Bench Testing LM3900 and LM359 Input Parameters

National Semiconductor
Application Brief 24

Two input parameters are extremely important in designing circuits with Norton op amps. These are the input bias current, I_{BIAS}, and the mirror gain constant, A_I. The mirror gain is especially important when a Norton amplifier is used as a voltage follower.

A simplified schematic of the LM3900 is shown in *Figure 1*. The op amp is basically a common emitter amplifier (Q3), with an emitter follower output stage. Added to the base of Q3 is a current mirror (Q1 and Q2). If a fixed current is injected into the non-inverting input and the output is fed back to the inverting input, the output will rise until the current in Q2 matches that flowing in Q1. The currents in the input terminals will not be equal since some current (I_{BIAS}) flows into the base of Q3. This is especially noticeable when the mirror current is very small—for instance in the 1 to 10 μA range. Input currents may also be unequal due to mismatch in the mirror transistors, Q1 and Q2. The degree of matching is called mirror gain, A_I, and is ideally equal to ''1''.

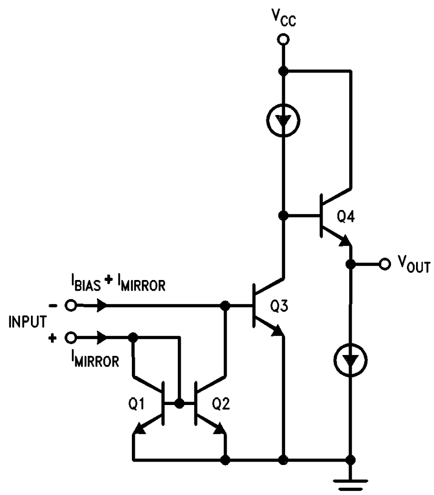

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FIGURE 1. A simplified schematic of the LM3900

The LM359 (*Figure 2*) differs from the LM3900 in that ''Q3'' is a cascode stage, and ''Q4'' is a darlington follower. Also, the internal biasing is variable; set current (I_{SET}) is determined by an external resistor. Gain-bandwidth product, slew rate, input noise, output drive current, input bias current and, of course, supply current all vary with set current.

Any modern text detailing the operation of an op amp will tell you how to bench test its parameters. Norton amplifiers are, however, frequently overlooked and their important input parameters are difficult to test in the usual manner. Two measurements and a simple calculation can provide accurate characterization of I_{BIAS} and A_I.

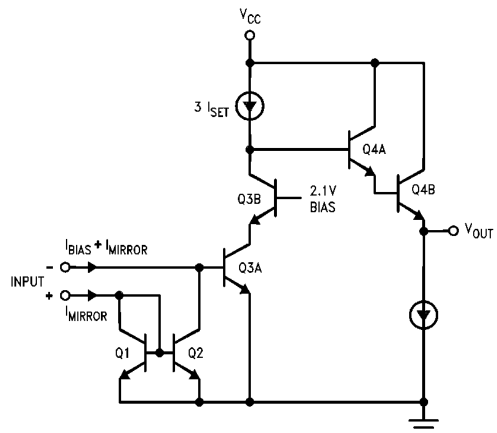

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FIGURE 2. A simplified schematic of the LM359

The test circuit for measurement of I_{BIAS} in the LM3900 is shown in *Figure 3*. Two voltage measurements are made at the output of the LM3900, one with S1 closed and one with S1 opened. The output voltage increase is equal to the voltage appearing across the 1 MΩ resistor, multiplied by the closed loop gain (A_V) of 5. It is the result of Q3 bias current flowing in the 1 MΩ resistor. For the circuit shown the output voltage increase multiplied by 200 gives the bias current in nanoamperes.

$$I_{BIAS}\,(nA) = 200\,\Delta V_{OUT} = \left(\frac{10^9}{A_V \times 1\,M\Omega}\right) \Delta V_{OUT}$$

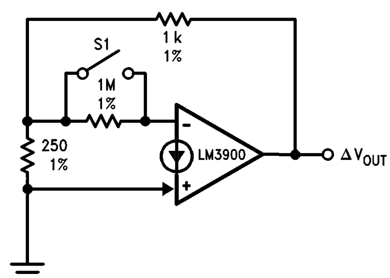

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FIGURE 3. I_{BIAS} can be evaluated by measuring the change in output voltage when S1 is opened and closed.

LM3900 mirror gain is measured using the circuit of *Figure 4*. ''R'' is selected to provide the desired mirror current. The voltage across each ''R'' is measured, and their ratio is equal to the mirror gain, A_I. As previously mentioned, the

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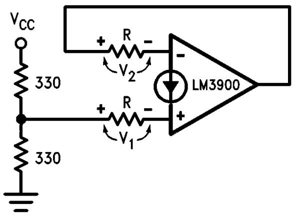
mirror gain is affected by the presence of I_{BIAS}. Where I_{BIAS} is a significant part of the mirror current, the formula (true for the LM3900 and the LM359) for A_I becomes

$$A_I = \frac{(V_2) - RI_{BIAS}}{V_1}$$

Many of the LM359's data sheet parameters, including I_{BIAS}, are measured with $I_{SET} = 0.5$ mA. Three times this current flows in the collector of Q3A, making its bias current about 15 μA. The LM3900 has a corresponding Q3 collector current of only 3 μA, and its $I_{BIAS} = 30$ nA. However, the



R (1%)	I_{MIRROR}
270 kΩ	20 μA
27 kΩ	200 μA

$A_I = \frac{V_2}{V_1}$ TL/H/5529–4

FIGURE 4. This circuit allows the measurement of the mirror gain, "A_I"

$10\ \Delta V_{OUT} = I_{BIAS}$ (μA)

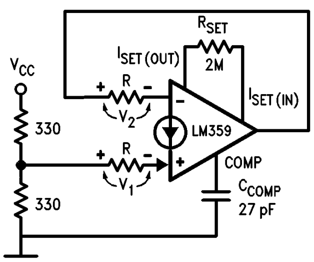


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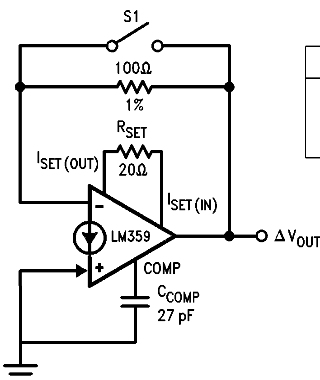
FIGURE 5. I_{BIAS} is measured with a set current of 500 μA

LM3900 doesn't have a 400 MHz gain-bandwidth product. The mirror gain is measured with $I_{SET} = 5$ μA, making I_{BIAS} so small it has little affect on the measurement. In a practical application I_{BIAS} may be a significant part of the mirror current, adding an unpredictable error term to the DC biasing equations. This circumstance can be avoided by sizing the mirror current at least ⅓ I_{SET}.

Figures 5 and *6* show how to measure and calculate I_{BIAS} and A_I for the LM359. R_{SET} is selected to provide the appropriate set current and C_{COMP} is added for stability. I_{BIAS} and A_I are measured with the same set currents used in the data sheet.

All of the test circuits assume $V_{CC} = 12V$. Accuracy is as good as the resistors and meter used. Matching is important for the two "R's" used in *Figures 4* and *6*. 1% tolerance is recommended for each resistor (5% resistors can be sorted for accuracy) in *Figure 3*, and the 100 kΩ resistor in *Figure 5*. Most 3½ digit DVM's have sufficient accuracy for the voltage measurements; input impedance must be at least 10 MΩ to prevent circuit loading in the mirror gain tests. Detailed information concerning the use of the LM3900 and LM359 can be found in their data sheets and in AN-72.



R (1%)	I_{MIRROR}
270 kΩ	20 μA
27 kΩ	200 μA
2.7 kΩ	2 mA

$A_I = \frac{V^-}{V^+}$ TL/H/5529–6

FIGURE 6. Mirror gain, A_I, is measured with $I_{SET} = 5$ μA

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