Anatomy of a Data Sheet – LF155 Series Op-Amps

Overview

This is a "dissection" of the data sheet for the LF155 series op-amps. The first four pages of the Dec. 1994 version of this data sheet are published in the textbook on pages 535 – 538. There is a revised version dated May 2000 available from the National Semiconductor website at *http://www.national.com* . The complete data sheet is 24 pages long.

Careful inspection of the various table headings shows that there are a number of distinct parts covered in this data sheet. The grids below shows these part names for both the text version and for the current version. Each checked box corresponds to a specific part. For example, in the text's version there is an LF156A and an LF357B, but there is no LF256A. In the newer data sheet, we see that the 255/256/257 parts have been dropped, as well as some others. We can assume these specific parts are now obsolete.

Parts listed in the text version of the data sheet (Dec. 1994) – 18 distinct parts.

suffix	**LF155**	**LF156**	**LF157**	**LF255**	**LF256**	**LF257**	**LF355**	**LF356**	**LF357**
(none)	√	√	√	√	√	√	√	√	√
A	√	√	√				√	√	√
B							√	√	√

Parts listed in the most recent version of the data sheet (May 2000) – 7 distinct parts.

suffix	**LF155**	**LF156**	**LF157**	**LF255**	**LF256**	**LF257**	**LF355**	**LF356**	**LF357**
(none)	√	√	√				√	√	√
A									
B								√	

Careful study of the data sheet reveals the following breakdown of the series:

First digit: The distinction among the 1xx, 2xx, and 3xx parts is the operating temperature range, as evidenced by the table on page 4 (text) or page 3 (revised) under "Notes for Electrical Characteristics." The row labeled "T_A" gives the allowable ambient temperature range for operation. The ambient temperature is the temperature of the air surrounding the chip while it is operating. The temperature ranges are as follows:

Parts	**T_A (min)**	**T_A (max)**	**range name**
1xx	-55 ^{o}C	125 ^{o}C	military
2xx	-25 ^{o}C	85 ^{o}C	industrial
3xx	0 ^{o}C	70 ^{o}C	consumer

Third digit: The main distinction among the xx5, xx6, and xx7 parts is in the AC electrical characteristics, including slew rate, bandwidth, and settling time. These can be seen in the "Uncommon Features" table on page 1, and in the "AC Electrical Characteristics" tables on the following pages. For example, the LF157 has a typical gain-bandwidth product of 20 MHz, compared with 2.5 MHz for the LF155.

Suffix: The letter suffixes (none), 'A', and 'B' mainly indicate distinctions in the DC electrical characteristics. For example, the LF356B has a minimum large-signal voltage gain of 50 V/mV, compared with 25 V/mV for the LF356. Also, the minimum common-mode rejection ratio is higher for the LF356B (85 dB) than for the LF356 (80 dB).

Section-By-Section Analysis

Title

LF155/LF156/LF355/LF356/LF357
JFET Input Operational Amplifiers

The title indicates the covered part numbers, and the function of the part. A breakdown of the title words follows:

Monolithic: This word (literally “one stone”) indicates this circuit is built on a single chip. This distinguishes it from “hybrid” packages, in which a number of single chips are interconnected within one package. Monolithic construction is the best technology for producing well-matched transistors and passive components, resulting in reduced offsets, drift, and noise.

JFET Input: Junction field effect transistors are used at the input terminals. This is to distinguish from BJT (bipolar junction transistor) or MOSFET inputs. JFET inputs provide lower input currents than BJT’s, and are not as sensitive to damage by electrostatic discharge (ESD) as are MOSFET’s.

Operational Amplifiers: This states the function of the circuit.

General Description

The general description section provides an overview of the most significant features of this series. In this section, we learn that these are the first op-amps to incorporate both JFET’s and BJT’s on the same chip. This was a significant technological achievement, because traditionally FET and BJT processing was completely different, and chip designers had to choose one technology or the other for the entire chip. Here, we get the advantage of low input currents due to the JFET’s, together with high voltage gain and large output current (high drive) of the BJT’s.

Advantages

This is the “sales pitch” for the series. Here the manufacturer highlights why you should buy one of these parts instead of another op-amp.

Applications

Here the manufacturer provides some suggested uses that take advantage of the specific benefits of this series. Note that each of the listed applications takes particular advantage of the high input impedance, high bandwidth, and/or high drive capability of these parts.

Common Features

This section lists the features shared by all the parts in the series. For simplicity, just the “top of the line” parts are actually listed, and specifications are generally given for the most favorable test conditions.

Uncommon Features

This section tells what distinguishes the parts in the series from each other. Again, only the top-of-the-line parts are listed.

Simplified Schematic

This provides sufficient detail for a designer to understand the limitations and requirements for interfacing to external circuitry. Notice, for example, that the (+) and (-) input terminals are connected to the gates of JFETS, whereas the output is driven by a pair of BJT’s.

Absolute Maximum Ratings

This section gives the maximum allowed power supply voltages and input terminal voltages, as well as information about soldering temperature and power dissipation. The latter information can be used to develop printed circuit board assembly protocol, and to determine whether a package must be mounted on a heat sink, and/or if a fan must be used to provide cooling.

Information about ESD tolerance is also included in this section.

DC Electrical Characteristics

This table lists a number of parameters describing the performance of the parts in this series at DC or very low frequency. Be sure to look carefully at the column headings to see which part(s) are being specified. In the text's version of the data sheet, there are two separate tables labeled "DC Electrical Characteristics" which cover two distinct subsets of parts. In the newer version, there is just one table.

Breakdown of the table—

Symbol: The symbol the manufacturer uses for referring to this parameter. This is sometimes not the same symbol our text uses for the same parameter. In particular:

- The parameter "**Large Signal Voltage Gain**" is given the symbol $\mathbf{A_{VOL}}$ on the data sheet, but this is actually the same parameter our text refers to as $\mathbf{A_o}$, the **open-loop, DC voltage gain**.
- The **input resistance**, which is called $\mathbf{R_{IN}}$ on the data sheet, is equivalent to our text's **input differential resistance**, $\mathbf{R_{ID}}$.

Parameter: Description of the parameter in words.

Conditions: These are the measurement conditions. Often there are multiple lines of information. For example, for V_{OS} the specifications are given both at the fixed temperature of 25 ^oC, and also over the full temperature range (given in the "Notes...").

Min/Typ/Max and Units: These are the actual specifications. Depending on the particular parameter, the minimum, typical, or maximum value may be specified, as appropriate. The extreme values (min or max) can be used for worst-case analysis. For example, any circuit we design must work in the presence of the worst-case (largest) input offset voltage. From the table, we see that the LF155 has a typical value of 3 mV, and a (guaranteed) worst-case maximum value of 5 mV at 25 ^oC, or 7 mV over the full temperature range. No minimum value is given, since any design that works for the worst case will work for any better case (i.e., smaller V_{OS}).

Be sure to read the units carefully, as some are tricky. For example, A_{VOL} is given in V/mV. The use of "mV" in the denominator is the same as multiplying by 1000. For example 50 V/mV is the same as 50,000 V/V.

AC Electrical Characteristics

This table lists a number of parameters describing the performance of the parts in this series at higher frequencies (typically audio range and above). Be sure to look carefully at the column headings to see which part(s) are being specified. In the text's version of the data sheet, there are two separate tables labeled "AC Electrical Characteristics" which cover two distinct subsets of parts. In the newer version, there is just one table.

This table is laid out in the same format as the DC table. The two most important parameters are discussed below:

GBW (Gain-Bandwidth Product): This is the product of the dc open-loop gain ($A_{VOL} = A_o$) with the open-loop bandwidth (f_B). The gain is expressed in V/V (not V/mV or dB), and the bandwidth is expressed is Hz (not rad/s). This number can be used to deduce the bandwidth, as shown in the example below:

Bandwidth Calculation Example:

Q: What is the open-loop bandwidth of the LF155? Use typical values at 25 ^oC. State any constraints on the values you use.

Ans: We use the AC table to find GBW for this part is 2.5 MHz, and the DC table to find A_{VOL} is 200 V/mV at 25 ^oC. Both GBW and A_{VOL} are measured with power supply voltages of ±15 V. Converting A_{VOL} to V/V and solving for f_B we have:

$$f_B = \frac{GBW\left(Hz\right)}{A_{VOL}\left(V/V\right)} = \frac{2.5\times10^6}{2\times10^5} = 12.5\ Hz$$

SR (Slew Rate): This is the maximum rate of change of the output under the given conditions. Note that this is NOT an open-loop specification, since the "Conditions" shown are $A_V = 1$ and $A_V = 5$. For example, we can see that a unity-gain buffer built with an LF155 would have a typical slew rate of 5 V/µs. An example using this data is given below.

Slew Rate Example:

Q: What is the full power bandwidth for a unity gain amplifier using the LF155? Use typical values and note any other constraints.

Ans: The SR of 5 V/µs is measured with power supply voltages of ±15 V. Under these conditions, we read from the DC table that the maximum output voltage swing, V_O, is typically ±12V into a 2 kΩ load. Then we can use Equation 12. 132 from the text to determine the full power bandwidth, f_M:

$$f_M = \frac{SR}{2\pi V_{FS}} = \frac{5\times10^6\left(V/s\right)}{2\pi\left(12\,V\right)} = 66.3\,kHz$$

This is the maximum frequency at which the op-amp can produce an undistorted sine wave at the output with an amplitude of 12 V.

Notes For Electrical Characteristics

This section lists important information about test conditions, and defines various terms used in the data tables.

Following Pages

The remaining pages of the data sheet include voluminous, detailed information in graphical form; example circuits; and mechanical information about the package necessary for printed circuit board layout. The circuit applications are especially useful, as they often contain many practical design "tweaks" that are not covered in our study of "ideal" op-amp circuits.