Commodity IC Data: LM339/393/324/358/392

by Dennis L Feucht

Q: I am having trouble doing detailed design of analog circuits for low-cost products using commonly-available integrated circuits. Data sheets for single-supply op amps and comparators fail to give their full functional diagrams or models of their output or input characteristics. Can you provide some of this information?

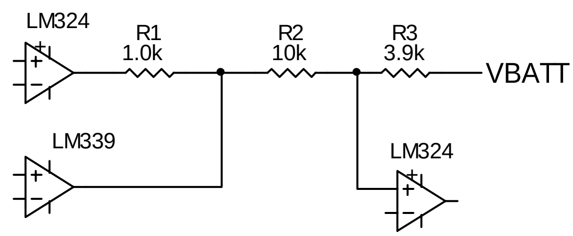
A: Commonly-used commodity ICs are described in the commercial literature but these specifications sometimes do not include important design parameters. Here are some of those parameters from my investigations from using these parts in designs. In this part of the response, the most common BJT single-supply op amps and comparator are covered.

LM339 and LM393

The single-supply LM339 quad and the dual LM393 comparators sometimes have tenuous output pull-down characteristics. When the open-collector BJT is on, then the output resistance is:

$R_o \approx 75\ \Omega$, $0\text{ mA} \le I_O \le 10\text{ mA}$

This does not seem like much resistance, but it can affect analog accuracy, as it does in the following circuit example.



This is from a battery charger. The LM339 output is intended to ground a node of the divider circuit to select which input to the PWM controller – current or voltage – will be fed back and controlled. Current control is used during bulk charging, and voltage control for the absorption and float stages. The upper-left LM324 op amp is the battery-current sense amplifier. When the LM339 output is off (open-circuit), it dominates over the battery voltage, VBATT, in determining the input voltage to the second (lower-right) op amp. This op amp is a buffer driving the PWM controller of the charger.

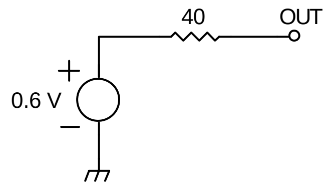
For lead-acid batteries, and for divider resistances compatible with the output current range of the LM324, the 75 Ω of pull-down resistance of the LM339 is enough that it has to be taken into account in this design. The variation in resistance is unspecified, of course, but can be assumed to be much less than the resistance itself, perhaps by 10 times. By including the nominal R_o in designs such as this, sufficient accuracy can often be achieved. If a variation of around 10 Ω is significant, then better switching is required than the open-collector output of the LM339.

The maximum output current sink is 10 mA. The input voltage range is $V_{CC} - 1.5$ V to 0 V. When using a 5 V supply, the maximum common-mode input range is 0 V to 3.5 V.

LM324 and LM358

The LM324 quad and LM358 dual single-supply op amp output characteristics are also not very close to the ideal. (The LM392 has one comparator and one op amp of these same kinds.) The model for the LM324 output when sinking current is shown below: a 0.6 V source behind a 40 Ω resistance for the current range of 10 μA to 10 mA:

$$V_O \cong 0.6\text{ V},\ 100\ \mu\text{A} \le I_{SINK} \le 10\text{ mA}$$



A table of output saturation voltage Vs. sink current is given below, derived from the National Semiconductor data on the part.

Output Voltage	Sink Current
10 to 30 mV	10 μA
0.6 V	100 μA
0.75 V	1 mA
1.0 V	10 mA

This is at least better than the LM339 and in cheap designs the LM324 will sometimes be used as a comparator instead for its better output characteristics.

At low sinking currents, of I_{SINK} < 10 μA, the output resistance is much greater:

R_o = 4.44 kΩ, I_o(sink) < 10 μA

While sourcing current, the high end of the output-voltage range is limited to 1.5 V less than the supply voltage at 10 mA and is always greater than 1 V. The current limit is 40 mA.

The LM324 input common-mode range is 0 V to $V_{CC} - 2$ V, or 0.5 V less on the high side than the LM339. For greater input range, it is tempting to consider the use of an LM339 comparator as an op amp, with its challenge of feedback stability. The open-loop gain is also not high (50 k min, 200 k typ), though sufficient for many applications. The part is designed to be fast, not stable, and the specifications do not include frequency response characteristics. The NSC data on the LM339, under typical applications, includes a *low-frequency op amp* implementation using the LM339. Frequency stabilization is achieved by the dominant-single-pole method, by using a pull-up resistor at the output of 15 kΩ and a capacitor of 0.5 μF to ground. Then the two-resistor divider (R_f, R_i) back to the inverting input completes the external components. By reducing the output time constant and shunting a capacitor across R_f, greater bandwidth should be possible.

Closure

The limitations of the classic BJT single-supply op amps and comparators are overcome to a great extent by the various single-supply CMOS components from multiple suppliers. Both input and output ranges on some op amps now include nearly the entire voltage range between supply terminals. Until these newer parts are reduced in the market to a few enduring ones, they will continue to exceed the classic parts in cost. Even so, the additional complications required to overcome these limitations in design are sometimes best handled by using the newer parts. CMOS outputs can source within a few tens of millivolts of the supply voltages for moderate output currents, and inputs can sometimes even exceed the supply voltages.

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