Many prior art oscilloscopes suffer from the disadvantage that the time base thereof shifts up and down in response to line voltage variations. This is as a result of changes in the A.C. filament voltages of electron discharge devices common to the D.C. balance control circuitry of the scope. This problem is overcome in an inexpensive manner by means of a transistor whose response is made to vary responsive to line voltage variations and that is connected to compensate for any changes in emission resulting therefrom to keep the D.C. voltage across the vertical gain control potentiometer of the scope at substantially zero volts.

10 Claims, 1 Drawing Figure
This invention relates to A.C. balance control networks that are particularly suited for use with oscilloscopes.

Conventional oscilloscopes are provided with D.C. balance controls that are used to control the location of the time base. At any given line voltage, the D.C. balance controls of most cathode ray tube type scopes can be adjusted so that the time base does not shift up or down as the vertical and/or horizontal gain controls are varied throughout their range. However, it has not been common practice, at least in the less expensive scopes, to compensate for line voltage variations. Line voltage variations result in changes in the A.C. filament voltages of electron discharge devices that are common to the D.C. balance control circuitry. These voltage changes cause the emissions of these devices to change with resulting displacement of the time base and inaccurate readouts when the scopes are used as A.C. or D.C. voltmeters.

While networks that automatically compensate for line voltage variations have been built in to more expensive scopes, such networks are expensive and have not been used generally in less expensive scopes.

In accordance with this invention there are provided simple and inexpensive A.C. balance control networks that overcome the problem hereinafore stated attendant upon changes in line voltage applied to an oscilloscope.

In brief, in accordance with this invention the D.C. voltage developed across the vertical gain control potentiometer of an oscilloscope is kept at substantially zero volts during line voltage variations by means of a transistor whose resistance is made to vary responsive to line voltage variations and which is connected to compensate for any changes in emission resulting from line voltage changes. The invention may be applied to the horizontal amplifier as well as to the vertical amplifier to decrease its sensitivity to line voltage changes.

This invention will become more apparent from the following detailed description, taken in conjunction with the drawing, the latter being a diagram, partly in block form and partly a schematic, showing a conventional oscilloscope embodying this invention.

The oscilloscope shown in the FIGURE, with the exception of the components within dotted line 10, is a conventional oscilloscope consisting of a vertical amplifier 11, a sweep generator 12, a horizontal amplifier 13 and a cathode ray tube 14. It is a "Heathkit" (trade mark) model 10-10 oscilloscope, and reference may be had to publications by the manufacturer describing the operation thereof.

Vertical amplifier 11 includes an amplification stage constituted by an electron discharge device (tube) 15 having plate 16, cathode 17 and grid 18 electrodes and a filament 19 for the cathode. Plate 16 is connected to B+ which, in this case, is +150 volts (regulated). Input signals to be displayed are coupled to the grid of tube 15.

The vertical gain potentiometer is designated P1 and has one of its fixed terminals grounded, the other being connected to one terminal of a resistor R1 that has its other terminal connected to cathode 17. The vertical D.C. balance control potentiometer P2 has one of its fixed terminals connected to cathode 17 and the other of its fixed terminals connected to one terminal of a resistor R2 that has its other terminal connected to B- which, in this case, is -75 volts (regulated). Resistor R2 is a voltage dropping resistor and limits the range of the D.C. balance control.

Normally the movable terminal 20 of potentiometer P2 is connected directly to the same terminal of potentiometer P1 as is resistor R1, i.e., the upper terminal of potentiometer P1, and is set so that for a given line voltage, the D.C. voltage at the upper terminal of potentiometer P1 is zero volts. With this connection, however, when increases in line voltage cause the emission of filament 19 to increase, the D.C. voltage at the upper terminal of potentiometer P1 will swing positive causing the time base to rise. Conversely, when decreases in line voltage cause the emission of filament 19 to decrease, the D.C. voltage at the upper terminal of potentiometer P1 will swing negative causing the time base to drop.

In accordance with this invention a transistor TR1 is provided and substituted for the aforementioned direct connection between potentiometer P1 and P2. The collector electrode of transistor TR1 is connected to movable terminal 20, while the emitter electrode is connected to the upper terminal of potentiometer P1. Thus the collector-emitter path of transistor TR1 plus resistor R1 is placed in parallel with a part of potentiometer P2 that varies with the setting of terminal 20.

An A.C. power source 21 supplies filament 19 and the filaments of other tubes of the scope. A rectifier 22 receives its input from source 21 and produces an unregulated D.C. output of, say, +330 volts. Since the output of rectifier 22 is unregulated, it will increase or decrease with increases and decreases in the A.C. voltage output of source 21, i.e., with line voltage changes.

Connected between rectifier 22 and the base electrode of transistor TR1 are an isolating resistor R3 and a variable resistor R4, the latter being for A.C. balance control.

It will be noted that transistor TR1 is connected in reverse configuration and in operation there is a negative D.C. voltage at its collector and zero volts at its emitter. The network hereinbefore described is set up for proper operation by inserting the maximum resistance in the base circuit of transistor TR1 and, with the minimum likely A.C. line voltage, say, 110 volts, moving terminal 20 until zero D.C. volts is the D.C. potential of the upper terminal of potentiometer P1. This condition is obtained when the movable terminal 23 of potentiometer P1 can be moved throughout its range without there being any movement of the time base. Once this has been done, the maximum likely A.C. line voltage, say 125 volts, is applied and resistor R4 adjusted for a stationary time base as terminal 23 is moved throughout its range.

In normal circumstances the line voltage will be, say, 117 volts and the upper terminal of potentiometer P1 will be at a D.C. potential of zero volts for this line voltage. Any increase in line voltage above 117 volts will increase the unregulated D.C. output of rectifier 22, thereby increasing the conductivity of transistor TR1 and decreasing the collector to emitter resistance of the transistor. This tends to make the upper terminal of potentiometer P1 more negative to compensate for the
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previous tendency of this terminal to become more positive due to the increased emission of filament 19. Conversely, any decrease in line voltage below 117 volts will decrease the unregulated output of rectifier 22, thereby decreasing the conductivity of transistor TR1 and increasing the collector to emitter resistance thereof. This tends to make the upper terminal of potentiometer P1 more positive to compensate for the previous tendency of this terminal to become more negative due to the decreased emission of filament 19.

In other words, increases and decreases in line voltage (and consequent increases and decreases in the emission of filament 19) result in decreases and increases respectively in the resistance of the path consisting of resistor R1 and the collector-emitter resistance of transistor TR1 and hence in decreases and increases respectively in the cathode resistance of cathode 17 measured between cathode 17 and B' (−75 volts), and the changes in cathode resistance compensate for the changes in emission.

As may be seen from the foregoing, transistor TR1 functions as a linear negative resistance and keeps the upper terminal of potentiometer P1 at zero D.C. volts despite line voltage variations between 110 and 125 volts.

In a typical network components having the following values may be used:

- Potentiometer P1 — 5KΩ
- Potentiometer P2 — 10KΩ
- Resistor R1 — 1KΩ
- Resistor R2 — 10KΩ
- Resistor R3 — 270KΩ
- Resistor R4 — 1MΩ
- Transistor TR1 — NPN type SE5025

The collector-base junction of transistor TR1 is forward biased and the base-emitter junction is reverse biased. Typical voltages are: collector — 2.6 volts, base — 1.85 volts, emitter zero volts. The cathode of tube 15 typically is at +2.3 volts.

Of course, with appropriate reversal of polarity a PNP transistor could be used in place of the NPN transistor shown in the FIGURE.

Where temperature stability is required, transistor TR1 should be made of silicon and have an epitaxial planar structure. In addition, it should have a low $I_{CB0}$ (in N amps) and a low beta (less than 35).

A preferred embodiment of the invention has been disclosed herein. Changes and modifications may be made therein without departing from the spirit and scope of the invention as defined in the appended claims.

What I claim as my invention is:

1. In combination, an amplifying device comprising an electron discharge device having plate, cathode and grid electrodes and a filament, a resistive network connected in circuit with said cathode, first and second terminals at positive and negative D.C. potentials respectively, means including said resistive network connecting said electron discharge device in circuit between said first and second terminals, a first potentiometer having two fixed terminals and a movable terminal, a third terminal at a D.C. potential intermediate that of said first and second terminals, said first potentiometer being connected in a D.C. path between said cathode and said third terminal, a source of alternating current, means connecting said source of alternating current and said filament to supply heating current to said filament, means deriving a D.C. voltage from said source of alternating current that varies with changes in the magnitude of the A.C. voltage of said source of alternating current, said resistive network including first and second D.C. paths connected in parallel with each other, said first D.C. path including a first resistor, said second D.C. path including a second resistor and the collector-emitter path of a transistor having base, collector and emitter electrodes, and means for supplying said D.C. voltage to said base to increase the conductivity of said transistor in response to an increase in said A.C. voltage and to decrease the conductivity of said transistor in response to a decrease in said A.C. voltage, whereby the D.C. voltage across said first potentiometer is kept at substantially zero volts.

2. The invention according to claim 1 wherein said means for supplying said D.C. voltage to said base electrode includes a variable resistor.

3. The invention according to claim 2 wherein said D.C. path between said cathode and said third terminal includes said second resistor.

4. The invention according to claim 2 wherein said D.C. potential of said third terminal is zero volts.

5. The invention according to claim 2 wherein said first resistor is the resistance of at least part of a second potentiometer having two fixed terminals and a movable terminal, said fixed terminals of said second potentiometer being connected in circuit between said cathode and said second terminal, said movable terminal of said second potentiometer being connected in circuit with said collector electrode.

6. The invention according to claim 5 wherein said D.C. path between said cathode and said third terminal includes said second resistor.

7. The invention according to claim 6 wherein said resistive network includes a third resistor connected between said second terminal and said second potentiometer.

8. The invention according to claim 7 including a fourth resistor connected between said variable resistor and said means deriving said D.C. voltage from said source of alternating current.

9. The invention according to claim 8 wherein said D.C. potential of said third terminal is zero volts.

10. In combination, an amplifying device comprising an electron discharge device having plate, cathode and grid electrodes and a filament, a resistive network, first and second terminals at positive and negative D.C. potentials respectively, means connecting said resistive network between said second terminal and said cathode in a D.C. path, means connecting said first terminal and said plate in a D.C. path, a first potentiometer having two fixed terminals and a movable terminal, a third terminal at a D.C. potential of zero volts, a first resistor, means connecting said first resistor in a series D.C. circuit between said cathode and said third terminal with one of said fixed terminals being connected to said third terminal and thus being at a D.C. potential of zero volts, a source of alternating current, means connecting said source of alternating current and said filament to supply heating current to said filament, means deriving a positive D.C. voltage greater than that of said first terminal and that varies with changes in the
magnitude of the A.C. voltage of said source of alternating current from said source of alternating current, said resistive network including a second resistor and a second potentiometer having two fixed terminals and a movable terminal, said second resistor being connected between said second terminal and one of said fixed terminals of said second potentiometer, the other fixed terminal of said second potentiometer being connected to said cathode, said resistive network also including said first resistor and the collector-emitter path of a transistor having base, collector and emitter electrodes, said first resistor and said collector-emitter path being connected in series circuit between said cathode and said movable terminal of said second potentiometer, means connecting the other of said fixed terminals of said first potentiometer and said emitter, and means including a variable resistor for supplying said D.C. voltage to said base to increase the conductivity of said transistor in response to an increase in said A.C. voltage and to decrease the conductivity of said transistor in response to a decrease in said A.C. voltage, whereby said other fixed terminal of said first potentiometer is kept at substantially zero volts.

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