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THIN-FILM ELECTRICAL NETWORKS WITH NON-RESISTIVE FEEDBACK ARRANGEMENT

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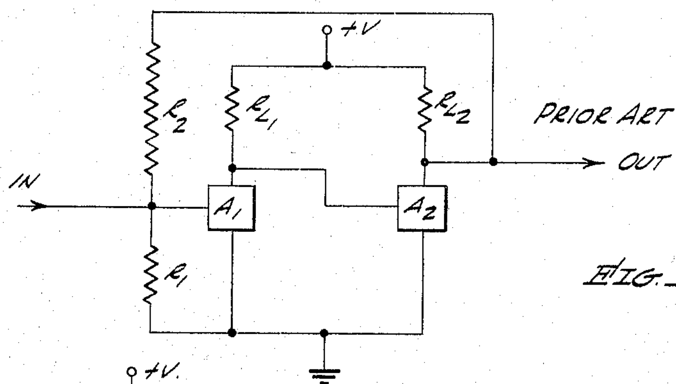

PRIOR ART

FIG. 1.

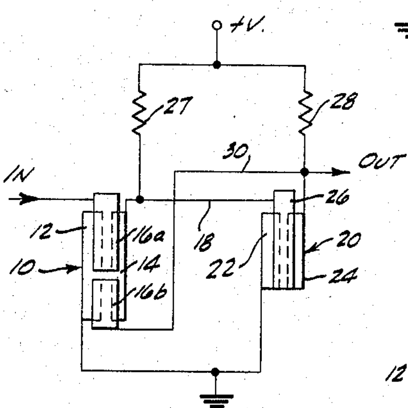

FIG. 2.

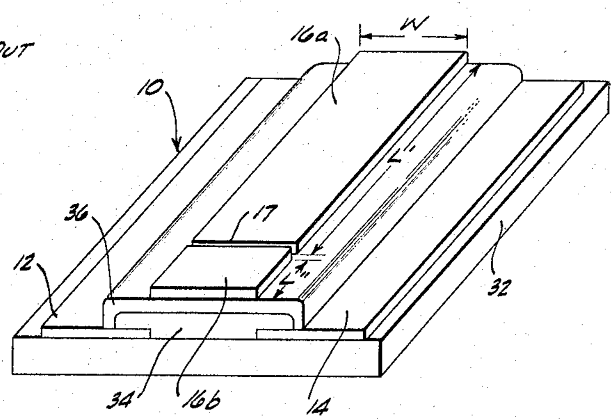

FIG. 3.

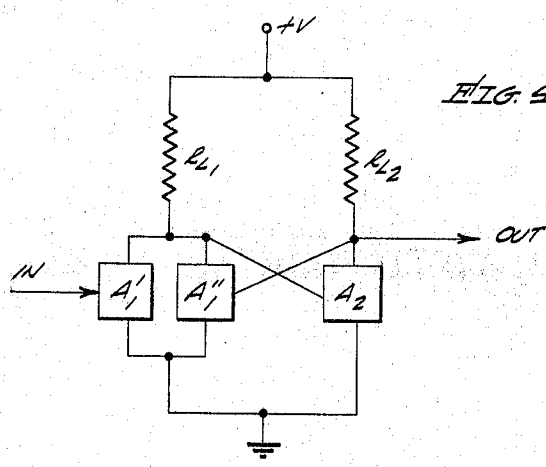

FIG. 4.

INVENTOR.
JOHANN G. DILL,
BY Paul M. Coble
ATTORNEY.

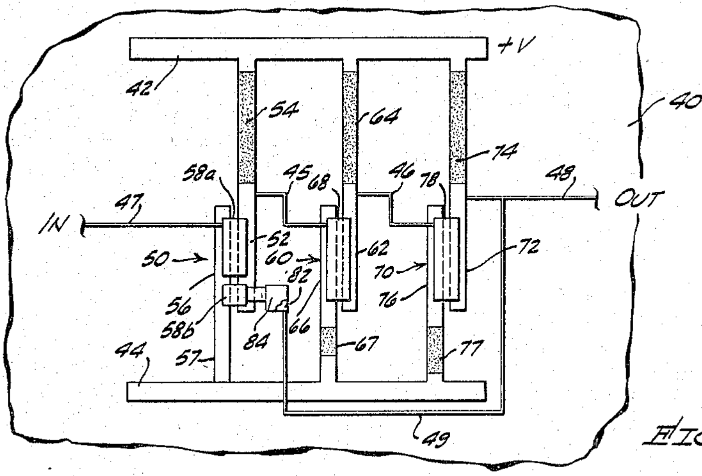

FIG. 5.

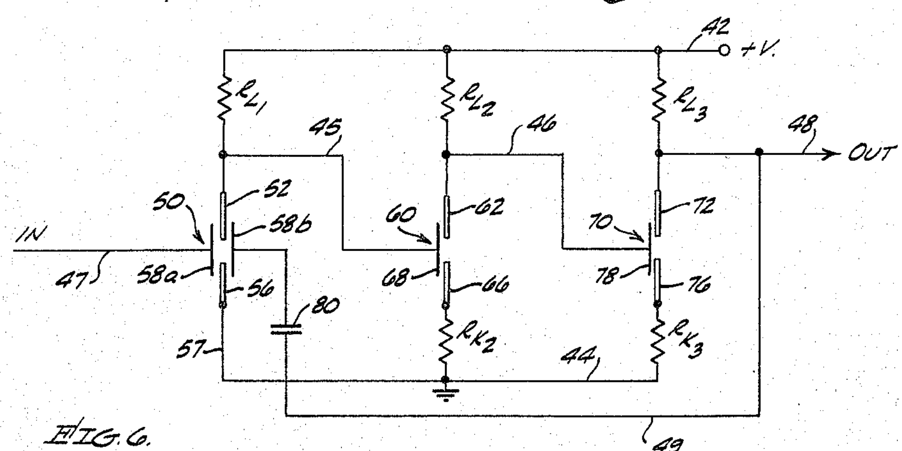

FIG. 6.

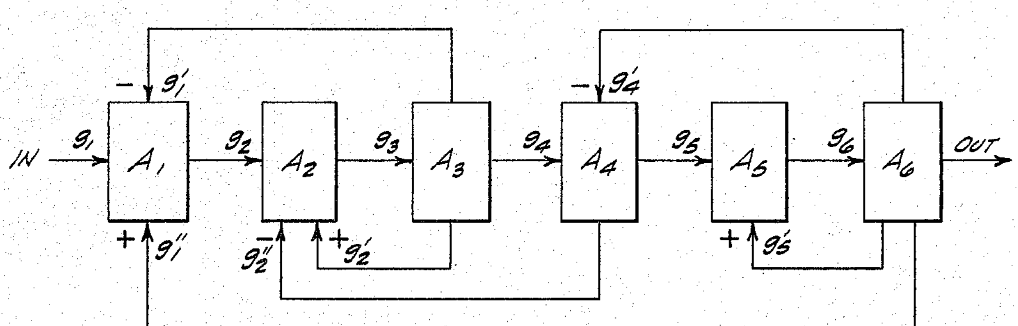

FIG. 7.

INVENTOR.
JOHANN G. DILL,
BY Paul M. Coble
ATTORNEY.

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THIN-FILM ELECTRICAL NETWORKS WITH NON-RESISTIVE FEEDBACK ARRANGEMENT

Johann G. Dill, Costa Mesa, Calif., assignor to Hughes Aircraft Company, Culver City, Calif., a corporation of Delaware

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10 Claims. (Cl. 330—19)

This invention relates to thin-film electrical networks, and more particularly relates to feedback networks employing cascaded thin-film transistors in which resistive circuitry is eliminated from the feedback path.

In order to improve stability, reduce noise and distortion, adjust input and output impedances, control frequency response, and achieve other advantageous effects, the concept of feedback has found extensive application throughout the art of electronics. According to the feedback principle, a portion of the output voltage or current from an electrical network is fed back and superposed on the input voltage or current to the network. As is well known, for a network gain A and a ratio β of feedback voltage to network output voltage, the overall gain A' of the network with feedback becomes

$$A'=A/(1-A\beta)$$

A common prior art scheme for achieving the desired feedback involves providing a resistive voltage divider across the output of the network and connecting the intermediate point of the voltage divider back to the input of the network.

A problem encountered with the aforementioned type of feedback circuit is that the resistive voltage dividers give rise to substantial power dissipation and often cause undesirable loading of the output. When the resistance values of the voltage dividers are made large in order to minimize this power loss, the RC cutoff frequency of the network is reduced accordingly. Therefore, a way in which such voltage dividing arrangements could be eliminated from feedback networks while still achieving the desired feedback would be highly desirable.

A recent innovation which has made such an accomplishment possible is the development of the thin-film transistor. This type of transistor operates by the control of injected majority charge carriers in a wide band-gap semi-conductor or semi-insulator material by means of an insulated control gate electrode. These devices are analogous to triode vacuum tubes; however, thin-film transistors are solid state devices, and all components including the semi-insulator as well as the necessary electrodes are usually deposited by evaporation upon a substrate. In triode vacuum tubes electrons emitted from the cathode flow through the vacuum to the anode, and the density of these electrons may be controlled by a grid electrode interposed between the cathode and plate electrodes. In thin-film transistor devices, majority charge carriers are injected into the solid state semi-insulator material by an electrode usually termed the "source," and these majority carriers move through the semi-insulator toward a second electrode called the "drain." The control electrode, which by its field effect in the semi-insulator can vary the density of majority charge carriers reaching the drain, is termed the "gate" and is usually insulated from the semi-insulator material to prevent majority carriers from flowing to it. In comparison with semi-conductor devices of the junction type in which charge carriers already available in the semi-conductor body are injected across a junction between regions of opposite conductivity type, charge carriers in thin-film transistors are normally not available in the body of semi-insulator material and are injected thereinto

from an electrode having a lower work function than the work function of the semi-insulator. For a more complete discussion of thin-film transistor devices, reference may be made to an article by P. K. Weimer entitled "The TFT—A New Thin-Film Transistor," published in the June 1962 Proceedings of the I.R.E., on pages 1462–1469.

With the advent of the thin-film transistor discussed above, there has been increased interest in solid state microcircuitry in which all the components of an electrical circuit are completely integrated on one solid slab of material. This is because integrating active elements with the passive patterns of conductors, resistors, capacitors, and inductors has been one of the more acute problems in the microcircuitry art, and the thin-film transistor is far more suited to incorporation in such microcircuits than previous active devices. Nevertheless, in thin-film circuitry high value resistors are not only difficult to build to precise specifications, but they tend to be unreliable. Moreover, when the resistance values of thin-film resistors are made large, stray capacitance and inductance is introduced which may become troublesome in certain instances. Thus, the elimination of large feedback resistors becomes even more desirable when dealing with thin-film circuitry than in vacuum tube and conventional transistor circuitry.

Accordingly, it is a principal object of the present invention to provide a thin-film electrical network in which feedback is provided without the need for large feedback resistors.

It is a further object of the present invention to provide a thin-film electrical signal processing or generating network employing feedback which has a higher upper cutoff frequency and less output loading than has heretofore been possible.

It is a still further object of the present invention to provide a feedback circuit employing cascaded thin-film transistors in which a smaller D.C. blocking capacitance may be employed in the feedback path than in the past.

It is a still further object of the present invention to provide a thin-film feedback amplifier or oscillator in which all of the circuit components may be integrated onto a single substrate of insulating material, thereby lending itself to the microminiaturization of electrical circuits.

It is still another object of the present invention to provide electrical circuits including a plurality of cascaded thin-film transistor stages with various combinations of positive and negative feedback between stages, and which circuits possess less power dissipation, reduced stray inductance and capacitance, and a higher upper cutoff frequency than thin-film circuits of the prior art.

In accordance with the foregoing objects, the present invention provides an electrical feedback circuit comprising a plurality of thin-film amplifying stages coupled in cascade. At least one of the stages prior to the final stage includes a body of semi-insulator material and a divided gate electrode, i.e. a plurality of gate electrode members capable of independently controlling the flow of injected majority charge carriers in the semi-insulator body. A signal to be amplified by this stage is applied to one of the gate electrode members, while a feedback signal from a subsequent thin-film amplifying stage is applied to another of the gate electrode members. No resistive voltage dividing network is required between the subsequent stage and the stage to which the feedback signal is applied.

Other and further objects, advantages, and characteristic features of the present invention will become readily apparent from consideration of the following detailed description relating to preferred embodiments of the invention when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic circuit diagram partially in block form of a two-stage feedback amplifier circuit according to the prior art;

FIG. 2 is a schematic circuit diagram partially in pictorial form of a two-stage feedback amplifier circuit according to the present invention;

FIG. 3 is a perspective view of a thin-film transistor device according to the present invention which may be employed in the first stage of the circuit of FIG. 2;

FIG. 4 is a schematic circuit diagram partially in block form illustrating an equivalent circuit for the circuit of FIG. 2;

FIG. 5 is a plan view of an integrated circuit arrangement of a three-stage amplifier provided according to a further embodiment of the invention;

FIG. 6 is a schematic circuit diagram illustrating an equivalent circuit for the amplifier of FIG. 5; and

FIG. 7 is a block diagram of a multistage amplifier having multiple feedback paths and further illustrating the manner in which the principles of the present invention may be employed.

Referring to FIG. 1, a typical two-stage feedback amplifier of the prior art may be seen to include first and second amplifying stages having respective gains A_1 and A_2. The amplifying stages A_1 and A_2 may comprise vacuum tubes, transistors, thin-film devices, or other active elements providing a gain between a control electrode and an output electrode. The control electrode of the first stage A_1 receives the input signal, while the output electrode of the second stage A_2 provides the overall output from the amplifier. Load resistors R_{L_1} and R_{L_2} connect the respective output electrodes of the active devices A_1 and A_2 with a source of bias potential designated as +V. In order to provide the desired feedback from output to input a voltage dividing network consisting of series resistors R_2 and R_1 are connected between the output electrode of the second stage A_2 and ground, with the point intermediate the resistors R_1 and R_2 being connected to the control electrode of the input stage A_1. By means of this voltage dividing arrangement, a proportion

$$\beta=R_1/(R_1+R_2)$$

of the output voltage is fed back and applied to the input of the amplifier circuit. As has been brought out above, the resistors R_1 and R_2 give rise to undesired power dissipation, cause extensive output loading, and limit the upper cutoff frequency of the amplifier. Thus, providing the desired feedback and at the same time eliminating the resistors R_1 and R_2 from the circuit of FIG. 1 is a primary objective of the present invention.

A feedback arrangement according to the present invention, in which the resistors R_1 and R_2 of FIG. 1 have been eliminated, is shown in FIG. 2. As is illustrated, an amplifier circuit according to the invention may include a first thin-film amplifying, or active, stage **10** illustrated as a thin-film transistor device having a source electrode **12**, a drain electrode **14** and a pair of independent gate electrodes **16***a* and **16***b*. The drain electrode **14** of the thin-film transistor **10** is connected via a lead **18** to the gate electrode **26** of a second thin-film amplifying device **20** also having a source electrode **22** and a drain electrode **24**. The drain electrodes **14** and **24** of the thin-film devices **10** and **20** are connected to a source of bias potential providing a voltage of +V via respective resistors **27** and **28**, while the respective source electrodes **12** and **22** of the devices **10** and **20** are connected to a level of reference potential indicated as ground. The input signal to the circuit is applied to the gate electrode **16***a* of the first thin-film amplifying stage **10**, while the output signal from the amplifier is obtained from the drain electrode **24** of the second thin-film transistor **20**. In order to provide the desired feedback, a lead **30** connects the drain electrode **24** of the second thin-film transistor device **20** with the gate electrode **16***b* of the first thin-film transistor device **10**.

FIG. 3 illustrates a preferred configuration for the first stage thin-film transistor device **10** of FIG. 2. As is shown, the thin-film transistor **10** may comprise an insulating base, or substrate, **32** of glass or the like onto which has been deposited first and second electrically conductive films **12** and **14** respectively serving as a source electrode and a drain electrode. The electrodes **12** and **14** are located a predetermined distance apart and coextensively extend parallel to one another along the length of the substrate **32**. A layer **34** of semi-insulator material is formed on the substrate **32** in the region between the electrodes **12** and **14**. The layer **34** has a thickness greater than that of the electrodes **12** and **14**, and outer upper regions of the layer **34** overlap portions of the electrodes **12** and **14**.

As used herein the term "semi-insulator" material means a material which has substantially no intrinsic charge carriers therein for the conductance of current but which is capable of having charge carriers injected thereinto from a material having a lower work function than that of the semi-insulator. A preferable semi-insulator material for the layer **34** is cadmium sulfide; however, other suitable semi-insulator materials are compounds formed by elements of the Second and Sixth Columns of the Mendeleev Periodic Table of Elements, as well as compounds formed by the elements of the Third and Fifth Columns of this Periodic Table. Some of the more preferable semi-insulator materials in addition to cadmium sulfide are: cadmium telluride, cadmium selenide, zinc sulfide, zinc selenide, zinc telluride, gallium arsenide, gallium phosphide, indium arsenide, indium phosphide, and indium antimonide. These materials are preferred primarily because of their more advantageous physical properties among which are thermal stability and ability to be vapor-deposited and plated with metal.

The source electrode **12** should be of a metal having a work function lower than that of the semi-insulator film **34**, while the metal which forms the drain electrode **14** should possess a higher work function than that of the semi-insulator layer **34**. These conditions may be achieved by forming the source electrode **12** of indium, for example, and by forming the drain electrode **14** of gold, for example, in the case where the semi-insulator material is cadmium sulfide. The work functions of gold and indium are, respectively, 4.8 ev. and 3.8 ev., while the work function of cadmium sulfide is 4.2 ev. Other satisfactory electrode materials which may be employed are aluminum, silver, gallium, tellurium, and cadmium. The electrodes **12** and **14** and the semi-insulator layer **34** may be formed by vapor deposition and masking techniques well known in the art, such as those described in the aforementioned Weimer article and the references thereof.

A layer **36** of insulating material, for example silicon monoxide, is formed on top of the semi-insulator **34**, and a pair of gate electrodes **16***a* and **16***b* separated by a gap **17** are formed on top of the insulating layer **36**. The gate electrodes **16***a* and **16***b* may be of a suitable metal such as gold, and along with the insulating layer **36** may be formed by well known vapor deposition and masking techniques. The width W of the gate electrodes **16***a* and **16***b* is substantially the same or slightly greater than the separation between the source electrode **12** and the drain electrode **14**. The overall length of the gate electrodes **16***a* and **16***b* is substantially the same as the length of the drain electrodes **12** and **14**. However, the gap **17** is selected to divide the gate **16** into portions **16***a* and **16***b* having respective lengths L′ and L″ according to the desired feedback ratio β, defined here as $\beta=L''/(L'+L'')$, an exemplary value of β being around 0.1. The distance across the gap **17** is as small as possible, the only requisite being that it be sufficient to divide the gate **16** into two portions **16***a* and **16***b* capable of providing independent control of the flow of majority charge carriers in the semi-insulator 34 flowing from the source electrode 12 to the drain electrode 14.

It should be apparent that the gate electrode film 16 need not be divided into only two segments, but rather as many independent gating elements may be provided for the thin-film transistor device as is needed to apply the desired number of feedback signals to the stage in question. Thus, where two feedback signals are to be applied to the transistor, it would have three independent gate electrodes; for three feedback signals, four independent gating segments are required; etc.

The thin-film transistor device 20 comprising the second amplifying stage of the circuit of FIG. 2 may be of the same configuration as that shown in FIG. 3 except that its gate electrode 26 would be formed as a single continuous element rather than a divided element such as used in the first transistor 10.

The thin-film transistor device 10 functions as two independent amplifiers in parallel, one under the control of the gate 16*a* and the other controlled by the gate 16*b*, having respective gains of A_1' and A_1'', where

$$\frac{A_1'}{A_1''}=\frac{L'}{L''} \text{ and } A_1'+A_1''=A_1$$

A_1 is the gain which the thin-film transistor 10 would have if its gate electrode 16 were constructed in a single continuous piece extending the entire length of the source and drain electrodes. Thus, the circuit of FIG. 2 may be represented by the equivalent circuit of FIG. 4 wherein R_{L1} represents the resistance of load resistor 27, and R_{L2} represents the resistance of load resistor 28. It may be seen that the input signal is amplified in the first thin-film stage by a factor of A_1' as defined above, with the output from the first stage being fed to the control electrode of the second thin-film stage which provides an amplification of A_2. The output from the A_2 stage is fed back to the gate electrode 16*b* of the first stage to provide amplification of the feedback signal by an amount A_1''. Thus, the overall gain A of the amplifier of FIGS. 2 and 4 becomes:

$$A=\frac{e_{\text{out}}}{e_{\text{in}}}=\frac{A_1'A_2}{1-A_1''A_2}=\frac{A_1'A_2}{1-A_1A_2\beta}=\frac{(1-\beta)A_1A_2}{1-A_1A_2\beta} \quad (1)$$

A comparison of FIGS. 1 and 4 will reveal that the circuit of FIG. 4 eliminates the troublesome resistors R_1 and R_2 from the circuit of FIG. 1, along with all the aforementioned disadvantages associated therewith. It should also be noted that although the loop gain of the two circuits is the same, the direct gain for the input signal through the first stage of the circuit of FIG. 4 is reduced slightly (by a factor of β) from that of the circuit of FIG. 1. However, this is indeed an insignificant limitation compared to the extreme advantages which accrue due to the elimination of the resistive feedback network.

Circuits according to the present invention may readily be formed in integrated circuit arrangement, i.e., with all the circuit components incorporated onto a single substrate. One such arrangement for a three-stage feedback amplifier is illustrated in FIG. 5, the equivalent circuit diagram for which is shown in FIG. 6. In the amplifier of FIGS. 5 and 6 thin-film transistors 50, 60, and 70 are formed at spaced regions on the surface of an insulating substrate 40. The transistors 50, 60, and 70 may be of the same materials mentioned above for the transistor 10 and may be formed by the same vapor deposition and masking techniques used to construct the transistor 10. Conductive strips 42 and 44 of relatively large width may be formed on the substrate 40 by vapor deposition of a metal such as gold, aluminum or copper to provide biasing leads for the circuit so that in operation the lead 42 may be maintained at a potential of +V, with the lead 44 maintained at ground potential, by external biasing means (not shown). The respective drain electrodes 52, 62, and 72 of the thin-film transistors 50, 60, and 70 may be electrically connected to the conductive strip 42 by means of respective resistive strips 54, 64, and 74. The resistors 54, 64, and 74, which may be vapor deposited nickel-chromium films, serve as load resisters R_{L1}, R_{L2} and R_{L3}, respectively FIG. 6), for the thin-film transistors 50, 60, and 70. The respective source electrodes 56, 66, and 76 of the thin-film transistors 50, 60, and 70 are electrically connected to the ground conductor 44 by means of a conductive strip 57, a resistive strip 67 and a resistive strip 77, respectively. The conductor 57 may be of the same material as the conductors 42 and 44, while the resistors 67 and 77 may be of the same material as the resistive strips 54, 64, and 74. The drain electrode 52 of the first stage thin-film transistor 50 may be electrically connected to the gate electrode 68 of the second stage thin-film transistor 60 by means of a conductive strip 45. A similar conductive strip 46 electrically connects the drain electrode 62 of the thin-film transistor 60 with the gate electrode 78 of the third stage thin-film transistor 70.

In accordance with the principles of the present invention, the first stage thin-film transistor 50 is constructed like the transistor 10 of FIG. 3, i.e. with a main gate electrode 58*a* and an auxiliary gate electrode 58*b* similar to the gate electrodes 16*a* and 16*b*, respectively, of the transistor 10. The input signal to be amplified is applied to the main gate electrode 58*a* by means of conductive strip 47, while the output signal from the drain electrode 72 of the thin-film transistor 70 appearing on output conductor 48 may be applied to the auxiliary gate electrode 58*b* of the transistor 50 via a conductive strip 49. The conductive strips 45, 46, 47, 48, and 49 may be of the same material as the conductors 42 and 44, although their widths may be smaller than that of the conductors 42 and 44 in view of the smaller currents involved.

A coupling capacitor 80 may be provided between the auxiliary gate electrode 58*b* and the feedback lead 49 by first depositing a conductive region 82 on the substrate 40, then depositing an insulating film on the conductive film 82, and finally forming a second conductive film 84 above the insulating layer. The lower conductive film 82 is electrically connected to the feedback lead 49 while the upper conductive film 84 is connected to the gate electrode 58*b*. The feedback capacitor 80, which provides a capacitance greater than the capacitance of the auxiliary gate electrode, allows for D.C. separation of the output signal from the signal at the gate electrode 58*b* in order to extend the low frequency response of the amplifier. It is pointed out, however, that in some instances, such as for a D.C. amplifier, the capacitor 80 may be omitted and the feedback lead 49 connected directly to the gate electrode 58*b*. Moreover, where the input signal on the lead 47 is received from circuitry other than a previous amplifier stage, additional means may be necessary to provide a proper D.C. bias between the gate electrode 58*a* and the ground conductor 44.

The divided gate electrode arrangement 58*a*–58*b* in the circuit of FIG. 5 functions in the same manner as that for the circuit of FIG. 2 to provide feedback without the necessity for a resistive feedback network. It should be noted, of course, that while the two-stage circuit of FIG. 2 provides positive feedback (due to a 180° phase shift of signals while passing through each of the stages 10 and 20), the three-stage circuit of FIG. 5 provides negative feedback on account of a net 540° phase shift of the feedback signal with respect to the input signal.

It will be apparent that thin-film transistors having divided gate arrangements according to the present invention may be employed in a wide variety of feedback arrangements. An example of a six-stage amplifier with multiple feedback loops is illustrated in FIG. 7. Feedback arrangements of this type are useful in producing a desired stability over a given frequency range. The amplifier of FIG. 7 comprises six thin-film transistor amplifier stages connected in cascade and designated A_1 through A_6. The gate electrode of the first stage thin-film transistor device A_1 may be divided into three distinct segments, with the main segment g_1 connected to receive the input signal, the second gate segment g_1' connected to receive a negative feedback signal from the third stage A_3, and the third segment g_1'' connected to receive a positive feedback signal from the sixth stage A_6. The lengths of the various gate electrode segments are selected in accordance with the desired feedback ratio β for signals applied to the gate segment in question in accordance with the principles discussed above with reference to FIG. 3. Similarly, the gate electrode of the thin-film transistor comprising the second stage A_2 is divided into a main section g_2 adapted to receive the output signal from the drain electrode of the first stage A_1, a first auxiliary gate electrode g_2' for receiving a positive feedback signal from the third stage A_3, and a second auxiliary gate electrode g_2'' to which is applied a negative feedback signal from the fourth stage A_4. The gate electrode g_3 of the third stage A_3 is constructed in a single piece since no feedback signals are to be applied thereto. The gate electrode of the fourth stage A_4 is constructed in two sections similar to the thin-film transistor **10** of FIG. 3, with the main gate g_4 receiving the signal from the drain electrode of the third stage A_3 and the auxiliary gate g_4' receiving a negative feedback signal from the sixth stage A_6. The gate electrode of the thin-film transistor comprising the fifth stage A_5 is constructed similarly to the gate-electrode of the A_4 stage so that positive feedback may be applied from the sixth stage A_6 to the auxiliary gate electrode g_5' of the A_5 transistor. The final stage A_6 contains a thin-film transistor in which the gate electrode g_6 is constructed in a single piece.

It will be appreciated that the principles of the present invention may be employed to provide feedback oscillators as well as amplifiers. For example, the circuit of FIG. 2 may be converted into an oscillator by replacing the resistor **28** with a resonant circuit tuned to the frequency at which the circuit is to oscillate, and the positive feedback factor β made sufficient for oscillations to be sustained. The gate electrode **16a** may then be used for D.C. biasing and temperature stabilization.

Thus, although the present invention has been shown and described with reference to specific embodiments, the principles of the invention have vast application and cover all changes and modifications of the examples of the invention herein chosen for purposes of disclosure which do not constitute departure from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. An electrical circuit comprising first semi-insulator means for amplifying a signal under the control of injected majority charge carriers, first and second control electrodes for independently controlling the flow of the majority charge carriers in said first semi-insulator means, means for applying an input signal to said first control electrode, further means coupled to said first semi-insulator means for obtaining a signal therefrom, said further means including second semi-insulator means for amplifying a signal under the control of injected majority charge carriers, said first and second control electrodes being constructed such that the ratio of the effective area of said second control electrode to the sum of the effective areas of said first and second control electrodes is determined by the portion of the output signal from said second semi-insulator means to be fed back to said first semi-insulator means, and feedback means for applying an output signal from said second semi-insulator means to said second control electrode.

2. An electrical circuit comprising a plurality of cascaded thin-film amplifying stages, at least one of the stages prior to the final stage including a body of semi-insulator material and a plurality of independent electrode members capable of controlling the flow of injected majority charge carriers in said semi-insulator body, means for applying a signal to be processed to one of said electrode members, feedback means for applying a signal from a subsequent stage to another of said electrode members, and said independent electrode members being constructed such that the ratio of the effective area of said another electrode member to the sum of the effective areas of all of said electrode members is determined by the portion of the signal from said subsequent stage to be fed back to said one stage.

3. An electrical circuit comprising a plurality of thin-film transistors coupled in cascade, at least one of said transistors prior to the final transistor in the cascaded arrangement including a plurality of independent gate electrodes, means for applying a signal to be processed to one of said gate electrodes of said one transistor, feedback means for applying a signal from a subsequent transistor in the cascaded arrangement to another of said gate electrodes of said one transistor, and said gate electrodes being constructed such that the ratio of the effective area of said another gate electrode to the sum of the effective area of all of said gate electrodes of said one transistor is determined by the portion of the signal from said subsequent transistor to be fed back to said one transistor.

4. An electrical circuit comprising a plurality of active thin-film devices; each said device including a body of semi-insulator material, first and second electrodes separated by said semi-insulator body and having respectively lower and higher work functions than the work function of said semi-insulator material, and at least a third electrode electrically insulated from said semi-insulator body but capable of controlling the flow of injected majority charge carriers in said semi-insulator body; at least one of said thin-film devices having a fourth electrode electrically insulated from the semi-insulator body thereof but capable of controlling the flow of injected majority charge carriers in said semi-insulator body; means for applying an input signal to the third electrode of said one of said thin-film devices; means for applying the signal at the second electrode of said one thin-film device to the third electrode of another of said thin-film devices; feedback means for applying the signal at the second electrode of said another thin-film device to the fourth electrode of said one thin-film device; and said third and fourth electrodes being constructed such that the ratio of the effective area of said fourth electrode to the sum of the effective areas of said third and fourth electrodes is determined by the portion of said signal of said another thin-film device to be effectively fed back to said one thin-film device.

5. An electrical circuit comprising a plurality of thin-film transistors each having a source electrode, a drain electrode and at least a first gate electrode; at least one of said thin-film transistors having at least a second gate electrode; means for applying an input signal to said first gate electrode of said one of said thin-film transistors; means for applying the signal at the drain electrode of said one thin-film transistor to said gate electrode of another of said thin-film transistors; feedback means for applying the signal at the drain electrode of said another thin-film transistor to said second gate electrode of said one thin-film transistor; and said first and second gate electrodes of said one thin-film transistor being constructed such that the ratio of the effective area of said second gate electrode to the sum of the effective areas of all of the gate electrodes of said one thin-film transistor is determined by the portion of said signal of said another thin-film transistor to be effectively fed back to said one thin-film transistor.

6. An electrical circuit comprising a plurality of cascaded thin-film amplifying stages; at least one of the stages prior to the final stage comprising: first and second films of electrically conductive material disposed on spaced regions of a surface of insulator material, said films being

substantially parallel to and coextensive with one another in a given direction along said surface, a film of semi-insulator material disposed on said insulator surface between said first and second electrically conductive films, said semi-insulator film having a thickness greater than the thickness of said electrically conductive films and having portions which overlap a portion of each of said first and second electrically conductive films, said first and second electrically conductive films having respectively lower and higher work functions than the work function of said semi-insulator material, a layer of insulator material covering said semi-insulator film, and a third film of electrically conductive material disposed on said layer of insulator material, said third electrically conductive film being substantially coextensive with said first and second electrically conductive films along said given direction and having at least one gap extending therethrough in a direction substantially perpendicular to said given direction to divide said film into at least two segments electrically insulated from one another, said gap being located such that the ratio of length along said given direction of one of said segments to essentially the overall length along said given direction of said third electrically conductive film is determined by the portion of the output signal from a subsequent stage in the cascaded arrangement which is to be fed back to said one stage; means for applying a signal to be processed to another of said segments of said third electrically conductive film; and feedback means for applying a signal from said subsequent stage to said one of said segments of said third electrically conductive film.

7. An electrical circuit comprising a plurality of thin-film transistors coupled in cascade; at least one of said transistors prior to the final transistor in the cascaded arrangement comprising: a source electrode and a drain electrode disposed on spaced regions of a surface of insulator material, said source and drain electrodes being substantially parallel to and coextensive with one another in a given direction along said surface, a film of semi-insulator material disposed on said insulator surface between said source and drain electrodes, said semi-insulator film having a thickness greater than the thickness of said source and drain electrodes and having portions which overlap a portion of each of said source and drain electrodes, a layer of insulator material covering said semi-insulator film, and gate electrode means disposed on said layer of insulator material, said gate electrode means being substantially parallel to and coextensive with said source and drain electrodes along said given direction and having at least one gap extending therethrough in a direction substantially perpendicular to said given direction to divide said gate electrode means into at least two independently operable gate electrodes, said gap being located such that the ratio of the length along said given direction of one of said gate electrodes to essentially the overall length along said given direction of said gate electrode means is determined by the portion of the output signal from a subsequent transistor in the cascaded arrangement which is to be fed back to said one transistor; means for applying a signal to be processed to another of said gate electrodes of said one transistor; and feedback means for applying a signal from said subsequent transistor to said one of said gate electrodes of said one transistor.

8. An amplifier circuit comprising at least first, second, and third thin-film transistors coupled in cascade; said first transistor including at least first, second, and third independent gate electrodes; means for applying a signal to be amplified to said first gate electrode; means for applying an output signal from said second transistor to said second gate electrode; and means for applying an output signal from said third transistor to said third gate electrode.

9. A thin-film integrated electrical circuit comprising an insulating substrate; first and second conductive strips disposed on said substrate; at least first and second active thin-film devices disposed on said substrate; each said active device including a body of semi-insulator material, first and second electrodes separated by said semi-insulator body and having respectively lower and higher work functions than the work function of said semi-insulator material, and at least a third electrode electrically insulated from said semi-insulator body but capable of controlling the flow of injected majority charge carriers in said semi-insulator body; said first active device having a fourth electrode electrically insulated from the semi-insulator body thereof but capable of controlling the flow of injected majority charge carriers in said semi-insulator body; resistive film means disposed on said substrate for intercoupling the respective second electrodes of said first and second active devices with said first conductive strip; strip means disposed on said substrate for intercoupling the respective first electrodes of said first and second active devices with said second conductive strip; strip means disposed on said substrate for applying an input signal to the third electrode of said first active device; means disposed on said substrate for applying the signal at the second electrode of said first active device to the third electrode of said second active device; and conductive strip means disposed on said substrate for applying the signal at the second electrode of said second active device to the fourth electrode of said first active device.

10. A signal translating circuit comprising first and second signal amplifying devices responsive to injected majority charge carriers, said first signal amplifying device including first and second control electrodes for independently controlling the flow of injected majority charge carriers, means coupled with said first control electrode for applying a signal thereto, means coupled between said first device and said second device for deriving a signal from said first device and applying said signal to said second device, means for deriving an output signal from said second device and including feedback means coupled with said second control electrode for applying said output signal to said second control electrode, and said first and second control electrodes being constructed such that the ratio of the effective area of said second control electrode to the sum of the effective areas of said first and second control electrodes is determined by the portion of said output signal to be effectively fed back to said first signal amplifying device.

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ROY LAKE, *Primary Examiner.*

F. D. PARIS, *Assistant Examiner.*