



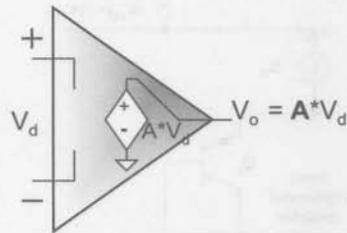
**National**  
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The Sight & Sound of Information

**Voltage Feedback Is  
From Venus**

**Current Feedback Is  
From Mars**

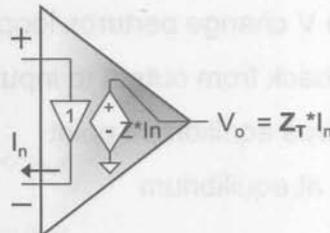
# Op Amp Architectures

## Voltage Feedback



- Both Inputs are High Impedance
- High Forward Voltage Gain  $A$ , ( $V_o/V_d$ )
- Low Output Impedance
- Error Signal is  $V_d$
- Constant Gain x Bandwidth Product

## Current Feedback



- Positive Input is High Impedance
- Negative Input is Low Impedance
- High Forward Transimpedance Gain  $Z_T$ , ( $V_o/I_n$ )
- Low Output Impedance
- Error Signal is  $I_n$
- Bandwidth Independent of Gain (almost)

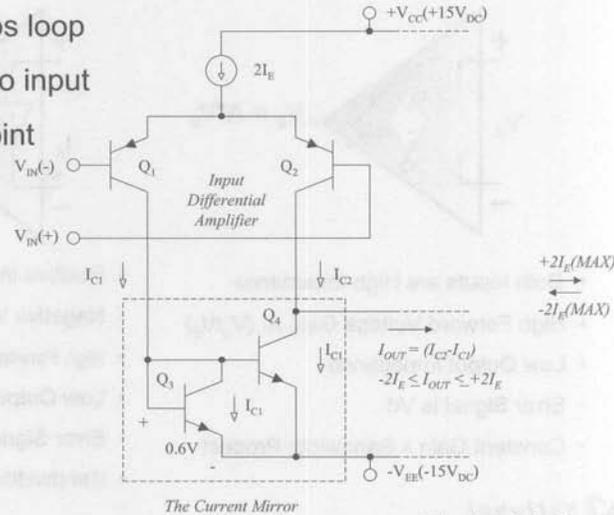


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Here is a brief summary of the differences between voltage and current feedback op-amps. Voltage feedback op-amps employ a differential pair configuration such that the impedance at each input is high. The inputs of a current feedback (CFB) op amp are unbalanced as seen in the schematic on the right. The non-inverting input exhibits the high impedance normally associated with the voltage feedback (VFB) op amp. However, the inverting input of the CFB present a low impedance to the outside. This is because there is a unity gain buffer between the negative and positive inputs to the CFB. We shall see in the following foils that the error signal employed is also different. The error signal for the VFB is the delta voltage between the inverting and non-inverting inputs. The error signal for the CFB is the current  $I_n$  flowing into or out of the non-inverting input. This characteristic accounts for the name, current feedback op-amp. A performance characteristic associated with this topology is the situation that the bandwidth of the amplifier is independent of the gain of the device. This contrasts with the VFB amplifier whose gain-bandwidth product is constant. This familiar curve slopes downward to the right for the VFB, as will be seen. Although the execution in internal circuitry is different, from the user viewpoint either may be used in the vast majority of applications.

# VFB Amplifier – Feedback Activity

- Vin+ - Vin- controls loop
- delta V change perturbs loop
- feedback from output to input restores equilibrium point
- I = 0 at equilibrium



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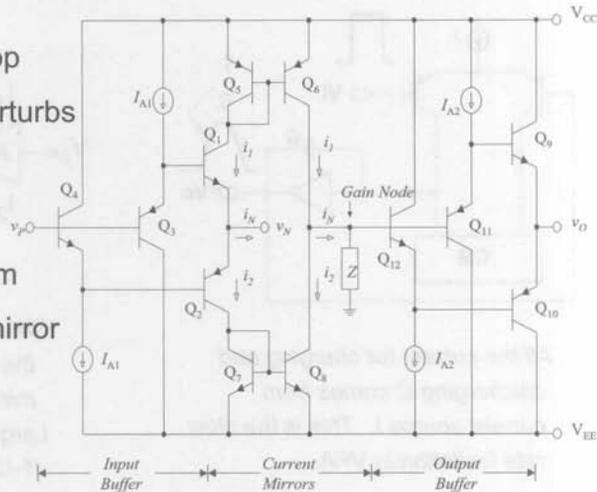
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This foil reviews the feedback action of the VFB op-amp. Seen in the input stage circuitry are, from top to bottom, a current source of magnitude  $2I_E$ , a differential pair  $Q_1$  and  $Q_2$ , and a current mirror formed by  $Q_3$  and  $Q_4$  such that the current  $I_{C1}$  is mirrored to  $Q_4$  causing both  $I_{C1}$  and  $I_{C2}$  current to appear at the collector of  $Q_4$ . The polarities are such that the delta current ( $I_{C1} - I_{C2}$ ) appears as the input current to the next (2nd) stage of the amplifier. This is the classic VFB input stage topology.

Under the assumption of zero input voltage between  $V_{in-}$  and  $V_{in+}$ ,  $I_{C1}$  and  $I_{C2}$  are equal and no delta current flows to the output, hence no signal is transferred. A non-zero input signal on either input causes a delta current to flow to stage two. This signal is amplified in the interstage and the output stage of the amplifier. Feedback from the output to the inverting input closes the loop.

# CFB Amplifier – Feedback Activity

- current at  $V_n$  controls loop
- current change at  $V_n$  perturbs equilibrium
- feedback current at  $V_n$  re-establishes equilibrium
- transistors  $Q_6$  and  $Q_8$  mirror currents in  $Q_5$  and  $Q_7$



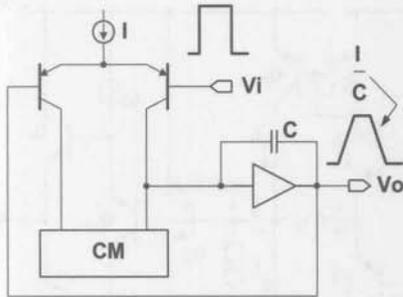
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In a CFB op-amp, the rebalancing action caused by loop closure happens at the node  $V_n$ . Upon addition of feedback from the output to  $V_{in-}$ , current is added or subtracted from the  $I_n$  current, that is the current at the output of the input buffer between  $V_{in+}$  and  $V_{in-}$ . In other words, the external network causes an imbalance between the currents of the push-pull pair,  $Q_1$  and  $Q_2$ . The feedback current signal then functions to re-balance the current at  $V_n$  causing the system to faithfully reproduce at the output, the input signal with or without gain as the case may be. This current action in restoring equilibrium produced the designation current-feedback op-amp. To reiterate: in the voltage feedback op-amp, circuit equilibrium is restored based upon the difference voltage,  $V_{in+}$  and  $V_{in-}$ . In the current feedback op-amp, circuit equilibrium is restored based upon the current condition at the  $V_{in-}$  node. Also note that the buffer currents  $i_1$  and  $i_2$ , are mirrored at an increased amplitude by current mirrors  $Q_5$ ,  $Q_6$  and  $Q_7$ ,  $Q_8$ . This will be important in the slew rate discussion that follows.

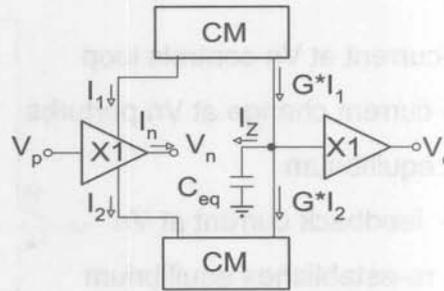
# Slew Rate Analysis

## Voltage Feedback



All the current for charging and discharging  $C$  comes from current source  $I$ . This is the slew rate limitation in VFA.

## Current Feedback



The current needed for slewing the node at  $Z$  comes from current mirrors  $G \cdot I_1$  and  $G \cdot I_2$ .

Larger step inputs causes greater  $I_1$ - $I_2$  and produce larger output slew rates.



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One of the two important differences between VFB's and CFB's is the capability of the CFB to produce higher slew rates than the VFB for the same quiescent current and process conditions. The other difference is the relative independence of gain and bandwidth in the CFB amplifier. The VFB op-amp is limited in slew rate by the ability of that circuit configuration to charge and discharge the interstage capacitor  $C$  in the voltage feedback schematic on the left. The current source  $I$  which supplies the balancing currents to the input differential pair, is the sole source of current available to charge and discharge  $C$  when the circuit is under large signal, slew rate conditions. Since a current source supplies the same current under all conditions, charging and discharging are limited to  $I$ , regardless of the magnitude of the input signal applied to the differential pair.

In the case of the CFB amplifier  $C_{eq}$ , the gain node capacitance is charged by the balanced current sources  $CM$  which produce current  $I_z$ . This becomes the charging and discharging current for  $C_{eq}$ . However, this current is not limited by the differential pair current source current as in the case of the VFB. Rather,  $C_{eq}$  is charged and discharged by the delta current  $I_z$  supplied by the current mirror. These matched current mirrors,  $CM$ ,  $CM$ , are responding to the magnitude of  $I_n$  which is driven by the input signal. Thus, the charging current for  $C_{eq}$ , which becomes the slew rate limitation in a CFB op amp, is proportional to the input signal and would be theoretically limited only by the size of the current mirror transistors.