July 25, 1961 F. D. WALDHAUER 2,994,040

TRANSISTOR TONE CONTROL FEEDBACK CIRCUIT

Filed Aug. 6, 1956 2 Sheets-Sheet 1

Fig. 1.

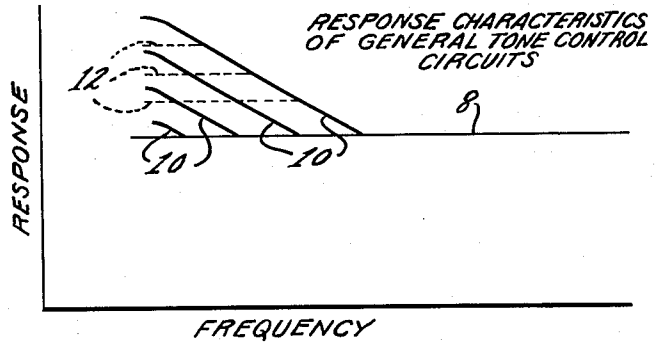



Fig. 2.

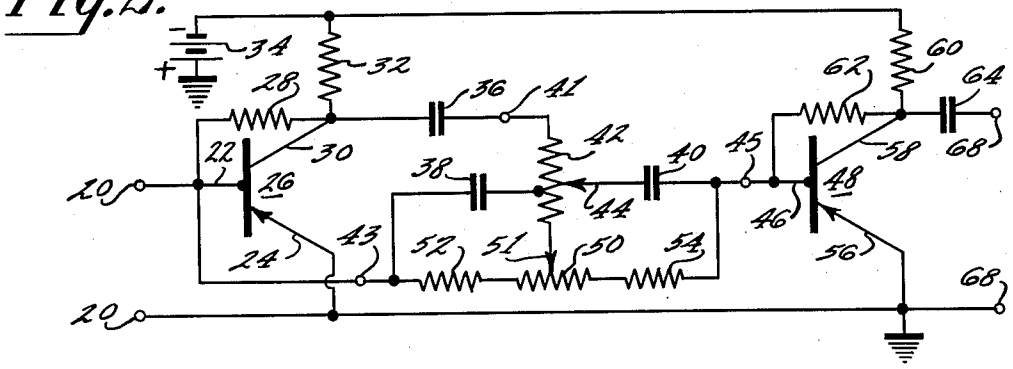
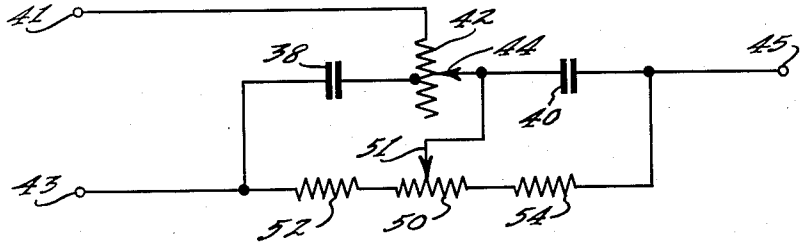



Fig. 3.




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Fig. 4.

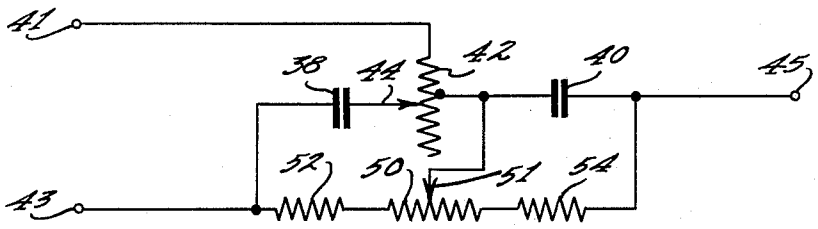
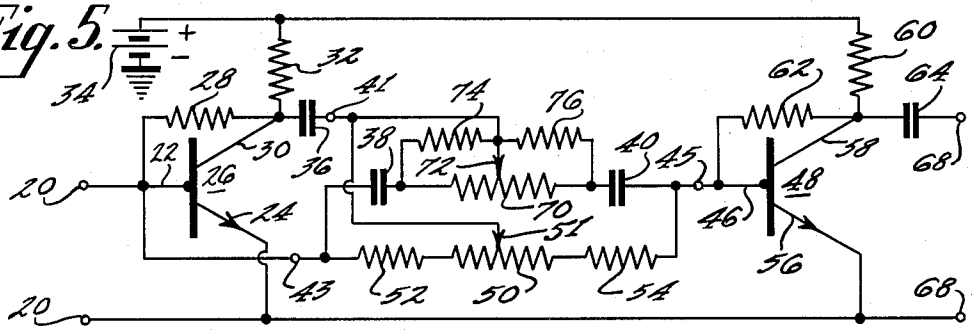



Fig. 5.



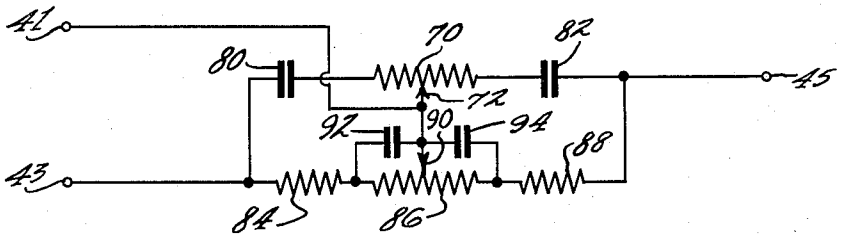




Fig. 6.

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2,994,040

# TRANSISTOR TONE CONTROL FEEDBACK CIRCUIT

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1 Claim. (Cl. 330—28)

This invention relates to tone control circuits, and more particularly to variable tone control circuits suitable for use with audio frequency amplifying systems employing transistors.

Audio frequency amplifying systems often utilize circuits to modify the frequency characteristics of signals translated therethrough. These circuits may be of a manually variable type, in which separate control is exercised over the low or bass frequencies and the high or treble frequencies. A combination of reactive and resistive impedance elements, introduced into the signal path, may be utilized to accomplish this control. Certain of the resistive impedance elements are made variable under manual control in order that the desired frequency characteristic may be selected.

Circuits of this type are generally of the signal divider type, in which signal division is a manually controllable function of frequency. Signal division may be introduced directly into the signal path, or may be utilized in a feedback network. The former type of circuit is generally termed a loss type tone control circuit while the latter is termed a feedback type of tone control circuit.

Simple loss type tone control circuits using various combinations of resistance-capacitance signal attenuating networks generally require source and load impedance that are widely different in value to secure proper circuit operation. In the case of electron tube circuits, it is common to use a low impedance source of signal voltage, such as a feedback amplifier stage, which provides a source impedance on the order of the low thousands of ohms and a load impedance, such as the grid circuit of a succeeding amplifier stage, which provides a load impedance on the order of a megohm. Thus the tone control is fed from a low impedance source and works into a high impedance load, with the ratio of source to load impedance being on the order of 1 to 200 or less. For transistor tone control circuits the ratio of source of load impedance may be interchanged, since the electron tube is essentially a voltage operated device and the transistor a current operated device, so that the ratio of the source to load impedance could be of the order of 200 to 1. The transistor tone control circuit is then driven from a high impedance source and operates into a low impedance load.

Ratios on the order of 200 to 1 between the source and load impedance in a normal transistor amplifer may be difficult to obtain, since the input impedance of a graunded-emitter transistor amplifier, which may be the load on the tone control circuit, may be on the order of 1,000 ohms, thus requiring an output impedance on the order of 200,000 ohms from the previous stage. With normal supply voltages, the load resistor of the driving stage may generally be limited to values of the order of 10,000 ohms, so that the source impedance must be lower than this value and is generally much lower than the desired value. This is true even with a grounded-base driving amplifier which provides a sufficiently high source impedance, but which also has a low value of load resistance.

The lowering of the load impedance into which the tone control circuit must work can be utilized to secure the proper ratio of source to load impedance. A grounded-base amplifier stage may thus be used following the tone control circuit or network, since the grounded base stage has a very low input impedance. Although such a stage may be designed to secure the proper ratio



of load-to-source impedance, the impedance level of the entire tone control circuit must be correspondingly lowered to the extent that the components utilized, particularly the capacitive elements, become large and costly. Other difficulties are encountered using a grounded base stage for this purpose, such as, costly bias arrangements, lack of current gain, and noise problems at low signal levels.

Tone control circuits generally provide variable attenuation of the various audio frequencies in the form of a boost or cut of the high and low frequencies (treble and bass response) with respect to the middle audio frequencies. The tone control may provide attenuating characteristics in which the low and high frequencies at which the boost and cut begins respectively (i.e., the crossover frequencies) are substantially constant at all settings of the controls, and the control setting determines only the amount of boost or cut. A "flat" position for the tone control, that is, one in which no boost or cut is applied to the audio signal, is, in this case, critically dependent upon component values. This type of control is known as "shelving" control. Such shelving type tone control circuits may require a large number of components, and the component values to secure proper operation may be critical. It is desirable from many standpoints to provide a simpler tone control circuit and one in which the frequency at which the boost or cut begins, commonly called the turnover frequency, is variable and one that does not limit the amount of boost or cut at any given control setting but only the frequency at which the boost or cut begins.

It is therefore an object of the present invention to provide an improved tone control circuit for transistor audio frequency amplifiers which effectively obviates many of the difficulties heretofore experienced with the use and operation of such circuits.

It is a further object of the present invention to provide an improved tone control circuit for effectively utilizing the characteristics of transistors in a single or unitary circuit with relatively few and low cost components.

It is another object of the present invention to provide an improved bass and treble tone control circuit for transistor amplifiers having a variable turnover frequency characteristic and simplified control means therefor.

It is another object of the present invention to provide an improved transistor tone control circuit having an accurate flat frequency response at the midpoint position of the variable control means therefor, and providing high values of bass and treble boost and attenuation while using components having non-critical values and wide tolerances.

In accordance with the invention a tone control circuit is connected to the output circuit of a common-emitter transistor amplifier stage, and arranged effectively in the form of a signal current divider network having an input terminal connected to the collector of a transistor amplifier stage. One output terminal is provided for the tone control output signal current, and a second output terminal is connected to provide a degenerative feedback current to the base electrode of the transistor. The current divider network is arranged to provide a current division ratio that is dependent upon signal frequency in a predetermined manner to secure a desired frequency response. Continuously variable tone control is obtained by variation in the current division characteristics.

The invention may be further understood when the following description is read in connection with the drawings, in which:

FIGURE 1 is a graph showing curves illustrating certain operational features of tone control circuits in general;

FIGURE 2 is a schematic circuit diagram of a transistor amplifier having a tone control circuit in accordance with the invention providing variable turnover characteristics;

FIGURE 3 is a schematic circuit diagram of a transistor amplifier tone control circuit illustrating another embodiment of the present invention;

FIGURE 4 is a schematic circuit diagram of a transistor amplifier tone control circuit in accordance with yet another embodiment of the present invention;

FIGURE 5 is a schematic circuit diagram of a transistor amplifier circuit having a tone control circuit in accordance with the present invention providing variable turnover at bass frequencies and shelving a treble frequencies; and,

FIGURE 6 is a schematic circuit diagram of a transistor amplifier tone control circuit in accordance with the present invention providing a shelving type tone control circuit.

Referring now to the drawings, and in particular to FIGURE 1, two families of curves **10** and **12** indicate basically the type of frequency response control that may be provided by loss type tone control circuits. The curves of FIGURE 1 show only the bass boost characteristics usually provided in the tone control circuits, and for illustration purposes represent the type of action for a bass cut, treble boost, and treble cut characteristics that also may be provided in a complete tone control system.

The families of curves **10** and **12** indicate the characteristics of different settings of two different types of tone control circuits that may be provided. It will be noted that the family of curves **10** of FIGURE 1 provide a boost at bass frequencies with respect to mid-band frequencies in which the point at which boost begins is at different frequencies for different settings of the tone control means, while the slope of each boost curve **10** is the same. This is known as variable turnover, that is, the frequency at which bass boost begins is variable. However, the family of curves **12** of FIGURE 1 all begin to provide a boost in response at approximately the same frequency and variation in the tone control setting provides variation in the amount of ultimate boost only. The family of curves **12** indicate what may be called a "shelving" type of control. The particular type of characteristic, variable turnover or shelving, for any particular tone control circuit which a particular designer may apply is dependent upon the requirements to be met. However, circuits providing the variable turnover characteristic are generally of the switched-capacitor type which does not provide continuously variable control, while circuits of the shelving type are generally variable by the use of potentiometers. This invention provides the continuously variable turnover or the continuously variable shelving characteristic, or a combination of both, without the use of switched capacitors.

Referring now to FIGURE 2, an input signal is applied to a pair of input terminals **20** of a transistor amplifier circuit, from which the signal is applied directly between the base electrode **22** and the emitter electrode **24** of a first stage transistor **26**, here illustrated as a PNP type junction transistor. A biasing resistor **28** is connected between the collector electrode **30** and the base electrode **22** of the first transistor **26**, and the collector electrode **30** is connected through a load resistor **32** to a suitable source of current, here illustrated as a battery **34** having its positive terminal connected to a point of fixed reference potential or ground for the amplifier, and having its negative terminal connected to the load resistor **32**.

It will be seen that a signal applied to the input terminals **20** will be amplified and translated through the transistor **26** and appear as an output current at the collector electrode **30**.

In accordance with the invention, signals appearing at the collector electrode are conveyed through a coupling capacitor **36** to an input terminal **41**. Signals applied to the input terminal **41** are applied through a treble control resistor **42** to a current dividing network comprising a pair of capacitors **38** and **40**. The first of the pair of current divider capacitors **38** is connected to a permanent tap on the treble control resistor **42** while the second current divider capacitor **40** is connected to a variable tap or slider **44** on the resistor **42**. The second capacitor **40** is directly connected to an output terminal **45** which is connected to the base electrode **46** of a second transistor **48**, again illustrated as a PNP junction transistor, while the first capacitor **38** is directly connected to a feedback terminal **43** which is connected to the base electrode **22** of the first transistor **26**. Connected in parallel with the current divider capacitors **38** and **40** are three resistors, namely, a bass control resistor **50** and a pair of limit resistors **52** and **54**. A control tap or slider **51** on the bass control resistor **50** is connected to the coupling capacitor through the treble control resistor **42**.

The emitter electrode **56** of the second transistor **48** is connected directly to ground and the collector electrode **58** is connected to the source energizing current, the battery **34**, through a collector load resistor **60**. Bias is supplied for the base electrode **46** through a bias resistor **62** connected between the collector electrode **58** and the base electrode **46**. Output signals from the collector electrode are coupled through a coupling capacitor **64** to one of a pair of signal output terminals **68**, the other of which is connected directly to ground.

In operation, the current divider capacitors **38** and **40**, with the sliders **44** and **51** set in the mid-position, provide a current division that is flat with respect to frequency. Attenuation is provided in two ways, by actual division of the output current of the transistor **26** to apply only a small portion of the output current of the first transistor **26** to the base electrode **46** of the second transistor **48**, and by feedback of the remainder of the output current of the transistor **26** to its own base electrode **22** to provide signal degeneration. The current division and degeneration provide attenuation of all frequencies equally over the entire audio frequency band when the sliders **51** and **44** on the bass and treble control resistors **50** and **42** are set in their mid-positions.

The feedback over the first transistor **26** also raises the output impedance of the transistor **26** to provide a proper source impedance for the tone control circuit as hereinbefore mentioned. The source impedance may be shown to be equal to the parallel combination of the collector junction resistance of the transistor **26**, the reactance of the collector junction capacitance of the transistor **26**, the bias resistor **28**, and the value of the load resistor **32** multiplied by the current gain between the base and collector of the transistor **26** ($\alpha_{cb}$). The important feature is the fact that the effect of the load resistor **32** in lowering the output impedance is reduced by the factor of the current gain, $\alpha_{cb}$, of the transistor **26**.

The values of the capacitors **38** and **40** are selected so that the desired amount of attenuation is obtained, considering both the hereinbefore mentioned actual division of the output current, and the feedback. The amount of attenuation required, of course, is dependent upon the amount of boost that is to be made available at the extreme high and low frequencies with respect to mid-band frequencies. Thus, as an example, it may be desirable to provide approximately 20 decibels of attenuation in order that approximately 20 decibles of boost may be applied. The impedance of the current divider capacitors **38** and **40** should then have a ratio such that the effect of the current division and the feedback, in combination, provide a current attenuation of 10 to 1. The exact value of the current divider capacitors **38** and **40** will depend upon the transistor characteristics in particular

the circuit and the remaining circuit values, but may typically have a ratio of 5:1 respectively, the second capacitor **40** having the larger impedance.

At the high audio or treble frequencies the reactance of the capacitors **38** and **40** are low compared to the base control potentiometer **50** so that at high frequencies the base control path may be treated essentially an open circuit. To provide treble boost, that is, less attenuation of the extreme high frequencies, the slider **44** is moved from its mid-position, which is at the permanent tap position, toward the upper extremity of the resistor **42**, as viewed in the drawing. It will now be seen that there is a substantial resistance in series with the first current divider capacitor **38**. As the frequency increases, the impedance of the output path of the current divider will become low relative to the feedback path, so that more high frequency current will flow to the base **46** of the second transistor and less will be fed back. This action produces a boost at the high frequencies. The turnover frequency, or the frequency at which an appreciable boost begins, is primarily determined by the relationship between the impedance of the resistance in series with the first capacitor **38** and the reactance of this capacitor, and thus varies with the setting of the slider **44** on the resistor **42**.

In a like manner, the treble frequencies may be cut or attenuated a greater extent by moving the slider **44** toward the lower extremity of the resistor **42** thus placing resistance in series with the second current divider capacitor **40**. Since the impedance of the first current divider capacitor **38** will decrease as the frequency increases and the resistance will not decrease, more current is fed back through the first capacitor **38** to the base electrode **22** and less current is applied to the base electrode **46** of the second transistor **48**. This action will provide a greater attenuation or cut in the extreme treble frequencies. The turnover frequency will depend upon the ratio of the value of the resistance in series with the second capacitor **40** to the impedance of the first capacitor **38** and will, of course, vary with the setting of the slider **44**.

At base frequencies, the reactance of the current divider capacitors **38** and **40** becomes large compared to the resistance of the bass control resistor **50**, and control of the bass frequencies is thus possible by moving the slider **51** on the bass control resistor **50**. To provide a bass boost, that is, less attenuation of the extreme bass frequencies, the slider **51** is moved toward the right extremity of the bass control resistor **50**, as viewed in the drawing. It will now be seen that the second current divider capacitor **40** is shunted by a lower resistance than with the slider **51** in its mid position and more bass current will thus flow to the base electrode **46** of the second transistor and less bass current will be fed back to the base electrode **22** of the first transistor **26**. This of course, produces a boost in the bass frequencies, with the turnover frequency, that is the frequency at which a substantial boost begins, determined by the relationship of the value of the resistance in shunt with the second current divider capacitor **40** and the reactance value of this capacitor. Thus, variation of the position of the bass control slider **51** to the right of its mid position will provide a bass boost with a variable turnover frequency.

Conversely, bass frequency cut will be provided if the bass control slider **51** is moved from its mid position toward the left extremity of the resistor **50**. The opposite action will occur to that previously explained with respect to the bass boost circuit, that is, less resistance will be shunted across the first current divider capacitor **38** and more current will be fed back to the base electrode **22** of the first transistor **26** and less current will be applied to the base electrode **46** of the second transistor **48**. This action will produce bass cut by further attenuating the extreme bass frequencies. The point at which bass cut becomes appreciable, that is, the turnover frequency, will be determined by the relation between the reactance of the first voltage divider capacitor **38** and the resistance in shunt therewith.

The base control potentiometer may have a logarithmic or a semi-logarithmic variation of resistance with shaft rotation, so that at its mid-point of rotation, the resistance shunting each of the current divider capacitors **38** and **40** will be in approximately the same ratio as their reactances.

The position of the slider **44** on the treble control resistor **42** will have no appreciable effect on the bass control characteristics since the resistance value of the treble control resistor **42** is very small compared to the resistance of the bass control resistor **50** and the reactance of the current divider capacitors **38** and **40**. The limit resistors **52** and **54** connected to either extremity of the bass control resistor **50** merely serve to limit the maximum turnover frequency of the bass control for bass cut or bass boost respectively.

The negative feedback connection of the tone control circuit provides two functions. First, it raises the output impedance of the first stage to provide a high source impedance for the current divider. Second, it aids in providing tone control action by making the overall transmission characteristic of the first stage vary with frequency in the desired manner. The negative feedback produces this result because it will be seen that not all of the current output of the first stage is fed back to the input electrode of the stage, since the useful output current which flows to the base of the second stage is not fed back. Suppose, for example, that bass boost is utilized. Then, at mid and high frequencies, a small portion of the output current of the first stage is fed to the second stage, and the remainder is fed back to the input electrode of the first stage. This feedback has the effect of reducing the mid and high frequency gain of the first stage. At low frequencies, however, most of the output current of the first stage is fed directly to the second stage, and little is left for feedback. Therefore, the transmission characteristic of the first stage is increased over its value at mid and high frequencies, thereby aiding the tone control action.

A "flat" position of the tone control providing equal attenuation at all frequencies is easily achieved, since there is an individual "flat" position for each of the bass and treble controls. Positioning the treble slider **44** at the permanent tap point on the treble control resistor **42** gives a "flat" treble position. The "flat" bass position is not as easily set; however, its "flat" position is with the slider **51** set on the low resistance end of the bass control resistor **50** where a large movement of the slider **51** produces only a small change in resistance.

The transistors **26** and **48** have been here illustrated as junction transistors of the PNP type. It should be understood, however, that other type transistors may be used and that transistors of an opposite conductivity type, that is a P type conductivity, may be used. If the transistors **26** and **48** were of P type conductivity, for example, an NPN junction transistor, the polarity of the supply voltages would obviously be reversed.

Referring now to FIGURE 3, a tone control circuit in accordance with the invention has the same components and connections as the circuit shown in FIGURE 1, and is adapted to be connected to the input, feedback, and output terminals **41**, **43**, and **45** of FIGURE 1. It will be noted that a slightly different connection of the bass control slider **51** is used. The slider **51** of the bass control resistor **50** is connected to the slider **44** on the treble control resistor **42**. The operation of the circuit shown in FIGURE 3 is, however, substantially as described in connection in FIGURE 2. The current division is accomplished by the current divider capacitors **38** and **40**, as previously explained. At the treble frequencies, variation of the position of the slider **44** on the

treble control resistor will produce a cut or boost in treble frequencies with a variable turnover characteristic. The action of the bass circuit will be the same as explained with reference to FIGURE 2 and boost or cut of the bass frequencies will be accomplished in the same manner. At bass frequencies the resistance of the entire treble control resistor **42** is small compared to the resistance of the bass control resistor **50**, and there is no noticeable effect upon the operation of the circuit.

Referring now to FIGURE 4, a further variation of a tone control circuit in accordance with the invention and adapted to be connected to the input, feedback and output terminals **41**, **43**, and **45** of the amplifier circuit of FIGURE 1, is the same as that described in FIGURE 3, with the exception that an alternate connection is shown for the circuit components. It will be seen the variable and fixed taps on the treble control resistor **42** are reversed from the arrangement shown in FIGURE 3 and that the slider **51** on the bass control resistor **50** is connected to the fixed tap on the treble control resistor **42**.

The operation of the circuit is the same as described with reference to FIGURE 2. Current division of the audio frequencies is provided by the current divider capacitors **38** and **40** and bass or treble control with the variable turnover characteristic is accomplished by positioning of the sliders **44** and **51** on the treble and bass control resistors **42** and **50**. Although the tap connections on the treble control resistor **42** are reversed from that of FIGURE 3, the operation of the circuit is the same as that of FIGURES 2 or 3, since the difference in impedance levels of the circuit at bass and treble frequencies, as previously explained, allows the bass control slider **51** to be connected to any point on the treble control resistor **42** without altering the operation of the circuit appreciably.

Referring now to FIGURE 5, the transistor audio frequency amplifier includes the pair of transistors **26** and **48** connected in the same manner as the circuit of FIGURE 2, with the exception that a modification of tone control circuit is provided in accordance with the invention. It will also be noted that the transistors **26** and **48** are illustrated as P type or NPN transistors. The use of P type transistors necessitates a reversal of the connection of the battery **34** as indicated. No change in the manner of operation of the amplifier or tone control circuits from that of FIGURE 2 results from the use of opposite conductivity type transistors. The bass control circuit is essentially the same as FIGURE 2; that is, the bass control potentiometer **50** is connected at one extremity through the limit resistor **54** to the output terminal **45** and thus to the base electrode **46** of the second transistor **48**, and at its other extremity through the limit resistor **52** to the feedback terminal **43** and thus to the base electrode **22** of the first transistor. The treble control, however, includes, in addition to the current divider capacitors **38** and **40**, a treble control resistor **70** connected serially therebetween, with a variable slider or tap **72** on the control resistor **70** connected directly to the input terminal **41**. A pair of current divider resistors **74** and **76** are connected between the variable slider or tap **72** and the ends of the treble control resistor **70**.

At base frequencies the operation of this tone control circuit is essentially the same as previously described with reference to the base controls shown in FIGURES 2, 3, and 4, that is, the current divider capacitors **38** and **40** provide the basic attenuation which is varied to provide bass cut or bass boost by positioning the slider **51** along the bass control resistor **50**. The current division is essentially capacitive at the bass frequencies, since the reactance of the current divider capacitors **38** and **40** at the bass frequencies is very much larger than the resistance of the treble control resistor **70** and its resistance may thus be neglected.

However, at the treble frequencies, the reactance of the current divider capacitors **38** and **40** becomes sufficiently small to be neglected and the resistance of the bass control circuit is very much larger than the reactance of the treble control circuit and its effect may also be neglected. It will be seen that at treble frequencies the current division is essentially resistive. The feedback path is through the first current divider resistor **74** and first current divider capacitor **38**, the reactance of which is very small to the feedback terminal **43**. The output circuit path is through the second current divider resistor **76** and the small reactance of the second current divider capacitor **40** to the output terminal **45**. Movement of the slider **72** changes the resistance in parallel with the current divider resistors **74** and **76** and thus changes the amount of current fed back to the base electrode **22** of the first transistor **26** and the amount of current applied to the base electrode **46** of the second transistor **48**. This current dividing action is unlike that of the circuits of FIGURES 2, 3, or 4, where the current division is accomplished by a capacitive divider. The treble tone control circuit of FIGURE 5 will thus have substantially the same turnover frequency for the treble control at all settings of the slider **72**, since the current division is resistive and hence not frequency sensitive. The position of the slider **72** will determine only the amount of boost or cut that will be given.

Other operational features of the circuit are the same as described in connection with FIGURES 2, 3, and 4; that is, the current through the first voltage divider resistor **74** and capacitor **38** is applied to the base electrode **22** of the first transistor **26**, and the feedback increases the output impedance of the transistor **26** in the same manner as hereinbefore described.

Referring now to FIGURE 6, a tone control circuit is adapted to be connected to the input, feedback, and output terminals **41**, **43**, and **45** of either the circuits of FIGURES 2 to 5. The tone control circuit has both treble and bass controls and provides a variable shelving type of control at both bass and treble frequencies.

The treble control resistor **70** is connected between the feedback and output terminals **43** and **45** by a pair of capacitors **80** and **82**, and the input current is applied through the input terminal **41** to the slider **72** on the treble control resistor **70**. The bass control circuit is also connected between the feedback and output terminals **43** and **45** and includes a first current divider resistor **84**, a bass control resistor **86** and a second current divider resistor **88**. A variable slider **90** on the bass control resistor **86** is connected directly to the input terminal **41**. A pair of capacitors **90** and **94** are connected between the slider **90** and either end of the bass control resistor **86**.

It will be seen that the tone control connection of FIGURE 6 will provide essentially resistive current division to provide the desired signal attenuation at both treble and bass frequencies. At treble frequencies the capacitors **80**, **82**, **92**, and **94** in the tone control circuit will exhibit a very low impedance, and the main current division will be provided by the current divider resistors **84** and **88**. The feedback current will be coupled through the first current divider resistor **84** to the feedback terminal **43** from where it is applied to the base electrode **22** of the first transistor **26**. The output current will be coupled through the output terminal **45** to the second transistor **48**. If the slider **72** on the treble control resistor **70** is moved to the right, less resistance will be shunted across the second current divider resistor **88** resulting in an increase in output current at the treble frequencies thus providing treble boost. The converse is true if the treble control slider **72** is moved to the left, that is, less resistance will be shunted across the first current divider resistor **84** thus feeding back more current and providing treble cut.

At bass frequencies, the capacitors **80**, **82**, **92**, and **94** will exhibit a very high impedance, so that the position of the slider **72** of the treble control resistor will have sub-

stantially no effect. The majority of the input current from the input terminal **41** at bass frequencies will flow to the variable slider **90** on the bass control resistor **86** and through the bass control resistor **86** in two paths. The feedback path at bass frequencies is through the portion of the bass control resistor **86** to the left of the slider **90**, as viewed in the drawing, and through the first current divider resistor **84** to the feedback terminal **43**, and the tone control output current will flow through the portion of the bass control resistor **86** to the right of the slider **90**, through the second current divider resistor **88** to the output terminal **45**. It is apparent that positioning of the slider **90** on the bass control resistor **86** will alter the division of current between the output and feedback paths to provide control of the bass frequencies. Thus, moving the slider **90** to the right of its mid-position will decrease the resistance of the entire right hand or tone control output path providing more current to the output terminal **45** and resulting in bass boost. Positioning the slider **90** to the left of its mid-position will decrease the entire resistance of the feedback path and feed back more current to the feedback terminal **43**, thus providing bass cut.

A tone control circuit in accordance with the invention suitable for use in transistor amplifiers is characterized by its simplicity and economy. Fewer components may be required than with present day circuits to provide a tone control having a variable turnover characteristic. The conventional variable shelving tone control circuit may also be used. Both types of tone control circuits have improved performance resulting from the aid to the signal attenuation provided by the feedback connection.

What is claimed is:

A combined bass and treble tone control circuit for a transistor audio frequency amplifier comprising in combination, a signal amplifier stage including a transistor having base, collector, and emitter electrodes; a treble frequency control resistor having two end terminals, a fixed tap, and a variable tap thereon; means for connecting one of said end terminals of said treble control resistor to said collector electrode; means for connecting a first current divider capacitor between said fixed tap and the base electrode of said transistor; means for connecting a second current divider capacitor between said variable tap and a tone control output terminal; means for connecting a bass frequency control resistor having two end terminals and a variable tap thereon between said tone control output terminal and the base electrode of said transistor; and means for connecting the variable tap on said bass frequency control resistor to said variable tap of said treble control resistor; the relative impedance values of said current divider capacitor and bass and treble control resistor being so related to provide a predetermined mid frequency attenuation of the output current appearing at said collector electrode and to vary the attenuation a the bass and treble frequencies by positioning of the variable taps on said bass and treble frequency control resistors.



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