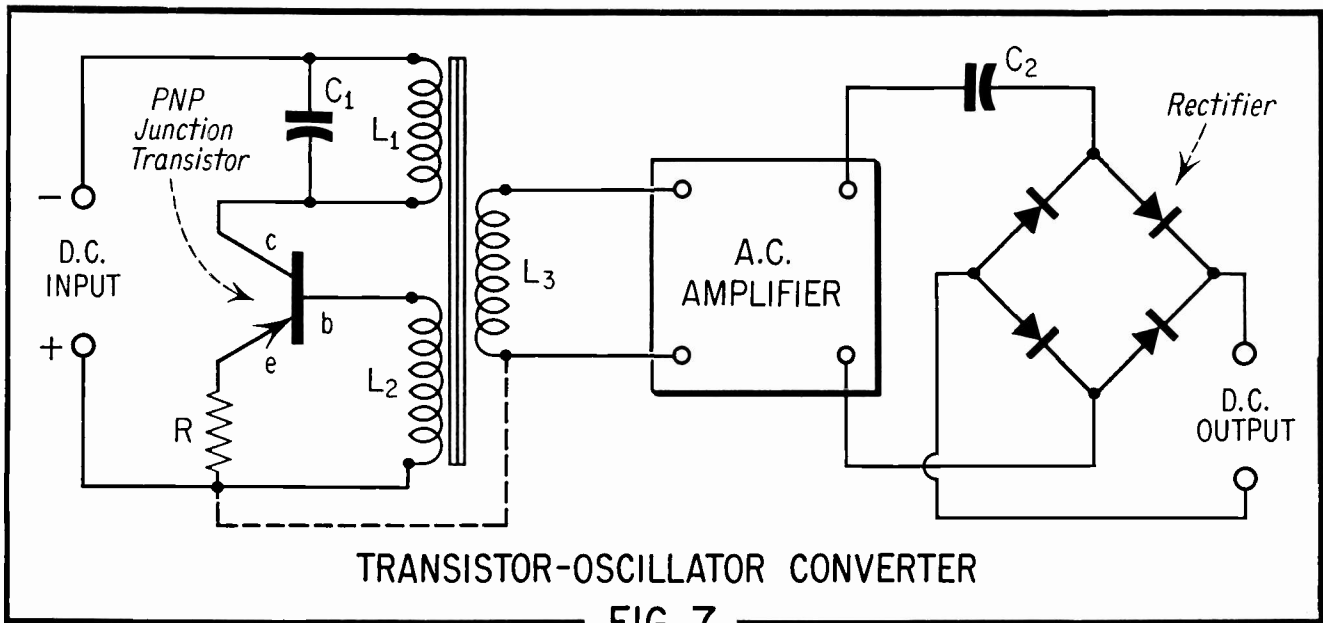


FIG. 7

and sub-subouncer series, having special alloy cores, are suitable for this application. L_1 and L_4 are primary windings (lesser number of turns), while L_2 and L_3 are secondaries (greater number of turns).

The secondaries are connected to buck, so that any a. c. induced in one by alternating current flowing through the paralleled primary windings (L_1 and L_4) will be cancelled by an identical a. c. induced in the other. In this way, no a. c. appears at the D. C. INPUT terminals.

This converter operates in the same general manner as the one shown in Figure 4. That is; the direct current flowing in L_1 and L_4 causes varying amounts of core saturation and thus alters the impedance of the a. c. windings L_2 and L_3 . This action causes a variation of alternating excitation current flowing through L_2 , L_3 , and resistor R. The a. c. signal voltage across R thus is proportional to the applied d. c.

The converter-output a. c. signal voltage is coupled, through capacitor C_1 , into the a. c. amplifier channel. Transformer coupling also can be employed without somewhat greater complexity.

The advantages and limitations of this converter are identical with those of the unit shown in Figure 4 and described in the preceding Section.

Tube Bias-Type Converter. The d. c. signal to be amplified may be employed to vary the control grid bias of the input stage of the a. c. amplifier section and thereby to yield an a. c. output voltage proportional to

the applied d. c. The a. c. amplifier is assumed to be transmitting a signal derived from the a. c. excitation source. This scheme is illustrated in Figure 6.

Here, the major amount of bias is developed by the input-stage cathode resistor, R_3 . The d. c. input signal voltage is applied across R, in series with the self bias of the tube. A. C. excitation voltage is applied through coupling capacitor C_1 . The filter network, LC., prevents this a. c. from reaching the D. C. INPUT terminals.

The a. c. excitation is a constant voltage, usually of millivolt level. As the d. c. input signal varies, the grid bias is shifted, and amplification of the excitation signal varies proportionately.

This system has the advantage of relative simplicity. It may be applied readily to an existing a. c. amplifier, occasioning few circuit alterations. It requires some care, however, in the selection of the static bias level, in order that changes resulting from input d. c. signal fluctuations might produce linear variations in a. c. output amplitude over a desired range. A particular advantage of this system is its adaptability to r. f. as well as a. f. amplifiers. At radio frequencies, rapid fluctuations in the d. c. input signal can be followed. In this case, the a. c. excitation voltage would be supplied by a radio-frequency generator.

Transistor - Oscillator Converter. Junction transistors will oscillate at audio frequencies down to very low levels of d. c. collector voltage and at only a few microwatts of collect-

or power. An interesting d. c. — a. c. converter can be made by using the d. c. signal voltage as collector supply voltage for the transistor. The strength of oscillation, and thus the a. c. output, will be proportional approximately to the d. c. voltage. This scheme is illustrated by Figure 7.

The transistor is connected in a common-emitter, tickler-feedback type of audio oscillator circuit. The operating frequency is determined former winding L_1 and the shunt chiefly by the inductance of trans-capacitance, C_1 . The third winding, L_3 , serves as output coupling.

The circuit is inoperative until a d. c. signal is applied. Indicated polarity of the D. C. INPUT terminals is correct for PNP junction transistors. The polarity must be reversed for NPN junction transistors. Point-contact transistors are not suitable for this circuit or application, since they will not oscillate at the very low d. c. voltages applied to the D. C. INPUT terminals. The input d. c. signal is the only transistor voltage required!

This type of converter has the advantages of small size and compactness. It may be built into a small container and mounted at the front end of the a. c. amplifier. Its disadvantage is temperature sensitivity of the transistor characteristics. However, this is compensated to a degree by the emitter degenerative resistor, R, which serves to stabilize the oscillator output not only against temperature effects but also against variations in individual transistor replacement units.

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