

GAIN CONTROL CELL

This invention relates to gain control cells for adjusting the gains of signal paths.

5 A number of different arrangements have hitherto been proposed for adjusting the gains of signal paths in analogue IC systems. One well known circuit uses a balanced multiplier arrangement having two pairs of emitter-coupled transistors coupled so as to eliminate variations in the
10 quiescent output voltage. This arrangement, however, provides a low output impedance and no rejection of supply line signals. Consequently other arrangements are often preferred.

In one solution, the bias and signal currents passing
15 through one of the multipliers are inverted by a current mirror and added to the bias current passing through the other multiplier so that the bias currents cancel and a high impedance output is provided.

The known arrangements described above suffer from
20 several disadvantages, notably complexity of biasing arrangements and sensitivity to the gain of the pnp transistors used in the current mirror. In general, pnp transistors in IC technology are of relatively poor performance. However, it is not normally desirable to
25 invert the structures described to eliminate the pnp current mirror problem since the base-emitter voltage/collector current characteristics of npn transistors are less ideal than those of the pnp transistors. The pnp devices must therefore be used for the current mirror where its low gain
30 causes dc offsets and gain errors.

It is thus an object of the present invention to provide a gain control cell which requires much less complex biasing than known arrangements and which is substantially insensitive to the current gain of current mirrors.

35 Accordingly, the invention provides a gain control cell comprising an input stage having first and second input nodes and including a first current mirror, an output stage having an output node and including a second current mirror

substantially matched to said first current mirror, and first and second current sources coupled to bias said input and output stages respectively, wherein the gain of the cell is defined by the ratio of said two current sources and is substantially independent of the current gains of the current mirrors.

The invention will now be more fully described by way of example with reference to the drawings of which:

Figure 1 shows a known balanced multiplier arrangement;

Figure 2 shows a known variation of the balanced multiplier arrangement of Figure 1; and

Figure 3 shows a gain control cell according to the invention.

Thus, in the balanced multiplier arrangement shown in Figure 1, an input current is supplied to input node 1. This input current is divided between the emitters of transistor T_1 and T_2 in response to a control voltage V_c applied between the bases thereof. Transistors T_1 and T_2 are biased by current generator I_1 and, in order to eliminate variations in the quiescent output voltage, a second pair of transistors T_3 and T_4 receiving the same control voltage V_c as transistors T_1 and T_2 and biased at the same current level is added, the bases of transistors T_2 and T_3 being coupled together, the bases of transistors T_1 and T_4 being coupled together and the transistors of T_1 and T_3 being coupled together. An output signal is then provided at node 2 from the collectors of transistors T_1 and T_3 . This arrangement provides only a low impedance and provides no rejection of supply line signals, as mentioned above.

In a variation of this arrangement, it is known to invert the current (bias and signal) flowing in transistor T_1 by a well known current mirror arrangement provided by transistor T_5 , as shown in Figure 2. The inverted current is then added to the bias current flowing in transistor T_4

which matches transistor T_1 . The bias currents at the output node 2 thus nominally cancel and the circuit provides an output signal current i.e. has a high impedance output.

Often, to provide a well defined gain control, the control voltage is developed by feeding known currents (I_2 and I_3) into a pair of diodes or equivalent. It is well known that the control voltage (V_c) is then given by

$$V_c = \frac{kT}{q} \ln \frac{I_2}{I_3}$$

and that the currents in transistors T_1 and T_2 in the arrangements shown in Figures 1 and 2 can be divided in the ratio I_2/I_3 in response to this voltage.

However the known arrangements described above suffer from several disadvantages as discussed earlier and consequently it is an object of the present invention shown in Figure 3 to overcome or at least alleviate some of these disadvantages.

Thus according to the invention, the gain control cell shown in Figure 3 consists of an input stage 10 and an output stage 11. The input stage 10 comprises a diode D_{11} , a transistor T_{11} and a current mirror formed by a transistor T_{14} , and is biased by a current source I_{11} . The output stage 11 comprises emitter-coupled transistors T_{12} and T_{13} and a current mirror formed by a transistor T_{15} , and is biased by current source I_{12} .

Diode D_{11} has its cathode coupled to the emitter of transistor T_{11} and its anode coupled to a first input node 12 and to the output of current mirror T_{14} , the transistor T_{11} having its collector coupled to the current mirror T_{14} , its emitter coupled to the current source I_{11} and its base coupled to a second input node 13. Transistors T_{12} and T_{13} have their emitters coupled to the second current source I_{12} and their bases coupled to input nodes 12 and 13 respectively. The second current mirror T_{15} is coupled between the collectors of transistors T_{12} and

T_{13} , the collector of T_{13} being coupled to the input of the second current mirror and an output node 14 is provided between the second current mirror and the collector of transistor T_{12} .

5 The bias current flowing in transistor T_{11} is mirrored by current mirror T_{14} and fed through diode D_{11} . The current I_{11} is thus divided into substantially equal parts flowing in transistor T_{11} and diode D_{11} . The differential voltage developed between the input nodes
10 12 and 13 is thus near zero and the current I_{12} thus divides substantially equally between transistors T_{12} and T_{13} . The current through transistor T_{13} is mirrored by current mirror T_{15} and is subtracted from that in transistor T_{12} at the output node 14 so that the quiescent
15 output current is nominally zero.

 The errors which are introduced in the division of current I_{11} between diode D_{11} and transistor T_{11} due to the finite current gain of current mirror T_{14} generate an offset voltage such that the current in transistor T_{13}
20 exceeds that in transistor T_{12} by the factor necessary to compensate for the errors due to the finite current gain of the current mirror T_{15} , provided that transistors T_{14} and T_{15} are matched. The quiescent output current is thus substantially independent of the current gains of the pnp
25 transistors used in the current mirrors.

 The input signal may be a current supplied to input node 12 in which case input node 13 is coupled to a suitable bias voltage or may be a voltage applied to input node 13 in which case input node 12 is coupled via a resistor to a bias
30 voltage, normally equal to the quiescent level at input node 13. In the second case the signal current flowing in the input circuit will usually be substantially defined by the resistor.

 To simplify the discussion consider the case where the
35 input signal is a current supplied to input node 12. The part of this current which flows through the input stage 10 is mirrored by transistor stage T_{14} the output current of which is also drawn from the input node 12. Thus,

apparently half the signal current flows through the input stage 10. The signal current flowing through the input stage produces a signal voltage which, applied to transistor pair T_{12} and T_{13} causes a signal current to flow therein 5 having an amplitude related to that flowing in the input stage 10 by the ratio of the bias currents I_{12}/I_{11} . The signal current flowing through transistor T_{13} is inverted by the current mirror T_{15} and added to that flowing in transistor T_{12} so the output current is approximately 10 twice that flowing through transistor pair T_{12} and T_{13} . The fraction of the input current flowing through input stage 10 will be increased above one half due to the finite current gain of current mirror T_{14} and the corresponding increase in the current flowing in transistors T_{12} and 15 T_{13} compensates exactly for the loss of output signal due to the finite current gain of current mirror T_{15} , assuming the gains of current mirrors T_{14} and T_{15} to be matched. The gain of the circuit is thus I_{12}/I_{11} and is substantially independent of the current gains of the pnp 20 transistors T_{14} and T_{15} .

It should be noted that the current mirror T_{15} may be connected in opposed phase to that shown.

In this case the circuit provides an output current of opposite phase to that in the case discussed above. The 25 gain remains substantially independent of the pnp current gains but a dc offset dependent thereon is now produced. This arrangement is thus a less preferred version.

It will be noted that the biasing of the circuit can be extremely simple: in the case of current input it 30 suffices to correct input node 13 to a suitable voltage source, which can be relatively high impedance since only the base current of transistor T_{11} must be supplied therefrom.

Thus, what has been described is a gain control cell 35 having a current driven and a voltage driven input terminals and a current output having a gain defined by the ratio of the two current sources, the gain being substantially

independent of the current gains of the transistors used in the current mirrors, the current gains not engendering any substantial offset output current provided only that they be matched.

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CLAIMS

1. A gain control cell comprising an input stage having first and second input nodes and including a first current mirror, an output stage having an output node and including a second current mirror substantially matched to said first current mirror, and first and second current sources coupled to bias said input and output stages respectively, wherein the gain of the cell is defined by the ratio of said two current sources and is substantially independent of the current gains of the current mirrors.

2. A gain control cell substantially as hereinbefore described by way of example with reference to Figure 3.

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