THE SHEET BEAM TUBE AS A GAIN CONTROL DEVICE

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PREFACE

The use of a new product in an area for which it was not designed has been and always will be a challenging goal for any design engineer. This thesis is a product application project which applies a new product to an area in which its function is not new, but its use extends the limits of operation.

The primary object of this thesis is to apply the 6AR8 sheet beam tube as a gain control device. However, since the area of gain control devices is large, it was decided to select a low frequency gain control device for the area of investigation and to show how it may be applied in other areas.

In order to comprehend the material covered in this thesis, a basic understanding of electronics is necessary. The reader also should be familiar with low frequency amplifiers and feedback networks.

The author wishes to gratefully acknowledge the encouragement and support of Professor Paul A. McCollum. A special note of thanks goes to my wife, Janet, for her hard work and encouragement throughout my college career and for her help in typing and preparing this manuscript.

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CHAPTER I

INTRODUCTION

The ability of modern conventional compressors to perform over a wide range of compression without resulting in distortion of the signal being compressed is sometimes limited. There is a need in many areas of industry for a compressor which has a very large range of compression. This thesis reflects how this might be accomplished by the application of a new type of electronic tube as the heart of a compressor.

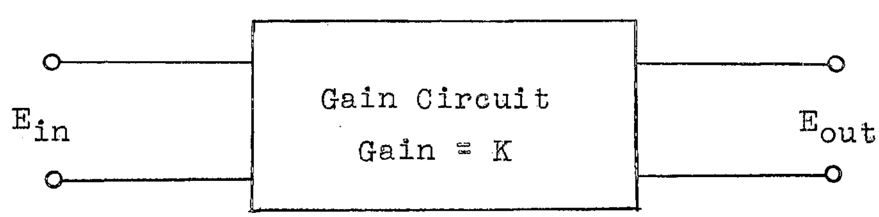
The function of the 6AR8 sheet beam tube as a compressor is one of a gain control device. The tube's ability to operate as a variable gain device, when the electron beam is switched from plate to plate by deflector voltage control, makes it adaptable as a compressing function amplifier. This electron beam switching principle is the heart of the compressor that will be studied and developed.

The need for a wide range compressor is especially critical in the areas where the signal level input cannot be set by manual operation to some optimum level for the conventional compressor to perform its function. One such area would be in seismograph work where the "shot" vibrations reaching the geophones vary over an extremely large range of signal levels. If the level varied over 60 to 80 db, many compressors could not handle this extreme range, and elaborate electronic gear would have to be built to record the full signal.

This thesis proposes the use of the special electronic sheet beam tube as a compressing amplifier in hopes of extending the ranges of compression obtainable for large varying signals. Basically, the tube operates as an active gain control device.

Gain Control Theory

A gain control device of any type can be described as a transfer function, as seen in Figure 1. The input signal level is referred to as E_{in} and denotes a magnitude of some type of voltage. The output voltage level is E_{out}, and also denotes the magnitude of some type of voltage. The ratio between these two voltages is denoted as the transfer function, K.

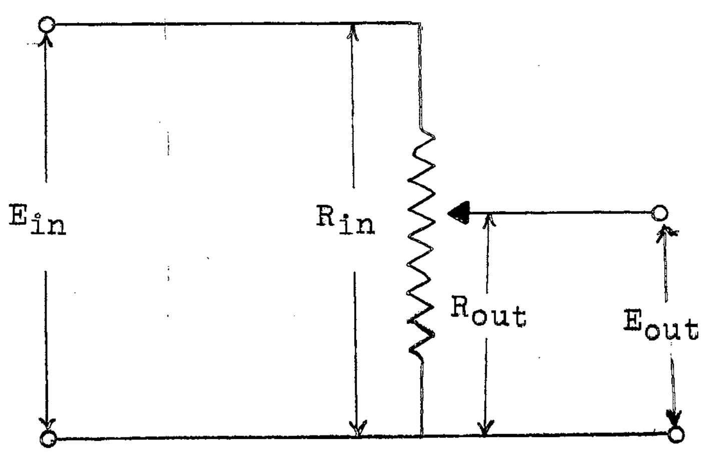


$$\frac{E_{out}}{E_{in}} = K \quad (1)$$

Figure 1. Block Diagram of General Transfer Function.

The transfer function, K, can be either a passive element or an active element. The nature of this element determines the relationship between the output voltage, E_{out}, and the input voltage, E_{in}.

Consider the transfer function to be a passive type element. A simple example of a passive type gain control device might be as shown in Figure 2. The operation of this circuit results in only amplitude control (gain). The output voltage, E_{out}, is identical in waveform to the input voltage, E_{in}, but is smaller by the ratio of $\frac{R_{out}}{R_{in}}$. If R_{out} equals R_{in}, the two voltages are identical, which is the case when the potentiometer arm is moved all the way up.



$$\frac{E_{out}}{E_{in}} = \frac{R_{out}}{R_{in}} \quad (2)$$

Figure 2. Simple Passive Type Gain Control Circuit.

A graph of the output voltage variation as a function of the ratio, $\frac{R_{out}}{R_{in}}$, results in a linear curve, as can be seen in Figure 3. Therefore, the gain control device is not only passive, but is linear.

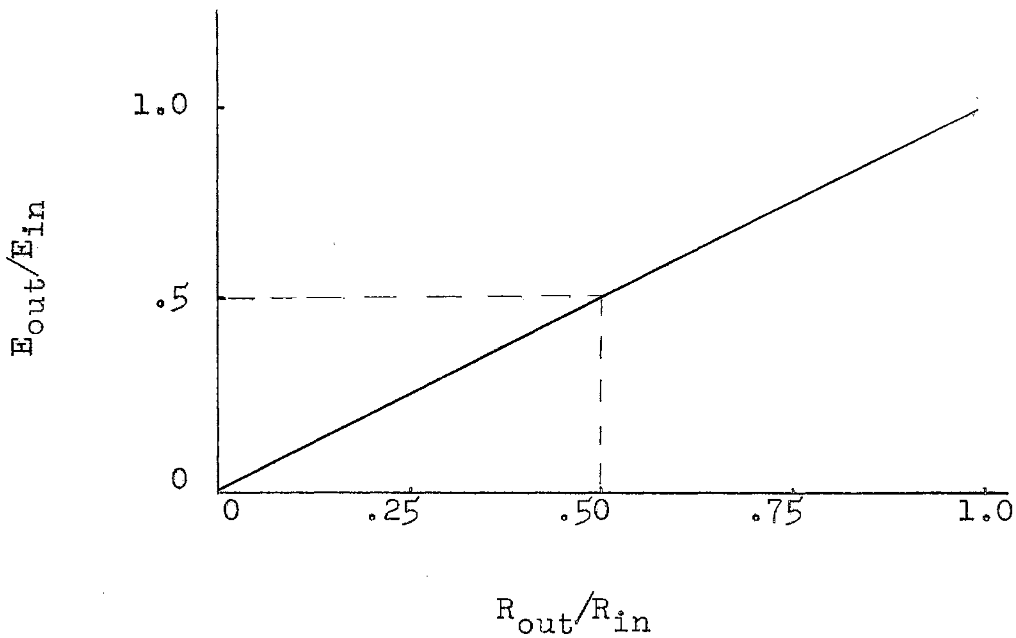


Figure 3. Output Voltage to Input Voltage Ratio as a Function of the Ratio of Output Resistance to the Input Resistance of the Circuit Shown in Figure 2.

The characteristics of the gain control device determine the relationship of the output voltage to the input voltage, but to assume that all gain control devices that are passive are linear would be in error. The passive class of gain control devices could be pursued further and in more detail, but, for the problem at hand, the consideration of active gain control devices is more pertinent, and will be reviewed in more detail.

An active gain control device can also be associated with the general transfer function depicted in Figure 1. A simple and active gain control device might be realized as shown in Figure 4. The relationship between E_{out} and E_{in} in the general case was referred to as K. In Figure 4, the gain function, K, is equal to $-\mu R_L/[r_p + R_L + R_K(1-\mu)]$.[1]

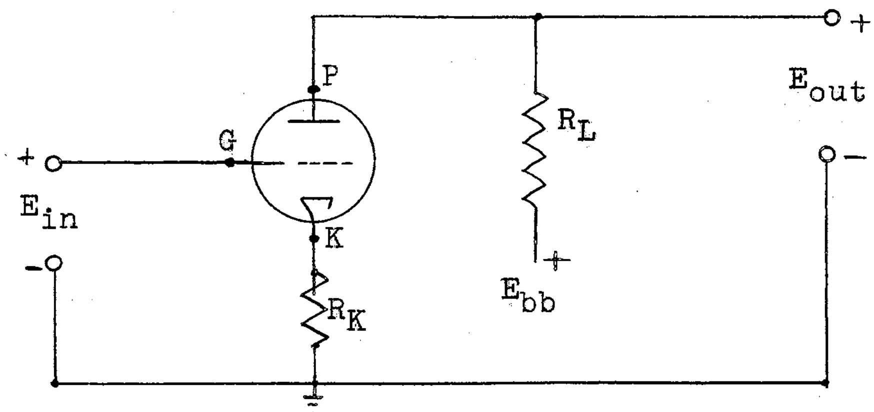


Figure 4A. Triode Amplifier Circuit.

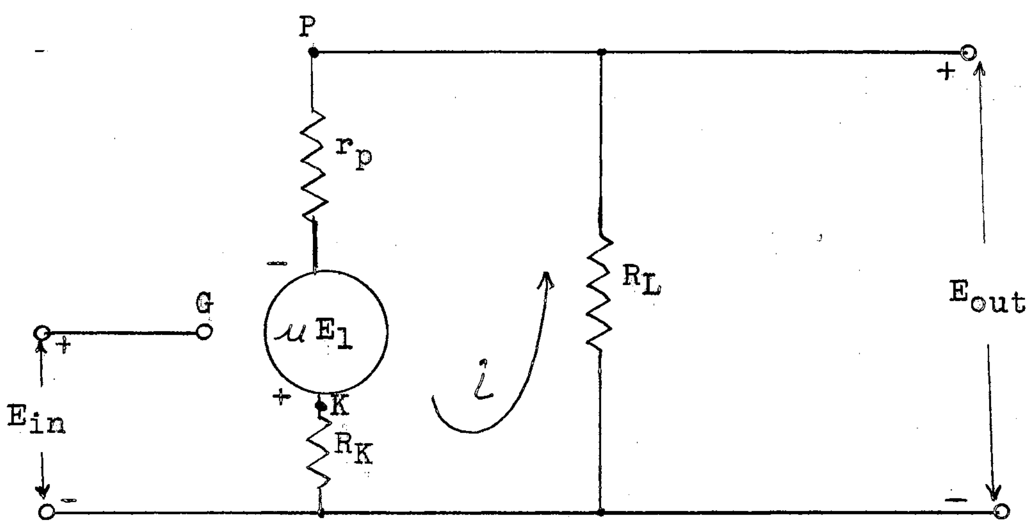


Figure 4B. Triode Amplifier Equivalent Circuit.

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[1] Wilbur R. Lepage and Samuel Seely, <u>General Network Analysis</u> (New York, 1952), p. 51.

R_L is the value of the load resistance in ohms, and R_K is the value of the cathode resistance in ohms. The dynamic amplification factor, μ, of the tube is dimensionless, and is equal to the negative of the ratio of the change in plate voltage for a given change of the grid voltage for a constant plate current. The dynamic plate resistance, r_p, in ohms is equal to the value of the ratio of the change in the plate voltage for a given change in the plate current for a constant value of grid voltage.

Assume that E_{in} is a sinusoidal varying voltage and that the tube is a 6J5. A typical value for μ is 20, and the dynamic plate resistance, r_p, is equal to 7,000 ohms.[2] Selecting a value for R_L of 20K, and 3K for R_K, K then becomes -4.45. Thus, the output voltage is shifted in phase by 180° (out of phase) from the input voltage, and 4.45 times greater than the input voltage.

The active circuit of Figure 4A could, in general, be considered a variable gain device, since any of the parameters associated with its transfer function could conceivably be varied. If the gain was to be controlled by some automatic means, then it would be more appropriate to vary some electrical parameter, such as μ.

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[2]RCA Receiving Tube Manual, Technical Science Series, RC-18, p. 192.

Compressing Amplifier Function

A compressor amplifier is a special gain control device that limits the output signal level to some predetermined maximum value. In practice, it usually does not limit the output signal level to one fixed value for all input signal levels, although this would sometimes be a very desirable feature.

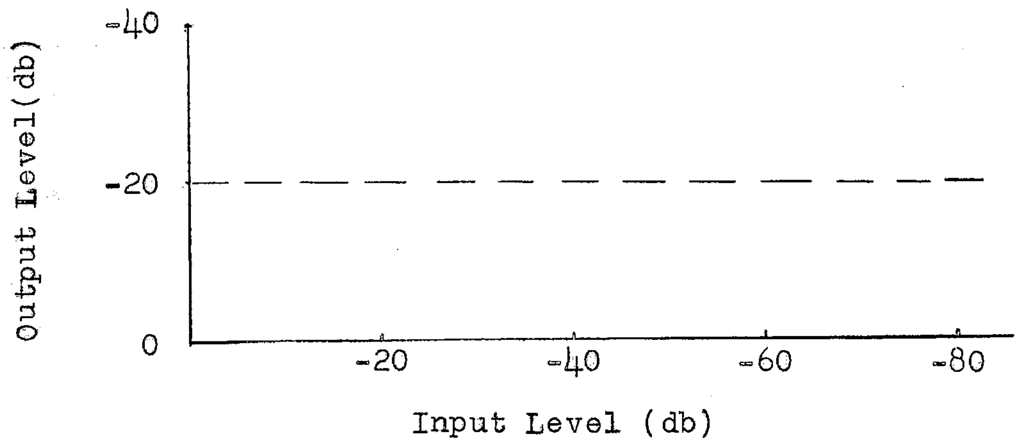

Figure 5. Ideal Compressor Characteristics.

A compressor, capable of holding the output signal level constant for all ranges of input signal, would have a response function similar to Figure 5. The compressor, which can perform in this manner would be an ideal compressor, since no limitations are imposed upon the nature of the input signal. (In the high-quality reproduction of speech and music, this extreme characteristic would not be too desirable because it would deteriorate the realism of the sound.) Furthermore, the magnitude of the output level would not be critical to the operation of the circuit as a compressor. The transfer function for such a compressor can be generalized as shown in Figure 6. The gain of the ideal circuit must vary inversely as a function of the input signal level to maintain a constant output level. The characteristics of the gain as a function of the input signal level would be similar to that shown in Figure 7. The gain must approach infinity for low levels of input and must approach zero for high levels of input signals. This circuit, while accomplishing the ultimate in compression, would be physically impossible to realize in terms of circuit elements. A more practical compressor, which could be physically realized, would have a characteristic similar to Figure 8.

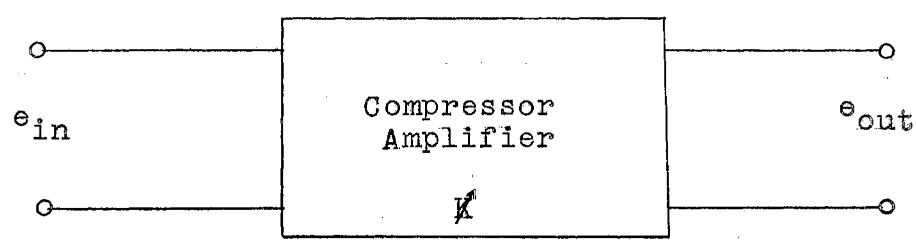

Figure 6. Basic Compressor Block Diagram.

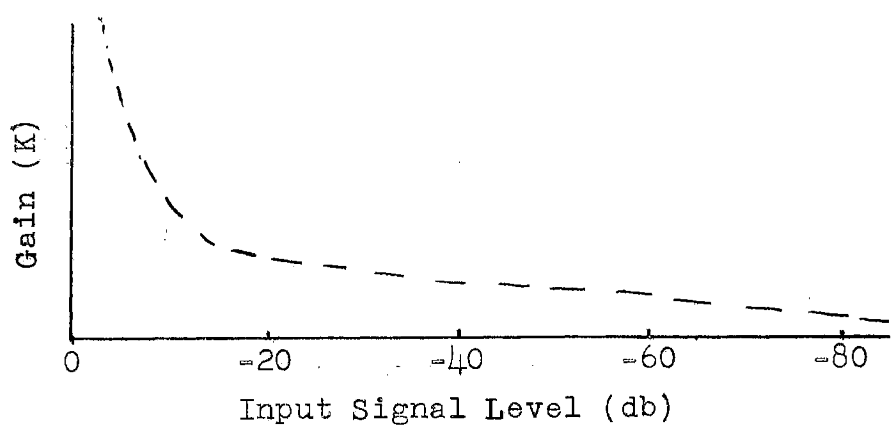

Figure 7. Gain as a Function of Input Signal Level for the Ideal Compressor.

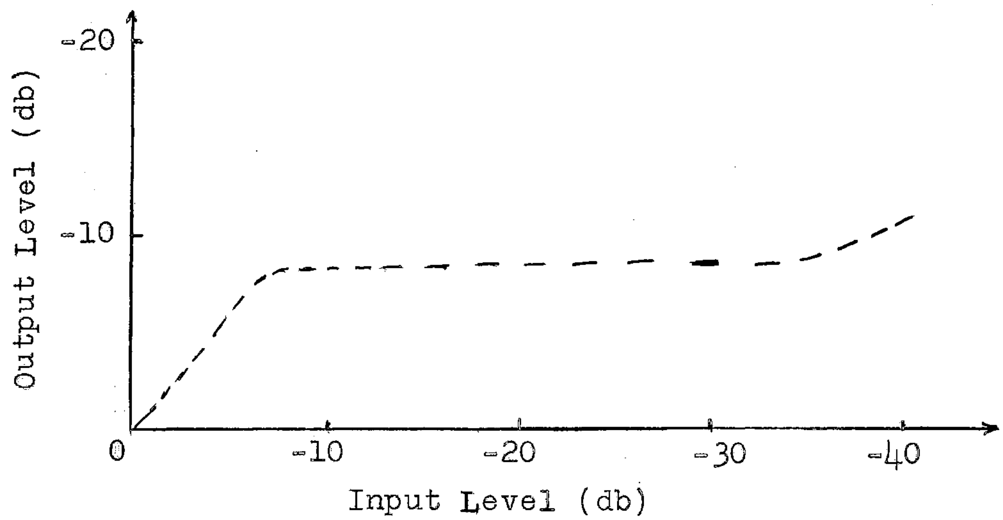

Figure 8. Typical Compressor Response Function of Output Level Versus Input Level.

This typical compressor operates as a conventional amplifier for low level signals, but limits or compresses the amplification of high level signals over a representative maximum range of 25 to 35 db. When the input signal level exceeds the normal maximum high level, then the compressor fails to function properly, due to overload of the circuit, and introduces distortion into the signal.

Analysis of a Conventional Compressor

Conventional compressors most frequently accomplish their task by virtue of varying the control grid bias of an amplifier tube as a function of the input signal voltage level (parallel control), or output signal voltage level (back control). When the bias of the amplifier varies, as a function of the signal voltage level, it shifts the dynamic amplification factor (μ). This can best be seen by an inspection of the static and dynamic tube characteristics of the tube. Let it be assumed that the compressor has one stage of controlled gain using back control. The functional block diagram is shown in Figure 9.

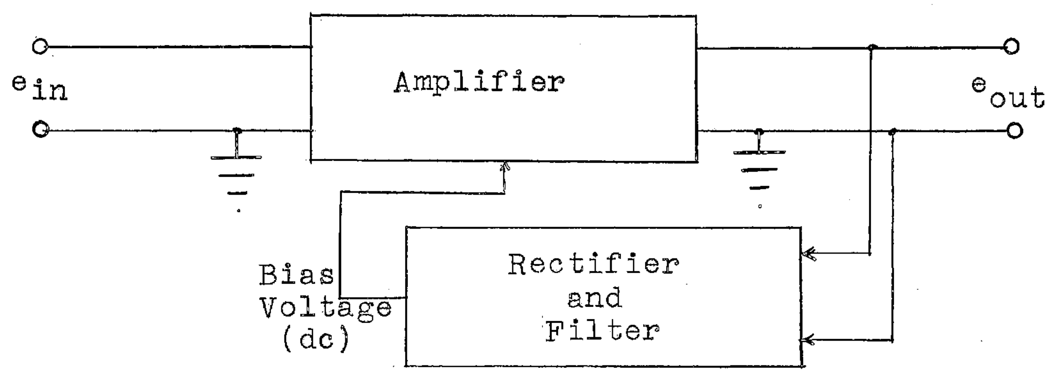

Figure 9. Block Diagram of a One Stage Conventional Compressor Using Back Control.

The functional operation of the circuit is to amplify the input signal with a gain that is a function of the output signal level. The amplifier itself can be assumed to be a triode tube whose static characteristic is similar to that shown in Figure 10.

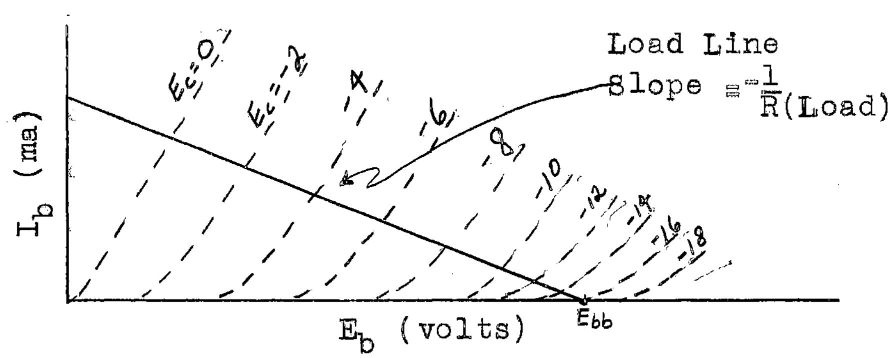

Figure 10. Static Plate Characteristics of a Triode Type Tube.

For purposes of discussion, a more straightforward interpretation can be derived from the dynamic transfer characteristics for the same tube, as represented in Figure 11. Remembering that E_c, the bias voltage, is a function of output signal level, the bias on the tube, and thus the operating point, can vary. As the output signal increases, the bias voltage grows more negative and shifts to the left in Figure 11. If the bias voltage becomes too highly negative, then the tube is effectively cutoff for part of the time of the input signal voltage.

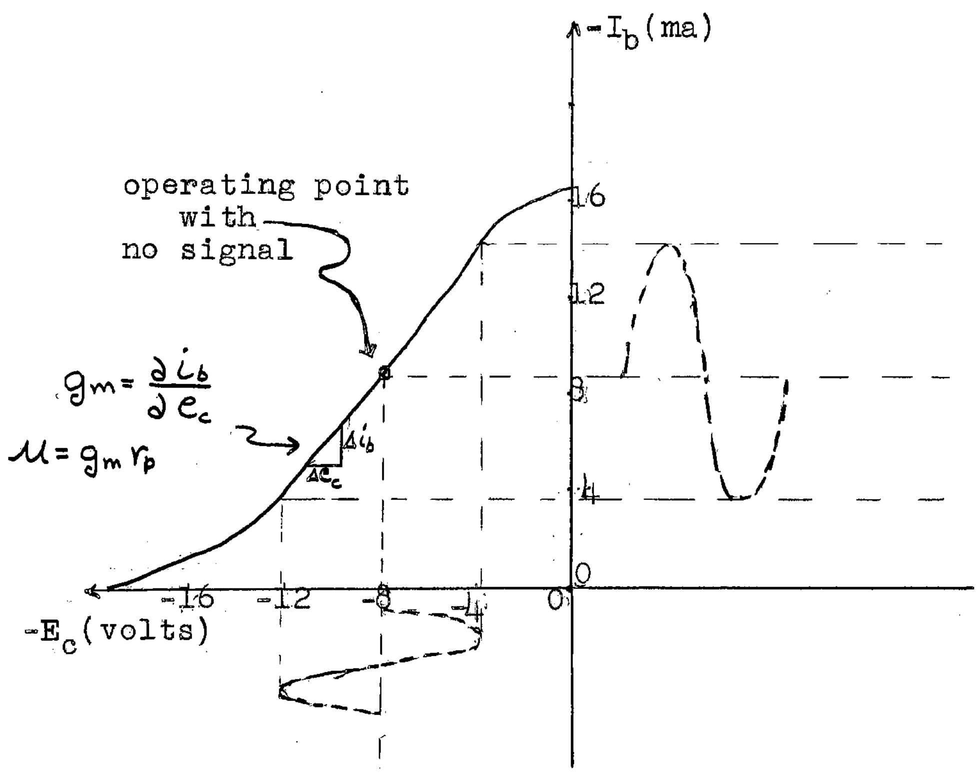

Figure 11. Dynamic Transfer Characteristics of the Triode Tube.

This extreme condition represents overload distortion and is not pertinent to the normal operation of the compressor. However, as the instantaneous operating point shifts along the characteristic above cutoff, the transconductance ($\frac{\partial i_b}{\partial e_c}$) changes as well as μ ($\frac{\partial e_b}{\partial e_c}$). Due to the intrinsic nature of the slope of the tube characteristic, the farther the operating point moves in a negative bias direction, the lower the μ. This means then, that as the output signal tends to increase, the operating point shifts, producing a smaller μ which, in turn, tends to keep the output from increasing.

The bias voltage, derived from the output signal, is not proportional to the instantaneous magnitude of output signal, but rather to more of an average of the output signal voltage.

At any given operating point, dictated by the average magnitude of the output signal, some nonlinear distortion of the signal can occur, due to the curvature of the characteristic. Obviously, the larger the input signal, the greater the distortion. Furthermore, when the operating point is nearer cutoff, the trend is for greater nonlinear distortion. Consequently, in order to minimize distortion in the compressor stage, it is important that the input signal level not be too large.

The effectiveness of a circuit as a compressor is usually expressed in "db of compression." In brief, this simply refers to how much the magnitude of the output signal is reduced by virtue of having the automatic gain control feature. Another way of putting it is that the terminology, "db of compression," relates the difference in gain of the stage with compression and without compression. Suppose that an amplifier stage, with one volt input signal, has a gain of 20 db when the automatic control voltage is removed. If, when the compression control voltage is reinstated, the output level drops to one volt, then the gain of the stage is now 0 db, and the compressing action of the stage is referred to as 20 db of compression.

Objective

The object of this thesis is to show how the sheet beam tube can operate as a gain control device, and to show its application as an automatic compressor amplifier.

The objectives include:

1. that the sheet beam tube can be utilized as a gain control device,
2. that the sheet beam tube can perform the automatic compressing function,
3. the construction of a compressor using the 6AR8 tube,
4. the study of very wide range compression,
5. the minimizing of distortion due to high range of compression.

The following chapters of this thesis will discuss the sheet beam tube and its integration into an automatic compressor amplifier.

CHAPTER II

INVESTIGATION OF THE SHEET BEAM TUBE

The 6AR8 beam deflection tube used was manufactured by the General Electric Company, and its characteristics are defined in their literature on the tube.[3] The tube can be used as a synchronous detector for color signal decoding in a color television set. One other application for which the tube could be applied is as a synchronous switch.[4] This thesis proposes a further application of this unique electronic tube as a gain control device.

Characteristics of the 6AR8 Tube

The physical structure of the 6AR8 tube is unique as can be seen by the cross-section schematic diagram shown in Figure 12. The tube is of the miniature variety and contains seven elements. Two of these elements, the deflector and the plate, are independent in operation, and as a result of their action, the tube is called a sheet beam tube or beam

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[3]"6AR8 Description and Rating Data Sheet," ET-T840A, General Electric Company, January, 1955.

[4]Raymond Golstein, "The Synchronous Switch," Sperry Engineering Review, Vol. 12, No. 1, March, 1959.

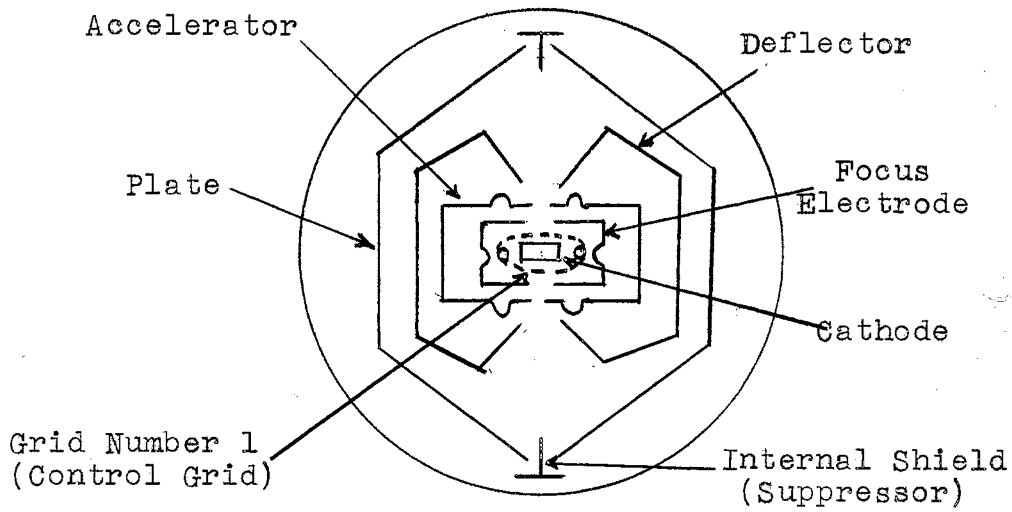
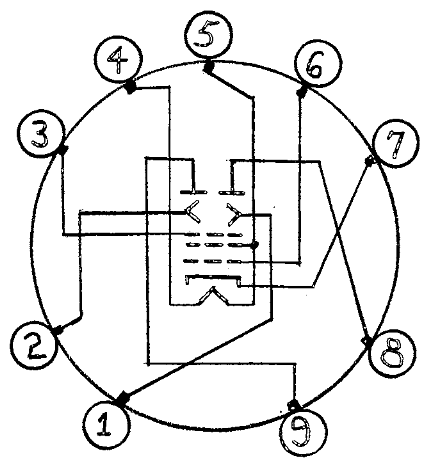


Figure 12. Cross-Section Schematic Diagram of the 6AR8.



Terminal Connections

Pin 1 - Deflector Number 2
Pin 2 - Deflector Number 1
Pin 3 - Accelerator
Pin 4 - Heater
Pin 5 - Heater, Internal Shield, and Focus Electrodes
Pin 6 - Grid Number 1 (Control Grid)
Pin 7 - Cathode
Pin 8 - Plate Number 2
Pin 9 - Plate Number 1

Figure 13. Basing Diagram of the 6AR8.

deflection tube. A better conception of the tube elements and their operation can be obtained from a basing diagram as seen in Figure 13.

Figure 13 shows the pin connections to the tube, as well as the elements internal to the tube. Note that the deflectors and plates are drawn as separate tube elements. The tube is similar to a pentode type tube with split plates and additional elements called deflectors. The static plate characteristics, as shown in Figure 14, are very similar to the static characteristics of a pentode tube. The average transfer characteristics of the 6AR8 tube are shown in Figures 15 and 16.

From Figures 14 and 15 it can be seen that the tube will operate similar to a high gain pentode tube, provided the deflectors are grounded. An analysis of Figure 16 will show that as the deflector voltages are varied, the current reaching each plate is a function of the deflector to deflector voltages. As deflector number 1 becomes more positive than deflector number 2, the plate current of plate number 1 increases and the plate current of plate number 2 decreases (assuming a constant control grid signal). Therefore, by varying the deflector voltages, the plate currents can be controlled. The ability of the deflectors to control the stream of electrons results in beam control or beam switching. Furthermore, the control is independent of the signal appearing on the control grid.

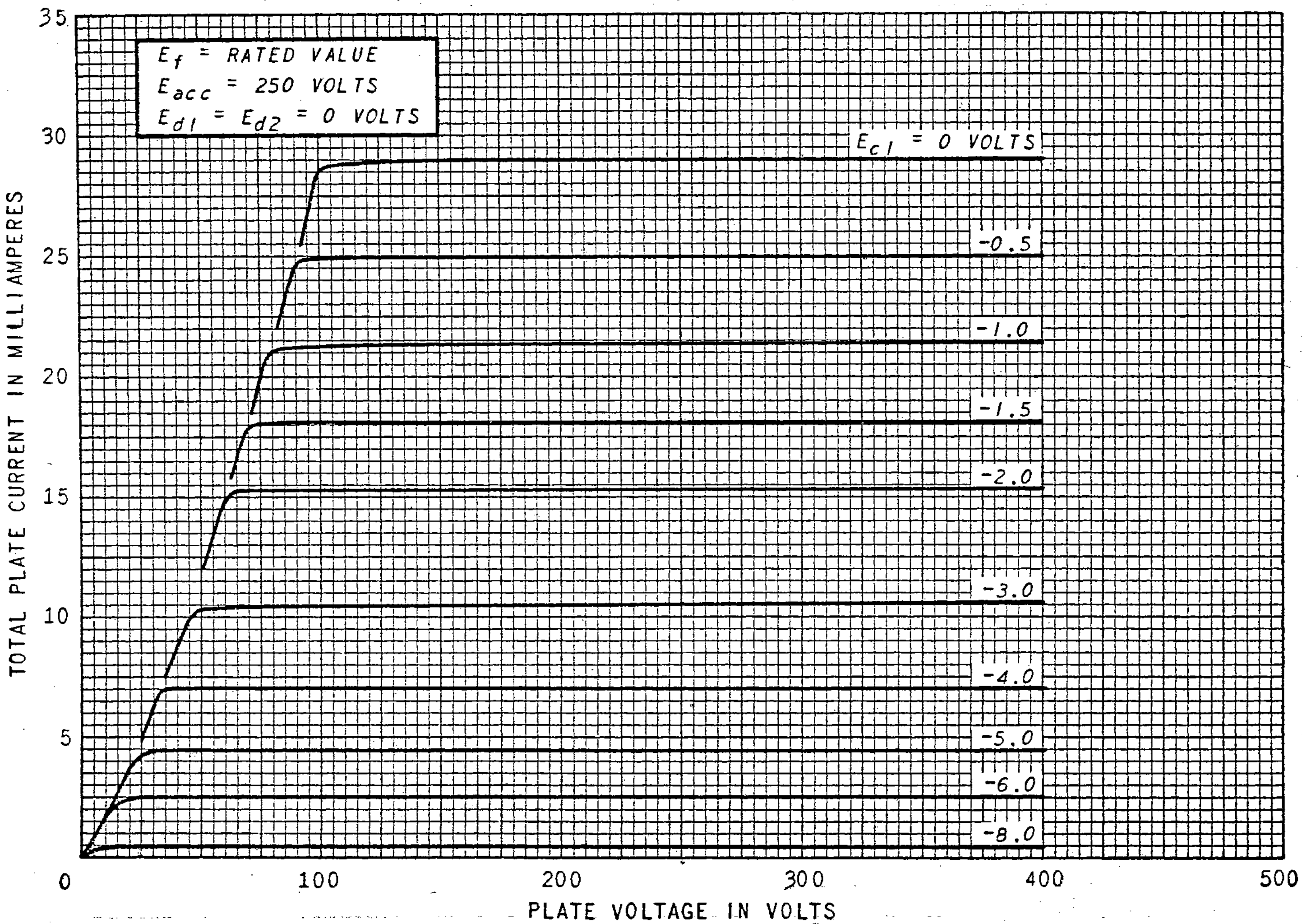


Figure 14. Average Static Plate Characteristics of Plate Voltage Versus Plate Current for 6AR8 Tube.

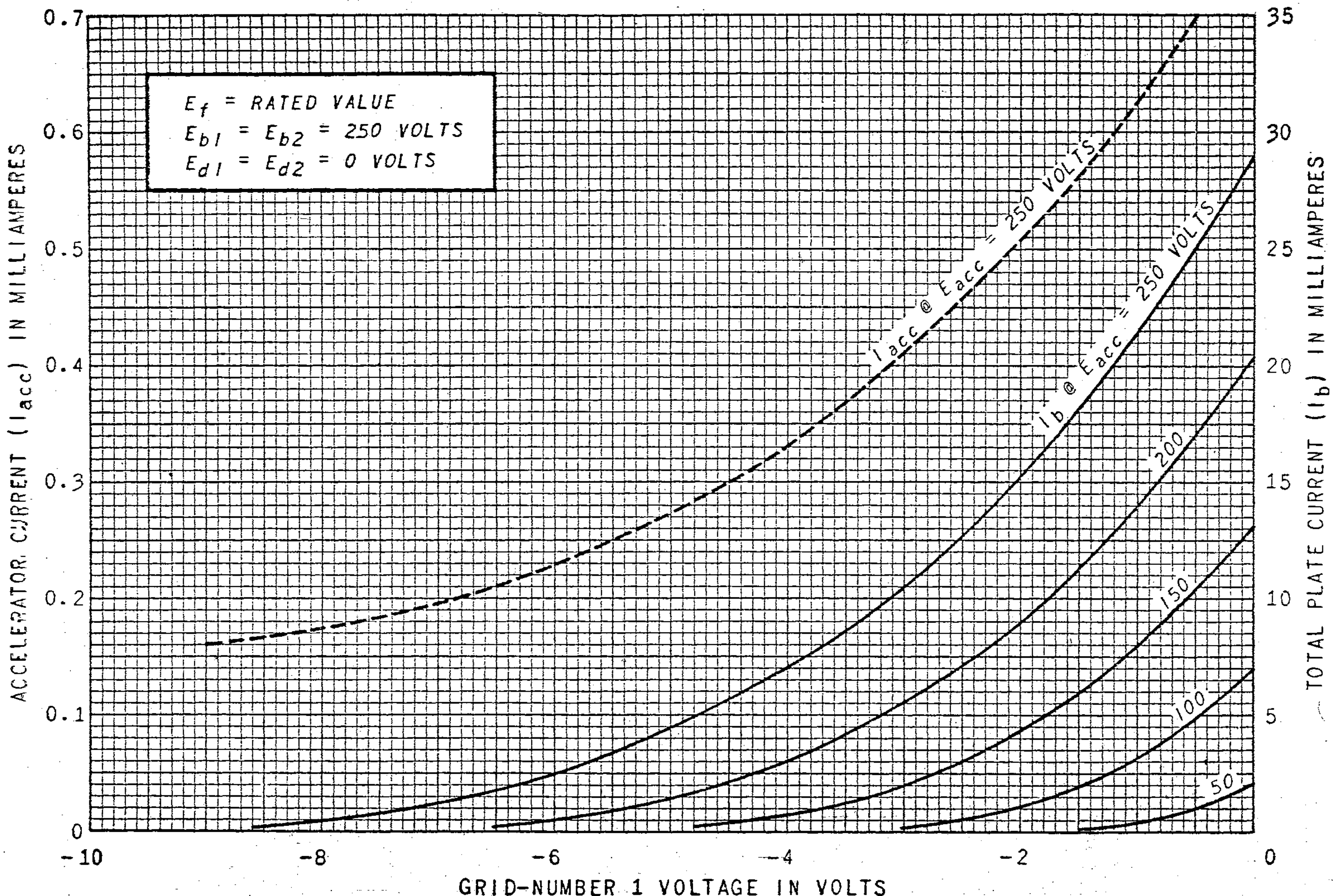


Figure 15. Average Transfer Characteristics of Total Plate Current and Accelerator Current Versus Control Grid Voltage for 6AR8 Tube.

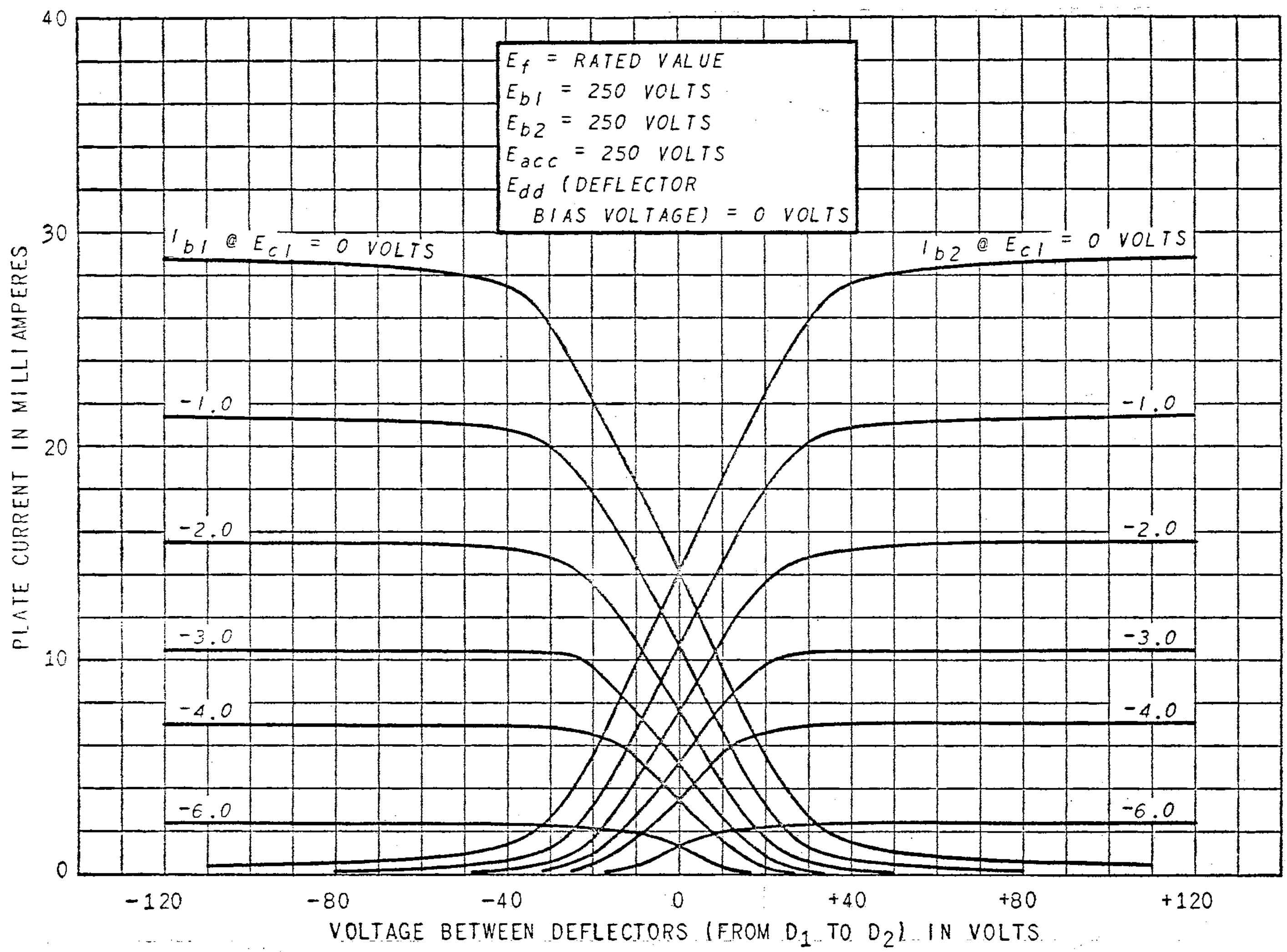


Figure 16. Average Transfer Characteristics of Individual Plate Currents Versus Voltage Between Deflectors for 6AR8 Tube.

The deflectors, in controlling the plate current by switching the beam effectively, control the signal voltage level appearing on the plate resistor. Therefore, by connecting the deflectors to variable voltage sources, the signal output level can be controlled manually and independent of the input signal. This manual control alone could be used for many purposes itself, and will be utilized in this thesis to define the range of compression.

From Chapter I it was shown how the output signal could be controlled by varying the bias on the control grid. It is conceivable that bias control could be incorporated along with deflector control for large ranges of compression to satisfy certain needs of such a circuit.

The 6AR8 Tube as a Gain Control Device

The ability of the 6AR8 tube to compress, and its compression characteristics, were studied using the circuit of Figure 17. The cathode resistor (R_3) was selected for a cathode bias of such magnitude that the input signal could be varied over a large range without driving the tube into the nonlinear operation. The results of the compression range are shown in Figure 18.

The output signal level was maintained constant, while the deflector voltages were varied. The initial condition was to apply a large input signal level to the grid and swing the majority of the beam to plate number two. As the

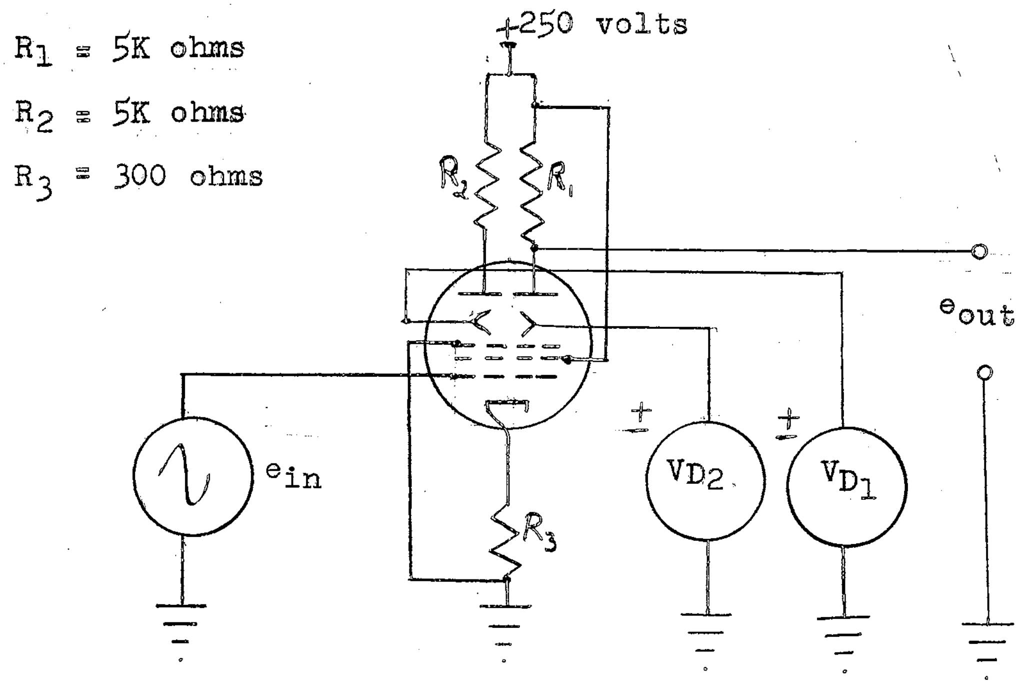


Figure 17. Circuit Diagram of Compressing Investigation.

input signal was decreased, the deflector voltage was altered to maintain the same signal level on plate number one. The graph of Figure 18 portrays the deflector to deflector voltage necessary to maintain the constant output, and is indicative of the compressing property of the tube.

A closer look at Figure 18 shows that the deflector voltage varies over a very large range around zero to obtain a significant compression (140 volts for 10 db). Above V_{D2-D1} equal to -20 volts, the effect of a smaller change in deflector voltage results in the same amount of compression. Furthermore, the ability to switch the deflectors from negative to positive voltages would result in trying to realize a control device that could switch from high negative voltages to high positive voltages.

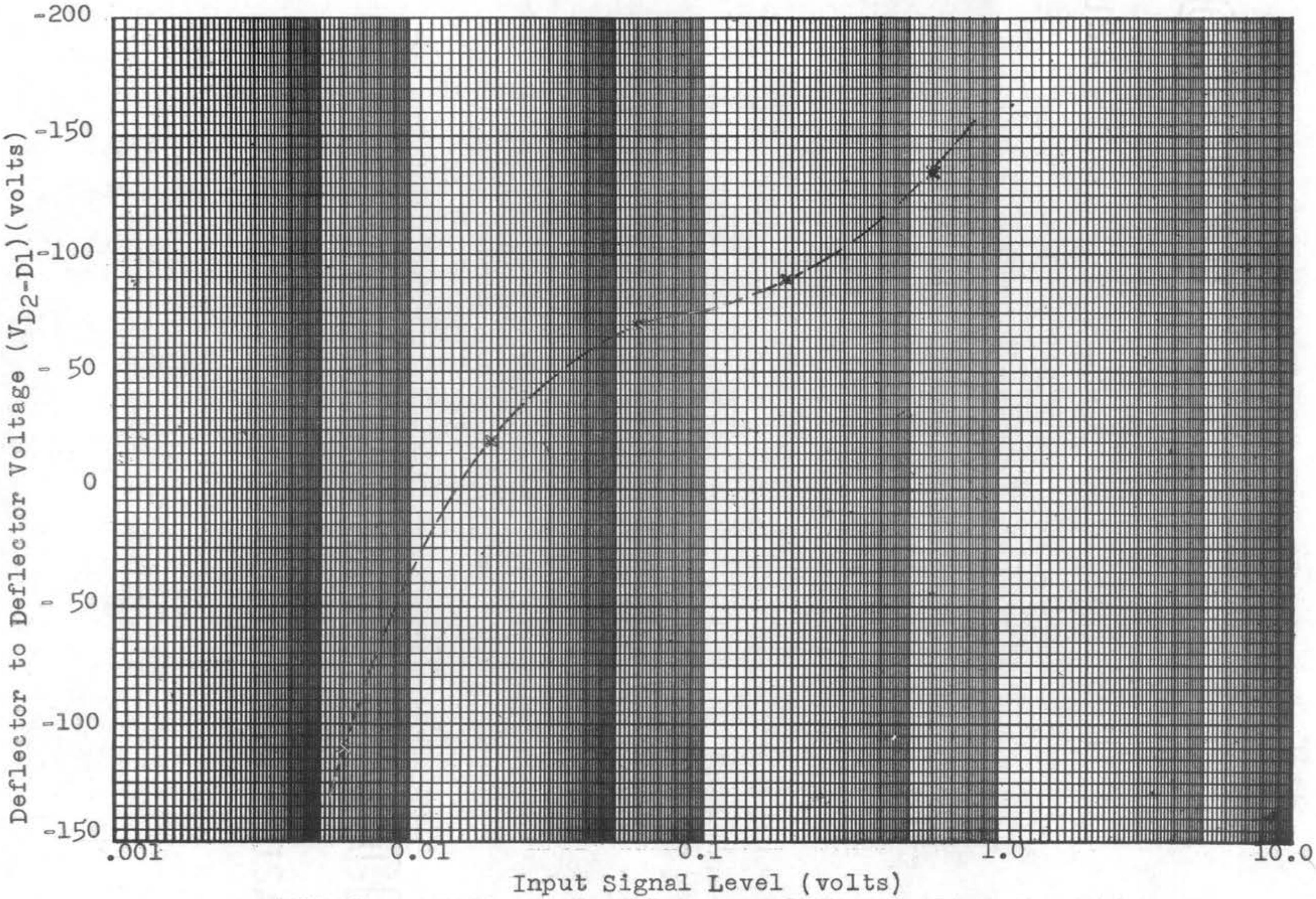


Figure 18. Input Level Versus Deflector to Deflector Voltage.

The high compression area of Figure 18 for the smaller changes of deflector voltage is only 30 db. It would be desirable to obtain more compression for this same range of deflector voltage change. Therefore, the investigation of two stages of compression using two 6AR8 tubes in cascade was initiated for purposes of increasing compression range for minimum deflection voltage change.

The circuit diagram of Figure 19 shows the two stages of 6AR8 tubes used as compressors in cascade. The number 1 deflectors were connected to ground, and the number 2 deflectors were connected to one controlled voltage source. The output signal level was taken from plate number two of the second tube, and the signal level input was varied from 2.82 volts (rms) to .0015 volts (rms). To maintain the output signal level constant, the voltage on deflectors number two had to undergo a variation from -100 volts (dc) to +70. The results are shown in Figure 20.

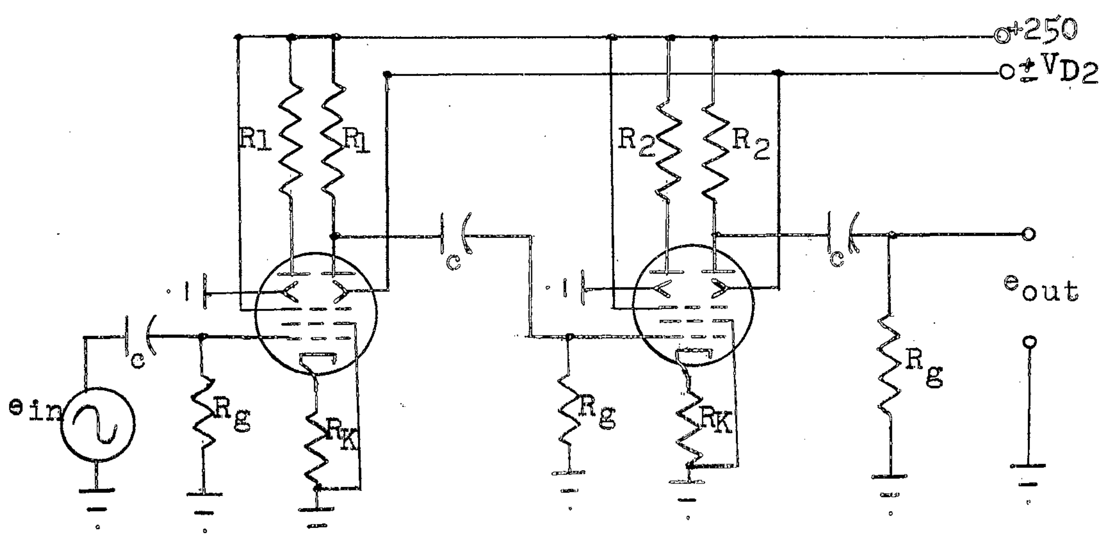


Figure 19. Two Stage Compression Using 6AR8 Tubes.

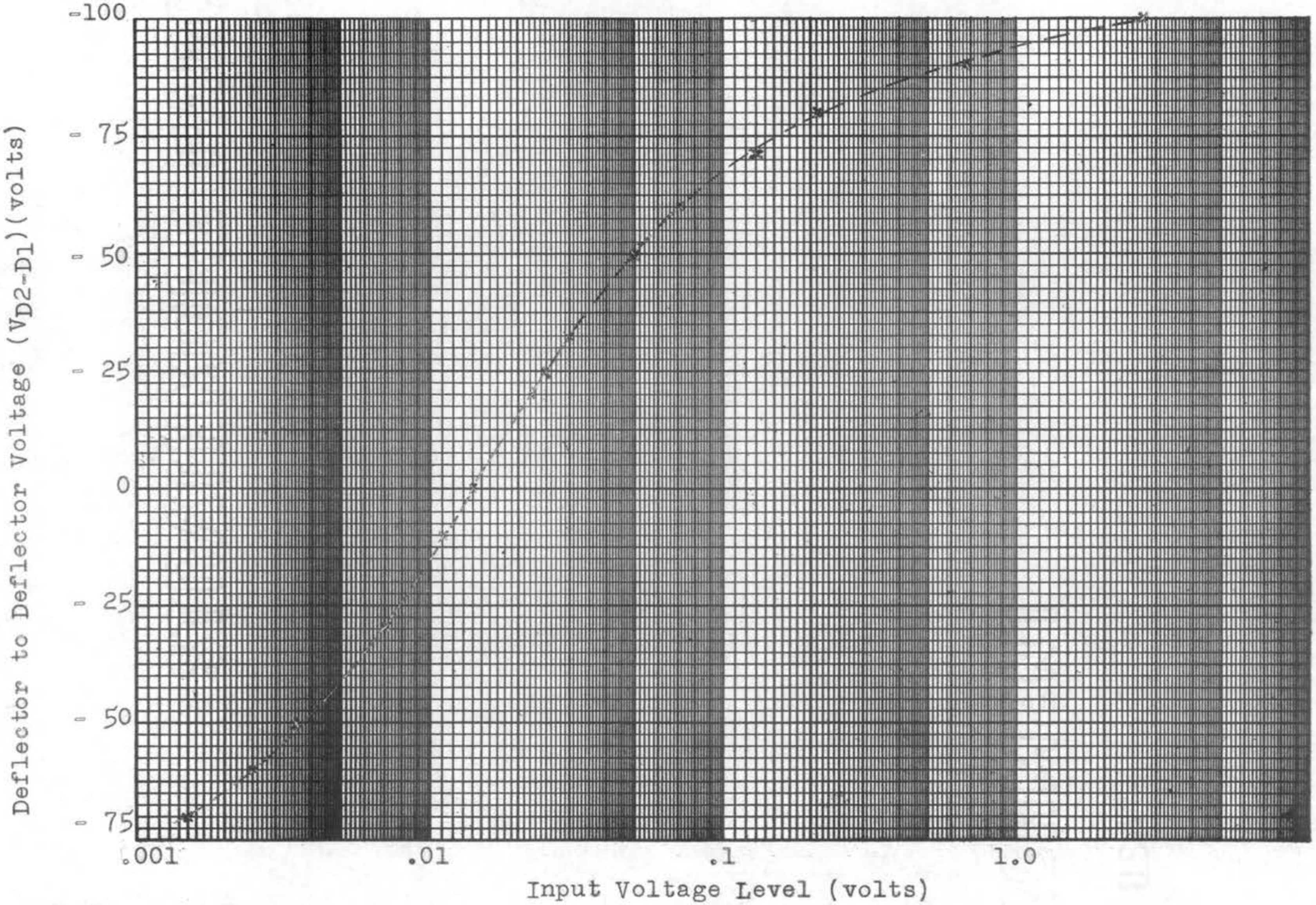


Figure 20. Deflector Voltage (V_{D2-D1}) vs. Input Signal Voltage for Two Stages in Cascade.

The results indicate that 65.28 db of compression can be obtained from a variation of deflector to deflector voltage ($V_{D_2} - D_1$) of +70 to -100 volts. This compression was accomplished with only slight distortion appearing on an oscilloscope at high input signal voltages. The data was taken prior to the point where the distortion just became noticeable.

The results of Figures 18 and 20 show that the compression range can be increased considerably by incorporating two cascade stages. The measured results yield curves that are broken, and an averaged smooth curve cannot be used without deviation in output results. A closer look at Figure 20 will show that the curve can be approximated very accurately by three straight line segments. These line segments result in linear deflection voltage variation within the region of input signal voltages that define these segments.

In this chapter, it has been shown how the 6AR8 beam is constructed and how it operates. It has further been shown what is the most desirable range of operation in relation to maximum compression with minimum deflector control. The 6AR8 sheet beam tube can be used as a gain control device as seen by Figures 18 and 20. To obtain automatic compression rather than manual compression through manual gain control, it is desirable to construct additional circuits for purposes of applying the results of Figures 19 and 20 to an automatic compressor amplifier. Therefore, from the data obtained from the two-stage analysis shown in Figures 19 and 20, the additional circuitry for an automatic compressing amplifier will be developed.

CHAPTER III

DEVELOPMENT OF THE COMPRESSOR AMPLIFIER

The results of the investigation of the circuit shown in Figure 19 was the basis for the design of the compressor amplifier.

It is recalled that the input signal level to the first tube of the two-stage compressing circuit varied from .0015 volt to 2.82 volts (rms), while at the same time, the differential deflector voltage varied from +70 volts to -100 volts. This is equivalent to a 65 db variation in the input signal level, while the output signal level is maintained constant at one plate of the tube. The curve in Figure 20 shows that the graph can be approximated very closely by three straight line segments. The straight line segments can be satisfactorly reproduced by a diode function generator.[5]

The function generator must produce a voltage that varies in a nonlinear operation from a high positive value to a high negative value. The nonlinear operation was shown in Figure 20. A diode function generator can reproduce a curve such as required, provided the curve can be broken

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[5]Granino A. Korn and Theresa M. Korn, Electric Analog Computers, (New York, 1956), p. 220.

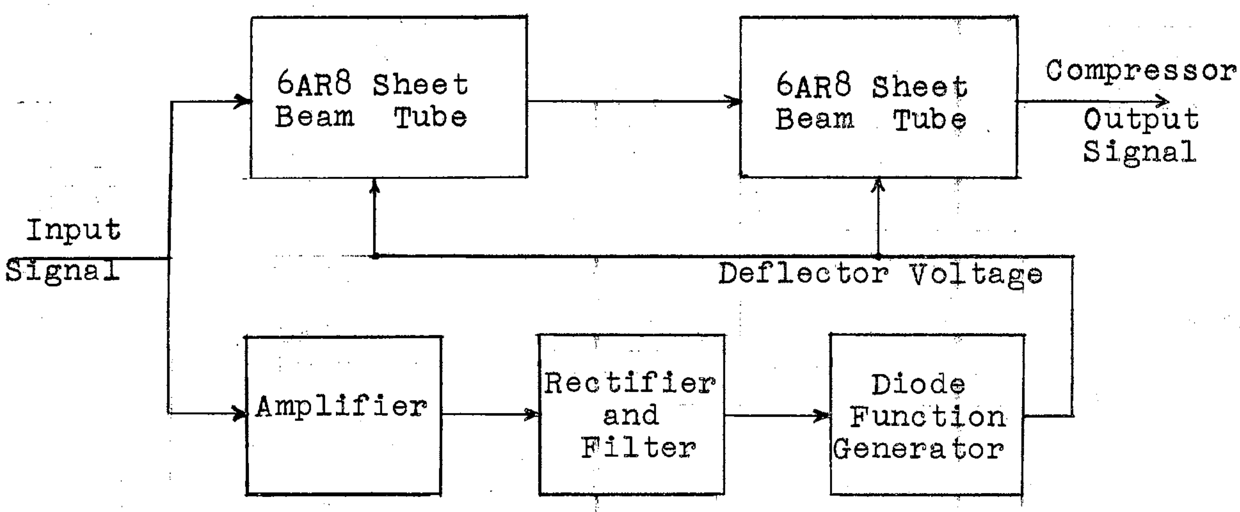

Figure 21. Block Diagram of Compressor Amplifier

into linear segments. The slope of the linear segments must be continuously increasing or decreasing if the input voltage is of only one polarity. The diode function generator was used to control the deflectors in such a manner as to maintain a constant output signal level while the input signal level was being varied. This, therefore, produced automatic compression or gain control. The overall compressor in block diagram form can be seen in Figure 21.

The input signal from a microphone, geophone, or any other source of audio frequency signal is to be applied to a matching network and threshold or level control circuit. This could be nothing more than a simple cathode follower and audio frequency amplifier with means for manual potentiometer control for setting the level of the input signal to the 6AR8 tubes to prevent overdriving, and insure optimum signal levels for maximum performance of the compressor.

The signal from the first input stage is then sent to two different circuits. One signal is fed to the 6AR8 tubes to be compressed. The other signal is fed to a high-gain amplifier stage which builds up the signal level to drive a rectifier-filter stage. The output of the rectifier-filter is fed to a diode function generator to produce a voltage for the control of the deflectors of the 6AR8. The deflector voltage output of the diode function generator is a function of initial input signal level to the compressor amplifier which has been amplified, rectified, and filtered, and is the automatic gain control voltage.

Development of the Diode Function Generator

The information represented by the graph of Figure 20 is presented again in Figure 22, but with a linear scale. This allows more detail to be shown in certain ranges. The graph of Figure 22 shows a sharp change in the slope of the deflector voltage at -20 volts which corresponds to an input signal of .018 volts. From an input level of .018 volts to a level of .063 volts, the deflector voltage varies from -20 volts to -60 volts. Finally, above an input signal level of .063 volts to a level of 2.82 volts, the deflector voltage changes from -60 volts to -100 volts. These three segments are the results of a three-segment approximation to the curve in Figure 22, and was used for the boundary conditions in designing the diode function generator.

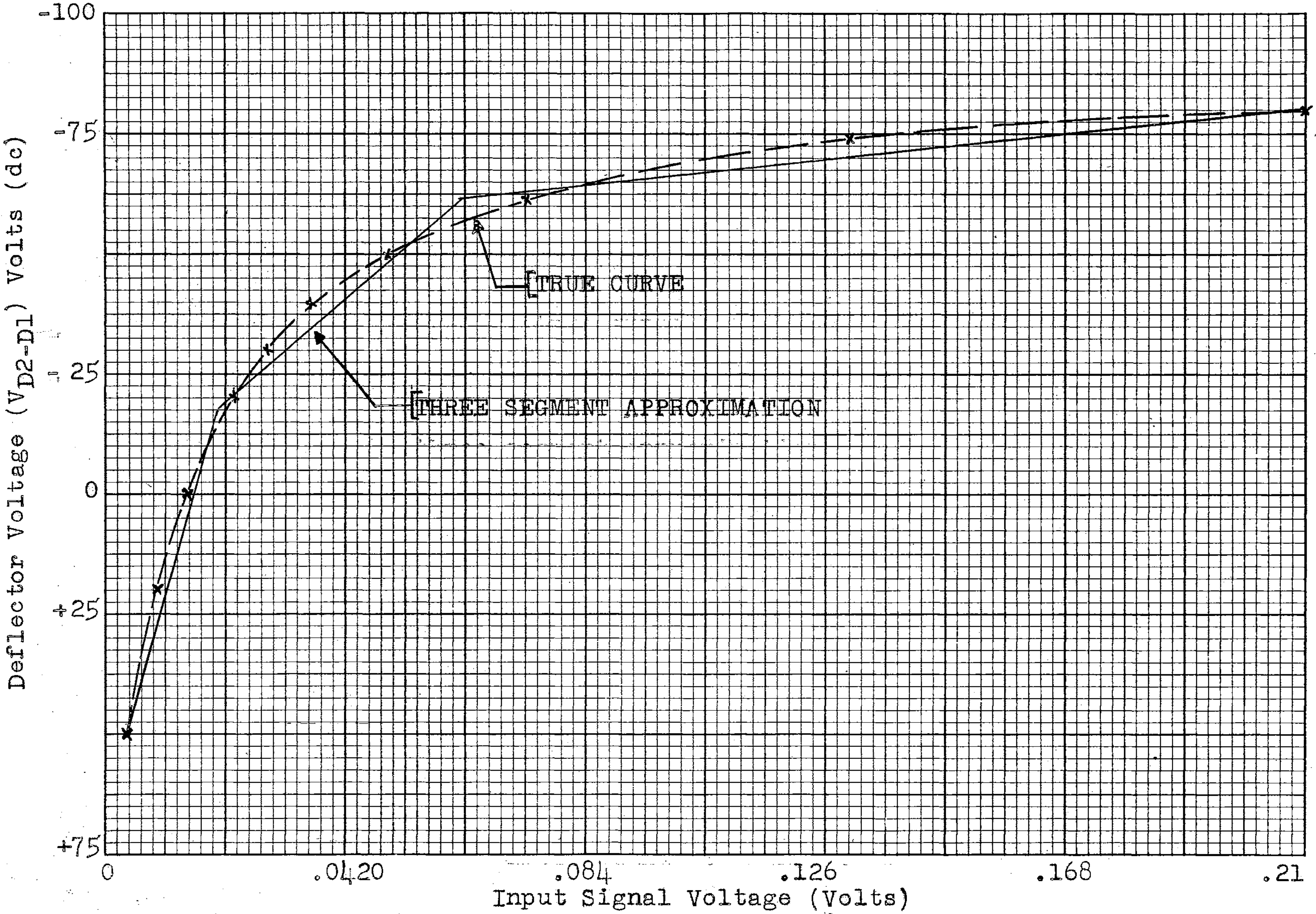

Figure 22. Deflector Voltage (V_{D2-D1}) Versus Input Signal Level for Two Stages of Compression.

The driving function (voltage) is a result of a level of input signal. This driving voltage comes from a rectifier filter network as described earlier. The ability to generate an output voltage as a function of an input signal level is fairly easy if the voltages are direct current voltages, and if the input and output voltages are not affected by loading. Some diode function generators are simple and convenient, but they may tend to load the input signal so heavily that the original conditions do not exist.

A diode function generator that satisfactorily meets the requirements utilizes two operational amplifiers.[6] This type of function generator was preferred over more simple types because the output voltage can assume both positive and negative values, the input impedance is high, and the output impedance is low. The circuit reflects a constant 100K ohms impedance to the filter which satisfied one condition. The second condition regarding output loading is satisfied by the second scaling operational amplifier. The circuit and its component's values are shown in Figure 23.

The voltages of two and six volts were obtained from a wet cell battery, which was ideal for the purpose, since the resistance offered to reverse current flow was negligible. The initial condition of -1.4 volts was necessary since the signal input is limited to only positive values. This

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[6]Dr. R. C. H. Wheeler, Basic Theory of the Electronic Analog Computer, Section XI.

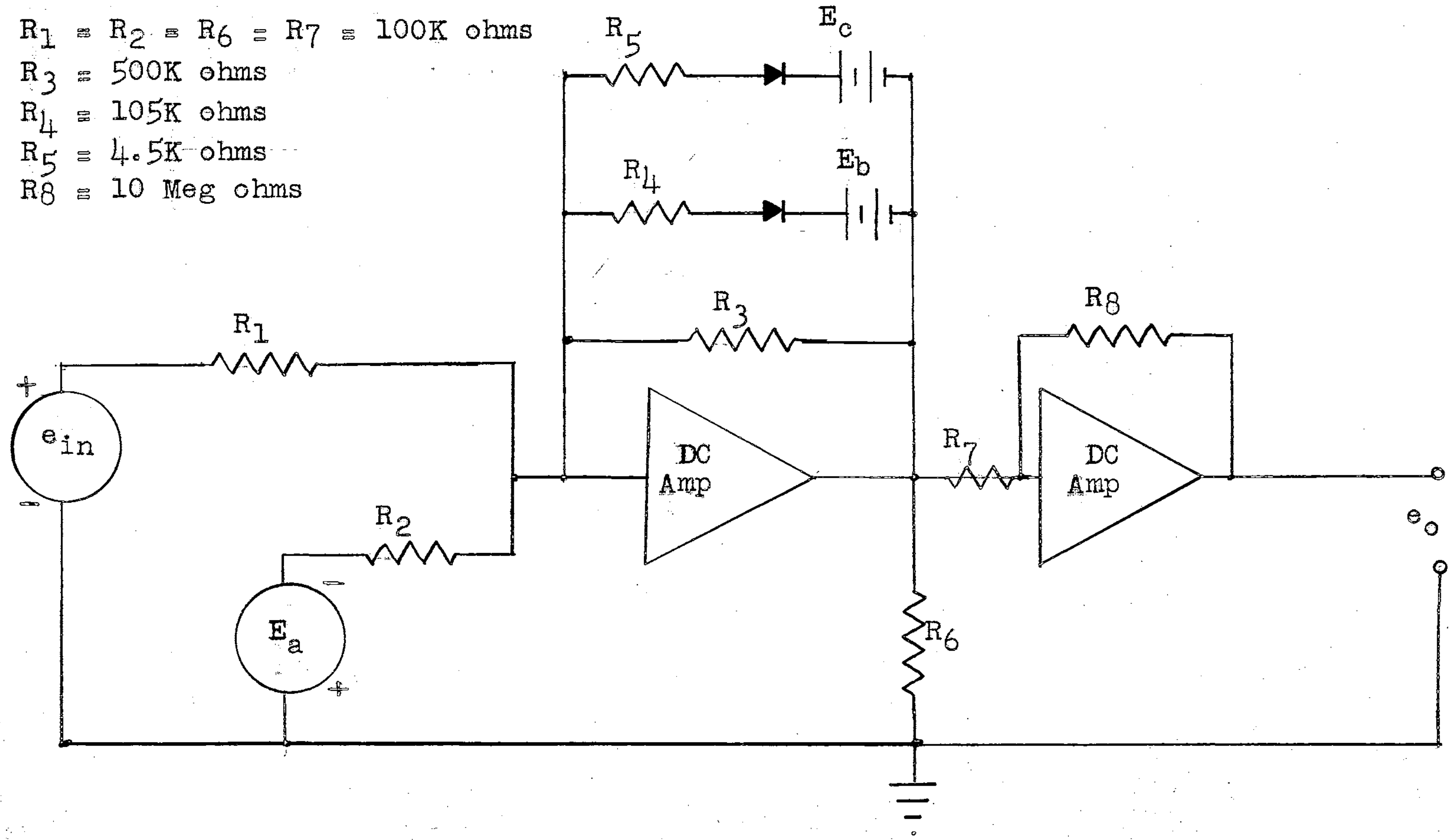

Figure 23. Diode Function Generator Operating From +70 to -100 Volts for e_o.

initial condition voltage results in +70 volts on the output of the diode function generator.

The ability of the diode function generator to perform its operation as designed proved to be very satisfactory, and the breakpoints were clearly defined. It should be noted that the resistances of the diodes (rd) are not constant and do vary, especially at the breakpoint where the diode first conducts. This results in rounding of the breakpoints, but results in no adverse effects of the circuit.

Development of the Amplifier, Rectifier, and Filter Stages

The input signal to the amplifier, as shown in Figure 21, is a low-level audio frequency voltage varying from .0015 volts to 2.82 volts (rms). The breakpoints of the diode function generator appeared at 1.8 and 6.35 volts (dc) corresponding to .018 and .0635 volts (rms) of input signal level. Utilizing a full wave rectifier with good filtering, the approximate gain of the amplifier would have to be $100/\sqrt{2}$ or greater. This requires a gain of approximately 70 for the amplifier circuit. This was accomplished by feeding the signal directly from the source to the amplifier and reducing the input signal to the control grid of the 6AR8 tubes by a factor of five. The required gain of the amplifier was then approximately 14 or greater.

The rectifier used was a full wave diode rectifier utilizing a transformer input with two diodes operating on the secondary terminals with the center tap of the transformer grounded. The output of the rectifier was fed directly to a π filter composed of two condensers and one resistor.

The amplifier, rectifier, and filter networks are shown in Figure 24. The output of the filter was fed to a 100K ohm pot for adjustment of the gain of the circuit. The amplifier used in the experiment was actually a Heathkit 70-watt amplifier which, obviously, had much more gain than was necessary.

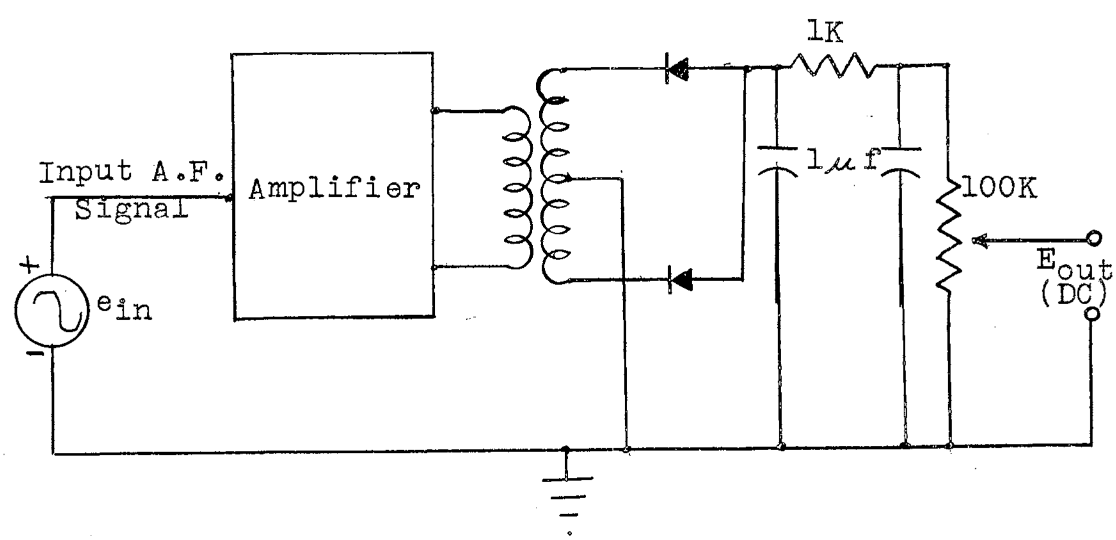

Figure 24. The Amplifier, Rectifier, and Filter Circuits.

The frequency response of the amplifier, rectifier, and filter circuit is shown in Figure 25. The boost in the high frequency output was due to the transformer that feed the rectifier. If deemed necessary, the high frequency response could be reduced at the expense of the gain of the circuit by

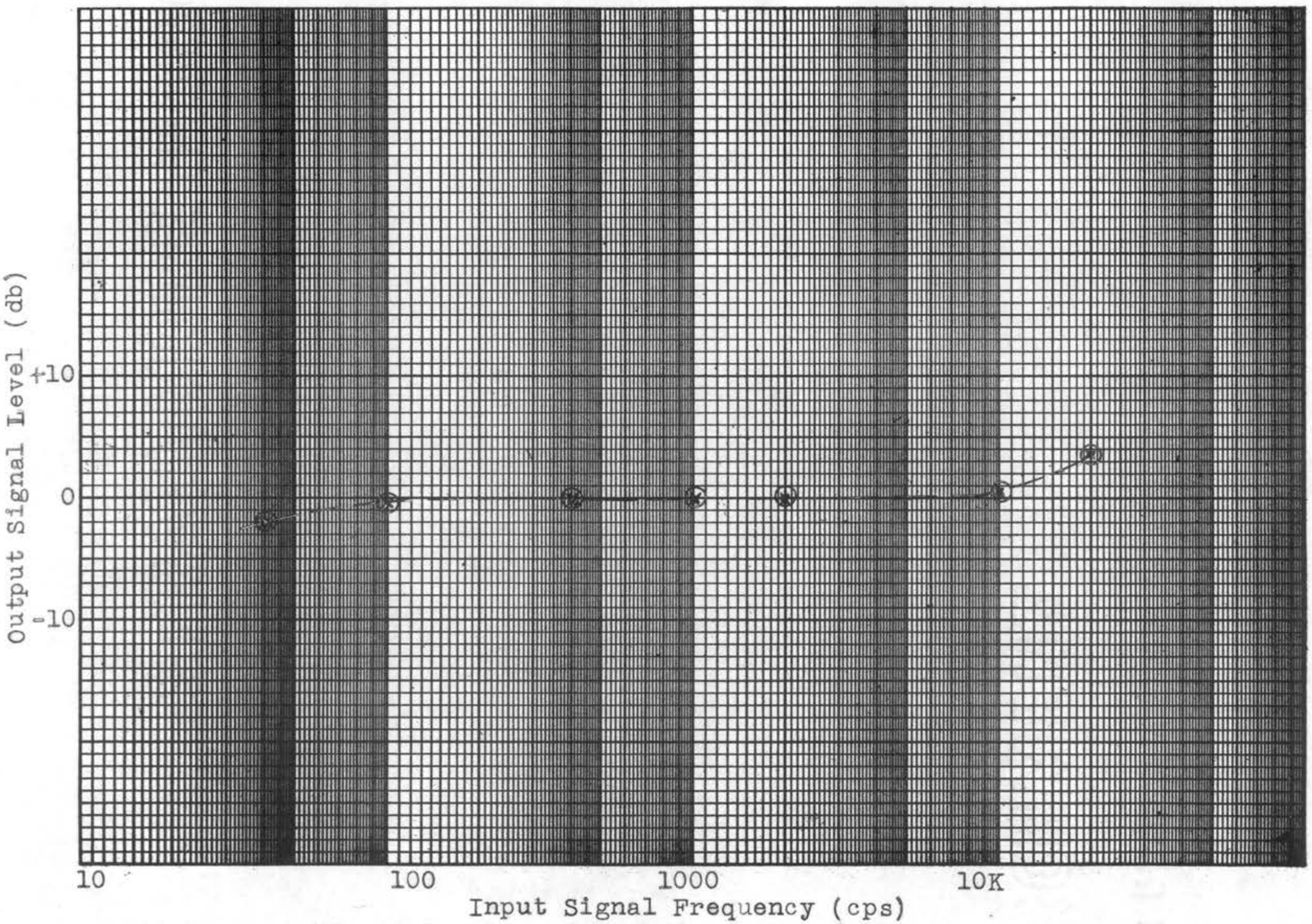

Figure 25. Frequency Response of Filter, Amplifier, and Rectifier Circuits.

loading the transformer secondary with a small resistance. The output of the filter circuit of Figure 24 feeds directly to the input of the diode function generator of Figure 23.

The Development of the System

The final compressor circuit appears in the schematic diagram of Figure 26. The operation of the compressor circuit is functionally the same as the block diagram of Figure 21. The input signal, derived from an audio frequency generator, is applied to the 100K ohm potentiometer which will be referred to as the "level control" potentiometer. The function of the potentiometer is to control the input signal by allowing an optimum signal level to be applied to the compressing amplifiers (the 6AR8 sheet beam tubes), and to the deflector voltage control circuits. The signal voltage from the potentiometer arm is applied to two different channels, the signal channel and the control channel.

The signal from the level control potentiometer that is applied to the deflector control channel circuits is sent first to the Heathkit amplifier. The output circuit of the amplifier includes the transformer input to the full-wave rectifier circuits. The output of the full-wave rectifier is applied directly to a π filter network.

The components chosen for the filter allow for adequate filtering, yet its response is fast enough to follow rapid variations in the level of the audio frequency signal. The

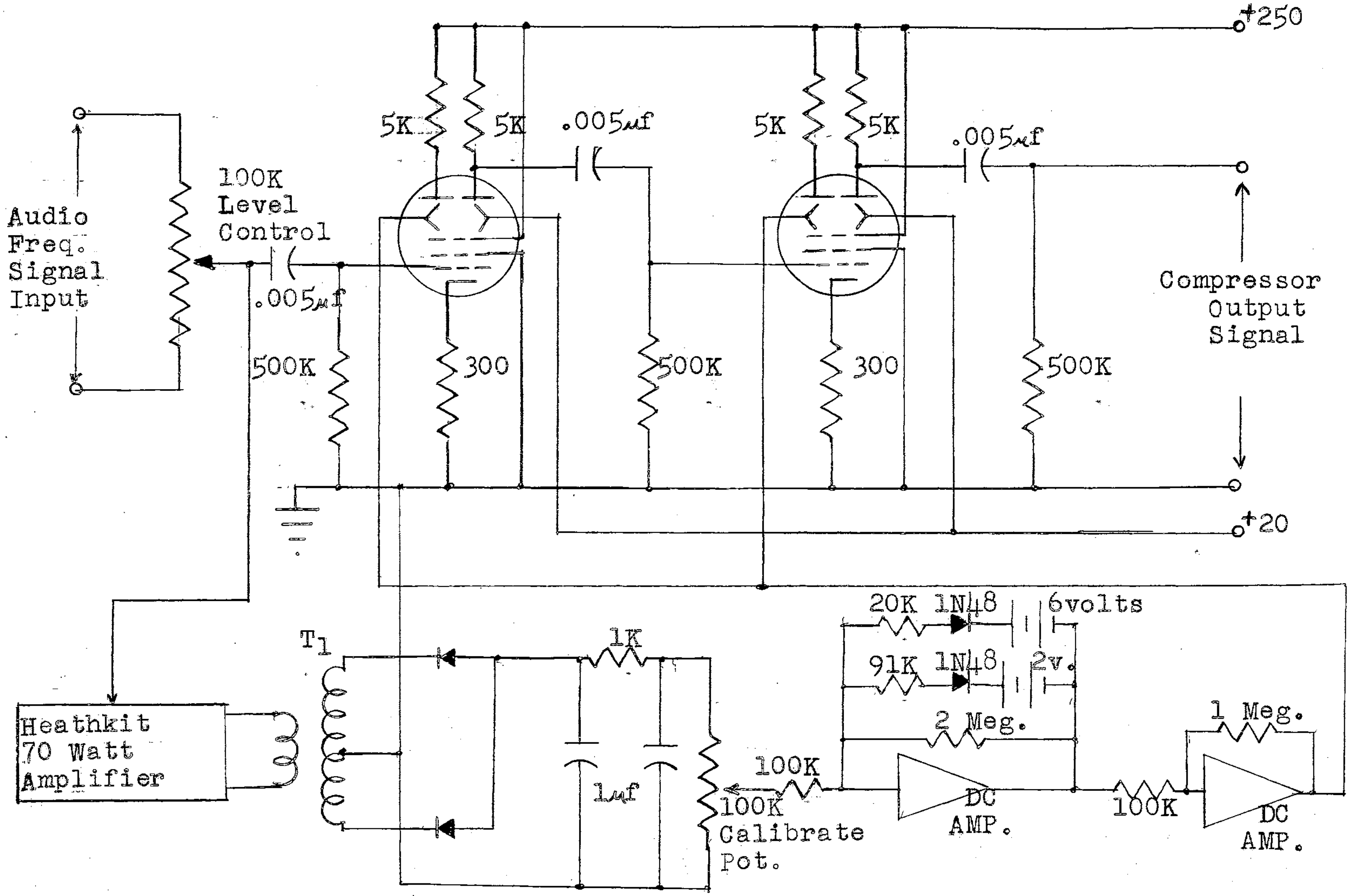

Figure 26. Final Compressor Amplifier Circuit

output voltage of the filter network is a d-c voltage that is proportional to the amplitude of the original audio signal. The 100K ohm potentiometer connected across the filter output could be called the "calibrate" potentiometer since its function is to set the proper ratio between the input signal voltage (audio frequency) applied to the compressing amplifiers and the signal voltage (dc) applied to the function generator.

As the level of the input to the function generator varies, the output also varies, but the output variation has three distinct and separate transfer functions or gain functions. These separate gain functions allow the output voltage to properly control the deflectors to maintain the signal level constant from the compressing amplifiers. The diode function generator utilizes two operational amplifiers. The first amplifier serves as the function generator, and the second as a scaling amplifier. The output of the second operational amplifier is connected directly to the number one deflectors of the 6AR8 tubes.

The number two deflectors of the 6AR8 tubes are shown in Figure 26 as being connected to a voltage source of + 20 volts. An alternate scheme would be to ground them; however, this was tried and difficulty was encountered in the performance of the operational amplifiers. The difficulty was internal to the amplifiers, and was evidenced by sporatic oscillations of small magnitude. When the output of the amplifiers was applied to the deflectors, noisy and erratic operation resulted when the potential between deflectors was in the neighborhood of zero.

The audio frequency signal applied from the level control potentiometer to the control grid of the first 6AR8 sheet beam tube becomes the compressed signal appearing on the output terminals of the compressor. The signal path is from the control grid of the first 6AR8 to the plate number two of the same tube. The output appearing on the number two plate is then coupled to the control grid of the second 6AR8 tube. The output of the compressor amplifier stages is taken from plate number two of the second 6AR8 sheet beam tube. The audio signal level appearing on the number one plates of both 6AR8 sheet beam tubes is not utilized and, therefore, the number one plates could be referred to as signal sinks, so to speak. The compressing amplifiers perform their gain control function by the transfer of the electron beam from plates number two to plates number one of the tubes. This transfer is controlled by the deflectors, and occurs in varying degrees when the input signal to the control grids increases or decreases in magnitude.

The ability of the compressor to perform its task is evidenced by the response curve of Figure 27. The inability of the compressor to maintain an exact flat response is principally due to the deflector control circuits. The design of these circuits was made from an approximation to the true control data. It will be recalled that the approximation consisted of using three straight line segments to represent the control curve. The compression range obtained from the final

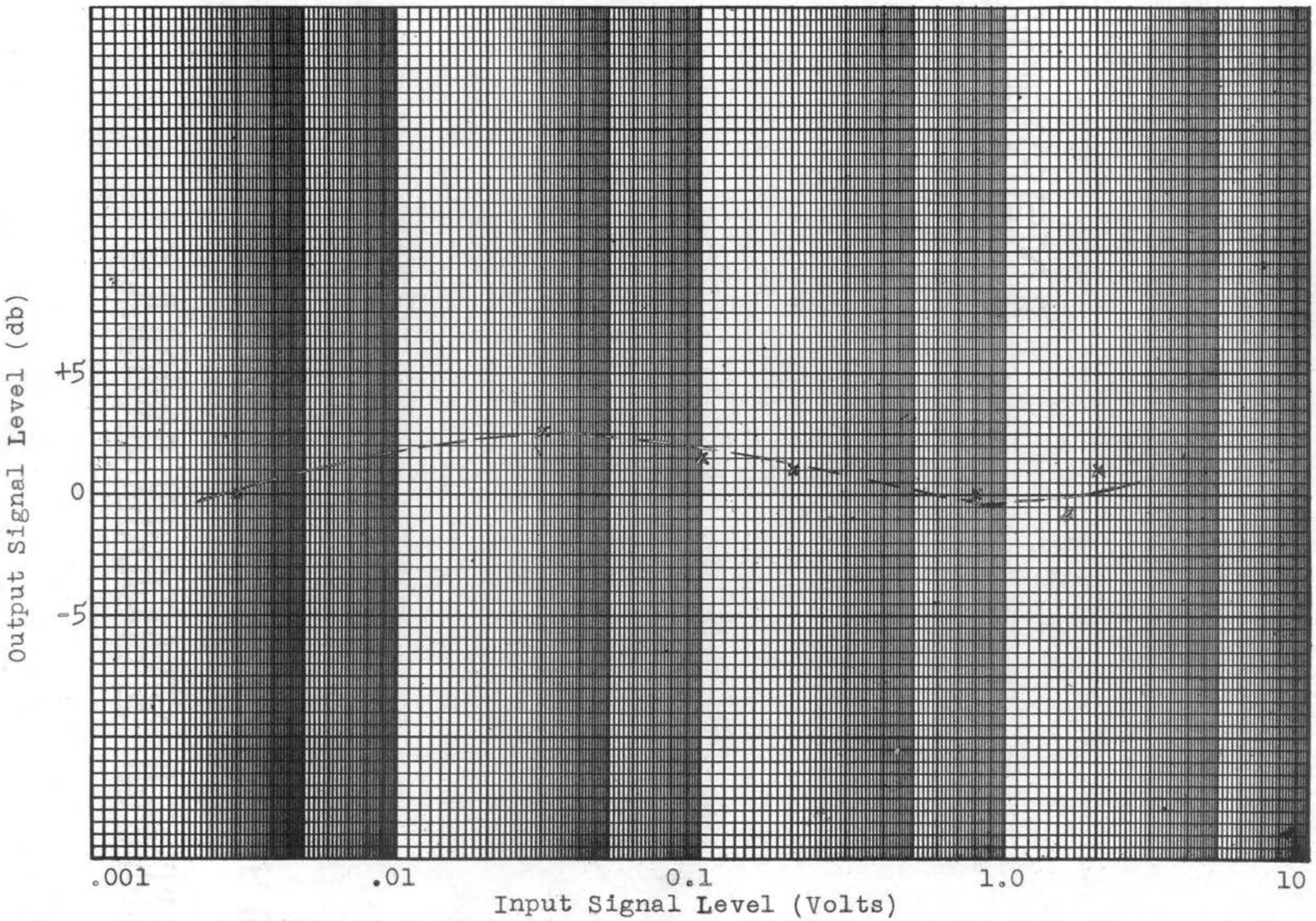

Figure 27. Compressor Response of Output Signal Level Versus Input Signal Level.

compressor amplifier was approximately 56 db. This result was very gratifying although not the maximum possible, which was shown to be approximately 70 db when the control voltage was manipulated manually.

The frequency response of the final compressor appears in Figure 28. The response of the compressor at low frequencies indicates a decrease in the output level, particularly at frequencies below 100 cps. A comparison with Figure 25 indicates that the reduction in gain can be attributed to the compressing amplifier stages. The high frequency response of the compressor indicates a decrease in the output level above 10 K cps. This decrease in the output level is partially affected by the deflector control circuits where it is directly attributed to the response of the transformer feeding the rectifier.

The overall frequency response could be improved quite easily; however, this was not the primary concern to the immediate problem.

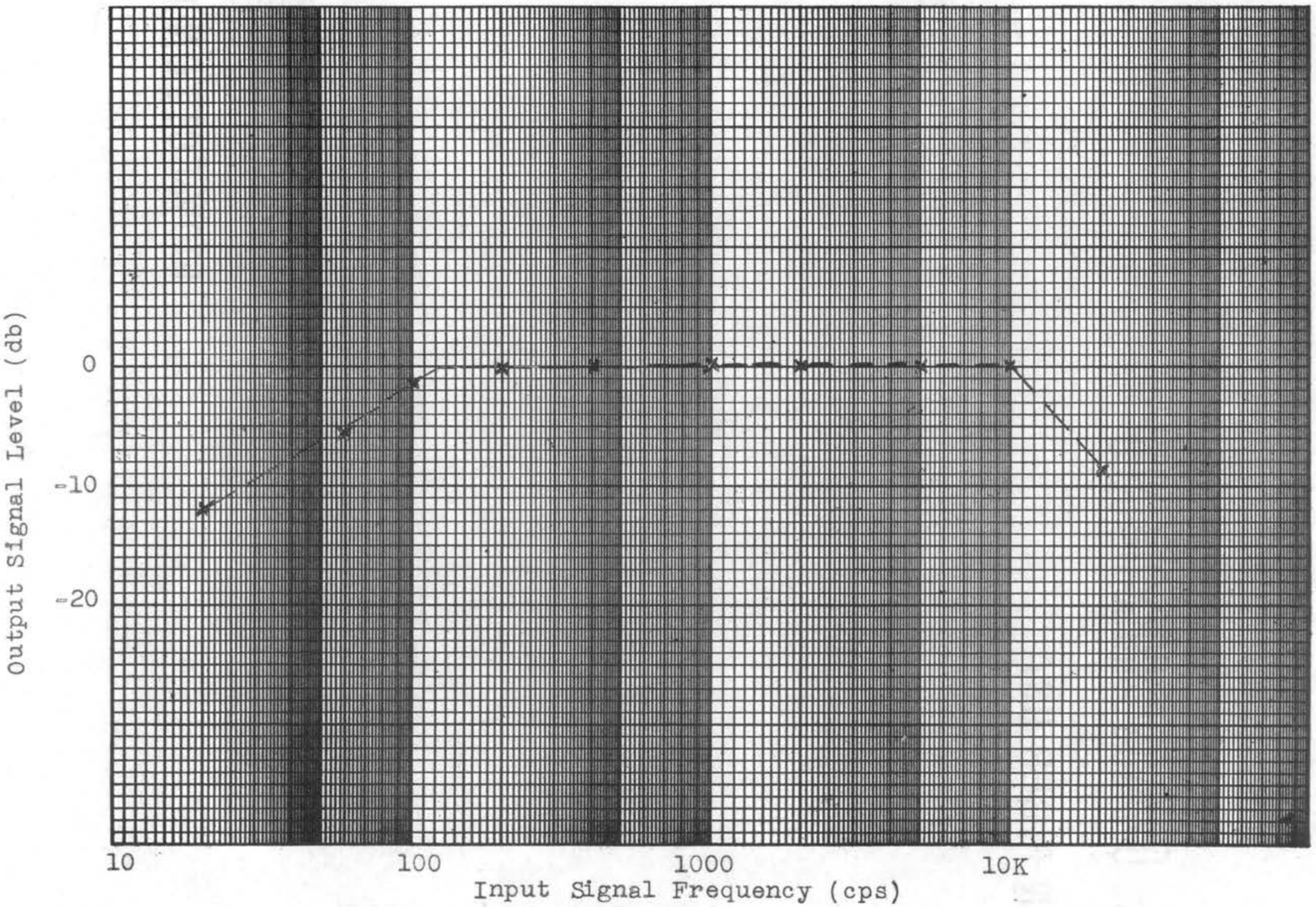

Figure 28. Frequency Response of Final Compressor.

CHAPTER IV

SUMMARY

The objective of this thesis was to investigate the ability of the 6AR8 sheet beam tube to perform as a gain compressing amplifier. Since this tube has deflection electrodes that can be employed to switch the electron beam from one of its two plates to the other, output control can be accomplished by using one plate as a signal output element, and the other plate as a signal sink. By manually controlling the deflector voltages on two 6AR8 tubes in cascade, a gain compression of approximately 70 db was obtained.

While the gain of the tubes could be effectively controlled by the deflectors, the gain versus control voltage characteristic was nonlinear; therefore, in order that the signal output from the 6AR8 tubes be more nearly constant for higher input signal levels, a function generator was included in the system for the purpose of producing the proper control voltage for each level of input signal. This function generator employed an operational amplifier with two biased diodes in the feedback loop. Another operational amplifier was associated with it for scaling purposes.

In the final circuit, some of the input signal was diverted through an auxiliary amplifier, converted to a d-c control voltage by a full-wave rectifier and π filter, and then modified by the function generator before being applied to the deflector electrodes of the 6AR8 tubes. The signal channel consisted of two such tubes in cascade.

When the input signal level was varied between the limits of 0.0013 and 1.2 volts, the output was within 2 1/2 db of being constant. The maximum degree of compression was 56 db. Variations in output over the stated input range was principally due to the fact that the function generator only approximated the necessary control characteristic.

The nominal frequency response was flat within 3 db from 80 to 13,000 cps. This could be extended easily, however, a particular frequency response was not of primary concern.

No actual distortion measurements were made, however, no discernable waveform distortion was apparent on a monitor oscilloscope.

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