Two input parameters are extremely important in designing circuits with Norton op amps. These are the input bias current, $I_{\text{BIAS}}$, 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 ($I_{\text{BIAS}}$) 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”.

The test circuit for measurement of $I_{\text{BIAS}}$ 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.

$I_{\text{BIAS}}(\text{mA}) = 200 \Delta V_{\text{OUT}} = \left( \frac{10^3}{A_V \times 1 \, \text{MΩ}} \right) \Delta V_{\text{OUT}}$

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 ($I_{\text{SET}}$) 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 $I_{\text{BIAS}}$ and $A_I$. 
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 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 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 $\frac{1}{3} I_{SET}$.

Figures 5, 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 $V_{CC}=12$V. Accuracy is as good as the resistors and meter used. Matching is important for the two “R’s” used in Figures 4, 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.
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