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Volume Compressors and Expanders
Robert F. Scott
Radio Electronics March 1953

Volume Expanders and Compressors

By ROBERT F. SCOTT

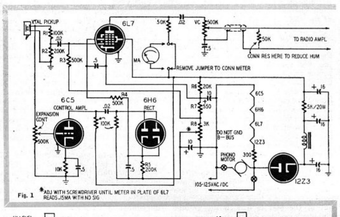

Fig. 1

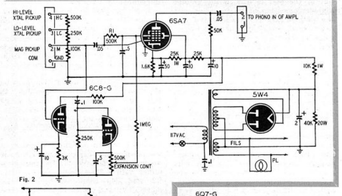

Fig. 2

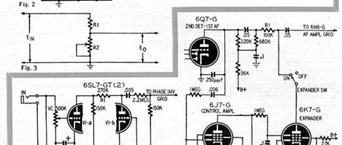

Fig. 3

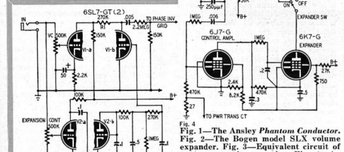

Fig. 4

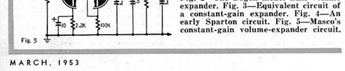

Fig. 5

Fig. 1—The Ansley *Phantom Conductor*. Fig. 2—The Bogen model SLX volume expander. Fig. 3—Equivalent circuit of a constant-gain expander. Fig. 4—An early Sparton circuit. Fig. 5—Masco's constant-gain volume-expander circuit.

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The tap on R8 is adjusted so the 6L7 plate current is 150 microamperes with no signal input. The setting of the expansion control determines the amount of signal applied to the 6C5 and subsequently, the amount of dynamic d.c. bias applied to grid 3 of the 6L7.

Ansley Phantom Conductor

Fig. 1 is the circuit of the Ansley model DA-PC *Phantom Conductor*, a volume expander similar to the one which was described in several editions of the RCA Receiving Tube Manual. This unit is designed for use between a crystal pickup and audio amplifier.

The variable-gain expander tube is a 6L7 pentagrid mixer, a tube designed for superheterodyne circuits having separate oscillators and for other applications where dual gain control circuits are desired in a single tube. In audio applications, grids 1 and 3 may be used as separate control grids. The amplification of a signal applied to either grid can be controlled by varying the bias voltage applied to the other grid.

The full output of the pickup is developed across the expansion control and R1 and R2 in series. A portion of the a.f. signal is tapped off the junction of R1 and R2 and is applied to the signal grid (grid 1) of the 6L7. Operating voltages for cathode and signal grid are taken from taps on a voltage divider consisting of R6, R7, and R8. The bias voltage for the injector grid (grid 3) is obtained from a movable slider on R8 and is applied to it through R4 and R5 in series.

The signal appearing across the expansion control is amplified by the 6C8 control amplifier and then rectified by the 6H6. When the 6H6 conducts, it develops a positive voltage across R5 which adds to the fixed bias to reduce the potential difference between grid 3 and the cathode and to increase the amplification of the signal applied to grid 1.

Bogen model SLX expander

The Bogen model SLX expander shown schematically in Fig. 2 is fundamentally similar to the unit shown in Fig. 1. A 6SA7 replaces the 6L7 as the variable-gain amplifier. One triode of the 6C8-G replaces the 6C5, the other has its plate and grid strapped together as a substitute for the 6H6.

In this unit, the signal voltage is applied to grid 1 of the 6SA7 and to the control grid of the triode section of the 6C8-G. The dynamic bias voltage from the rectifier is applied to grids 1 and 3 to provide a greater control over the available amplification. The 0.5-μf capacitor bypasses the a.f. voltage to ground so it will not reach grid 3. The 500,000-ohm resistor R1 isolates the grids and prevents the a.f. signal on grid 1 from being bypassed to ground.

Single-ended variable-gain volume expanders produce a peculiar form of distortion when the incoming signal is modulated by the ripple and harmonic content of the dynamic bias developed by the control rectifier. Ripple and harmonics cannot be readily removed from the bias signal by filtering because this increases the time constant of the circuit to the point where the expander will not follow staccato passages.

To eliminate this effect and to permit the use of a short time constant, Amplifier Corp. of America has used a circuit which is basically a push-pull version of the single-ended expanders in Figs. 1 and 2. A push-pull audio signal is applied to the control grids in each of the push-pull variable-gain tubes and the dynamic bias is applied to the tubes in parallel. In this way, transients, ripple, and harmonics are balanced out because they are in phase on the grids and out of phase in the plate circuit. A modern version of the push-pull expander is used in the model 100-DC amplifier produced by Amplifier Corp. of America.

Constant-gain expanders

In a constant-gain variable-output expander, the output of a constant-gain stage is applied to a voltage divider in which one element is variable from zero to infinite resistance. The principle of this very interesting type of expander is illustrated by Fig. 3. The input voltage (from a constant-gain source) is applied across a voltage divider consisting of R1 and R2. The output voltage E_o can be varied from approximately E_{in} when R2 is infinite to zero when R2 is zero. In practice, R2 is replaced by the plate-cathode resistance of a vacuum tube. A control amplifier and signal rectifier supply dynamic bias to the tube represented by R2.

Fig. 4 shows the volume expander used in the Sparton 82TX, 997X, 1167 and similar receivers, which were manufactured about 15 years ago. A part of the voltage output of the 6Q7 is fed into the grid of the 6J7 expander-amplifier (control tube) which is biased to cutoff by returning its grid to the center tap on the power transformer.

The plate of the 6J7 is coupled directly to the suppressor grid of the 6K7 expander stage through a 1-megohm resistor. The control grid of the 6K7 is tied to the suppressor through a filter consisting of 0.2- and 0.5-μf capacitors and a 470,000-ohm resistor. The time constant of this filter network permits only very large changes in 6J7 plate current to affect the grid voltage of the 6K7.

The 6K7 and 6J7 are connected in series across the B supply. The 6J7 plate receives much of its voltage from the 470,000-ohm resistor connected to the 6K7 cathode. The voltage drop across this resistor biases the suppressor of the 6K7 expander tube.

Since the 6J7 expander amplifier is biased to cutoff, a fairly large signal must be applied to its grid to produce an appreciable change in plate current. With low signals, the 6J7 remains cut off, and there is no voltage drop across the 470,000-ohm plate resistor. Since there is no voltage drop across the resistor, the 6K7 suppressor is at cathode potential and the tube conducts heavily. Under these conditions, the plate-cathode resistance of the 6K7 is low compared to R1 and much of the output of the 6Q7 is lost in the voltage divider consisting of R1 in series with the plate-cathode resistance of the 6K7.

On loud passages, the 6J7 draws heavy current and the voltage drop across the 470,000-ohm plate load resistor is sufficient to place a heavy bias on the suppressor of the 6K7. This increases the plate-cathode resistance of the 6K7 and permits a greater voltage to be fed to the grid of the 6N6 a.f. amplifier.

Masco constant-gain circuit

Fig. 5 shows a simpler version of the variable-output constant-gain expander circuit, as used in recent Masco amplifiers. V1-a and V2-a are conventional voltage amplifiers. V2-b is the bias rectifier, and V1-b is the expander tube whose plate-cathode resistance is represented by R2 in Fig. 3.

When the signal applied to the grid of control amplifier V2-a is low, the dynamic bias voltage developed by V2-b is not high enough to cause a substantial increase in the plate-to-cathode resistance of V1-b. The resistance of V1-b is low and a large part of the signal developed in the plate circuit of V1-a is dissipated across R1. When a strong signal reaches the grid of V2-a, the dynamic bias reduces the plate current and increases the internal resistance of V1-b so that a greater portion of the output of V1-a reaches the grid of the following stage. The attack and release times of the expander are determined by the charge and discharge time-constants of the capacitors connected between the plate of the rectifier V2-b and the grid of V1-b.

Inverse-feedback expanders

If inverse feedback is applied to one or more stages in an amplifier, the gain of these stages may be varied by varying the feedback voltage. Fig. 6 is the diagram of the Thordarson T-31W11 and T-31K11 audio amplifiers designed for use with a radio tuner. These units use an inverse-feedback type of expander.

The output of V1-a is applied simultaneously to the variable-gain stage V1-b and to control-voltage amplifier V2-a. V2-b is a half-wave shunt rectifier connected to develop a positive output voltage. This voltage is filtered by R1, R2, and C1 and fed to the paralleled grids of V3, the feedback control stage, which is initially biased to cutoff by a positive voltage on its cathode taken from the 6B4 bias resistor.

The cathode of V1-b is unbypassed and its grid is returned to a point on the cathode biasing resistor. This causes degenerative feedback which reduces the gain of the stage to a level considerably below that which would be obtained without feedback. The amount of feedback depends on the a.c. cathode impedance of the stage.

The plate-to-plate impedance of V3 is reflected into the secondary of T1 which parallels the cathode resistance of V1-b. When V3 is cut off, its plate-to-plate impedance is so high that it has little or no effect on the cathode impedance of V1-b.

When the positive dynamic bias voltage on the grids of V3 reaches a point which permits conduction, the plate-to-plate impedance drops. Since this impedance is in parallel with the cathode impedance of V1-b, the amount of cathode feedback decreases and the gain of V1-b rises.

The grids of V3 are fed in parallel and the plates work in push-pull. In this way, the feedback control stage effectively eliminates thumps and transients which would normally be caused by rapid rises in the dynamic bias voltage.

Fig. 7 shows another Thordarson inverse-feedback expander circuit. In it we have a two-stage variable-gain amplifier with a 25-*db* feedback loop (R1, R2, and C1) connected between the plate of V2 and the cathode of V1. The secondary of the feedback control transformer is connected between ground and the junction of R1 and R2 to form a T network.

The control amplifier circuit is similar to that used in Fig. 6. However, this circuit was used in a recording-playback amplifier so it incorporates volume compression as well as expansion. The control amplifier V3-a is connected to the phono-radio input when used as an expander and to the second variable-gain stage when used as a compressor. This switching is handled by section S1-b of the EXPAND-COMPRESS switch. Switch sections S1-a, S1-c and S1-e reverse the polarity of the rectifier and cut in separate filter circuits for compression and expansion.

When the switch is set for expansion, the rectifier V3-b develops a positive control bias and V4 is biased to cutoff. When the input signal level is low, little or no voltage is developed by the control rectifier and the plate-to-plate impedance of V4 is high. This high impedance is reflected into the secondary of T1,

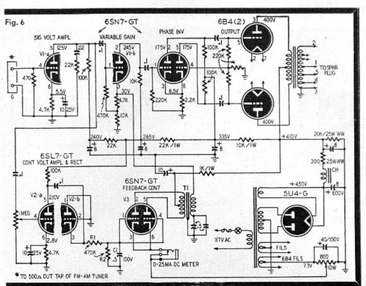

Fig. 6

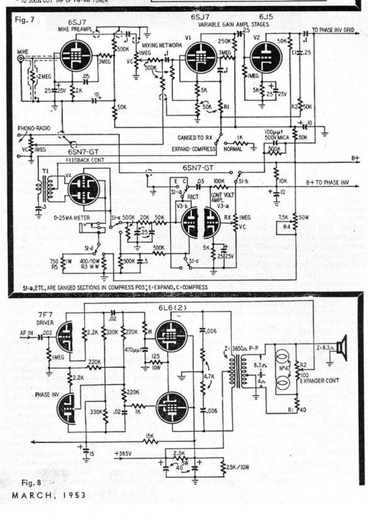

Fig. 8

Fig. 6—The schematic diagram of the Thordarson model T-31K11 and T-31W11 amplifiers using an inverse-feedback type volume expander. Fig. 7—Another adaptation of the Thordarson inverse-feedback expander. Fig. 8—A lamp-operated type of inverse feedback volume expander used in Sears Roebuck Silvertone type 8160 audio amplifier.

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where it forms a high-impedance shunt path in the inverse-feedback loop.

A sudden rise in signal voltage produces a high positive bias voltage at the output of V3-b. The positive voltage on the grids of V4 causes the plate-to-plate impedance to drop and lower the impedance reflected into the secondary of T1. This decreases the impedance of the shunt leg of the T, reduces the voltage fed back to the cathode of V1 and allows the gain to rise.

When the circuit is used as a volume compressor, the cathode biasing voltage across R5 limits the total plate current of V4 to about 16.5 ma and keeps the plate dissipation just within its maximum permissible value. The high plate current results in a very low plate impedance being reflected into the shunt leg of the T feedback loop. This reduces the voltage being fed from the plate of V2 to the cathode of V1 so the amplification of V1 and V2 is about normal.

When the audio signal rises above a given level, V3-b develops enough *negative* bias voltage to reduce the plate current and increase the plate-to-plate impedance of V4 and the impedance that is reflected into the shunt leg of the feedback loop. The increase in the shunt impedance increases the feedback voltage and causes a corresponding decrease in the gain of V1.

The attack-time of the compressor is about .03 second and the decay time is 0.25 second. This compares favorably with the 0.25-second attack and decay times of the expander circuit. The decay or *hangover* time of the expander circuit can be increased by replacing the 500-000-ohm bleeder resistor with a higher resistance.

A 1,000-ohm resistor is switched into the circuit to replace the secondary of T1 when the EXPAND-COMPRESS-NORMAL switch is turned to NORMAL.

Lamp-operated expander

Fig. 8 shows the novel inverse-feedback volume expander circuit used in the Silvertone model 8160 audio amplifier. Inverse feedback for the cathode of the driver stage is obtained from a voltage divider (R1 and R2) across the secondary of the output transformer. R2 is paralleled by two type 47 pilot lamps in series. When the signal level is low, there is comparatively little voltage across the lamps and their resistance is low enough to practically short-circuit R2 and permit maximum voltage to be fed back into the cathode of the driver stage. Loud passages increase the voltage in the transformer secondary and cause the lamps to heat. Their resistance rises and decreases the amount of feedback applied to the driver cathode.

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