Anyone trying to measure an op amp open loop gain ($A_{OL}$) parameter using a ‘Force Input Measure Output’ technique must measure the output voltages one at a time using two input voltages with different magnitudes then plug in all the data gathered in the general formula of $A_{OL} = \frac{\Delta V_O}{\Delta V_{IN}}$, typically from 100,000 to 1,000,000 and an ideal value of infinity. But op amps in real world do have an offset voltage ($V_{OS}$ or $V_{IO}$)*, an unwanted voltage source in the input terminals that will affect the device under test (DUT) output voltage. Like a general purpose μA741 with typical $V_{OS}$ of 1mV is more than enough to saturate the output at either $V_{CC}$ or $V_{EE}$ due to inherent very high gain thus this kind of measurement method is impractical & futile.

The solution is servo loop test method which does the opposite ‘Force Output Measure Input’ with the aid of null amplifier, remember you cannot directly inject voltage in the op amp output because it is a low impedance source aka voltage source. It controls the output to swing to 0V then a potential at the input is develop equal to the DUT’s $V_{OS}$ to satisfy $A_{OL} (V_{IN} - V_{OS}) = 0V$. The DUT input is amplified by the noise gain in the range of 100 to 10k (DUT dependent) to facilitate measuring even op amp with very low $V_{OS}$ (10 - 100μV, ex. OP07) using a decent multimeter (connected to the isolation resistor of null amp output) with 100μV maximum resolution. Open loop gain is the ratio of change in output to change in input; swinging the output from 0V to specific values the null amp will react accordingly that is an amplified version of the DUT input hence open loop gain can be computed with known output & measuring the DUT input (null amp output/noise gain).

"MAiSAKit" the Measuring Amplifier in Servo Amplifier Kit is an analog educational kit, it employs an LF411 op amp as the null (aka servo) amplifier to control the DUT output and with negative feedback produces a corresponding voltage at the DUT input. The DUT control voltage is derive from a REF102 10V voltage reference & 2x amplification is more than enough to bring the DUT (@±15V supply) into ±saturation thus the capability to verify output swing performance. The DUT supply was designed to provide a total of 50V or ±25V (current limited by LM317 and LM337) taking into consideration older op amps specified @±15V supply and ±10V common mode test condition.

The MAiSAKit with a laboratory DC power supply (capable of ±30V) and decent multimeter allows you to measure most DC parameters specified on the data sheet like offset voltage, bias current, offset current, open-loop gain, CMRR (Common-Mode Rejection Ratio), PSRR (Power Supply Rejection Ratio), output voltage swing, short-circuit current & supply current. An excellent material on the basics of testing op amps, part 1 to 4 written by David Baum & Daryl Hiser can be found at www.edn.com

* Another definition of offset voltage is the input required to force the output to 0V.
Time Required: 2 hours depending on experience
Experience Level: Intermediate

Required tools and parts:
1. Breadboard: 2157693
2. Multimeter: 1537328
3. Bench top Power Supply: 211722
4. Pliers Long Nose: 177608
5. Wire Cutter: 179902
6. Screwdriver: 34041
7. Wire Hook-up Solid 22 AWG: 2152876, 2152905, 2153553

Optional
1. Scope: 2145220
2. Potentiometer Adjustment Tool: 153315
3. Wire Cutter Stripper: 215889

Bill of Materials:

<table>
<thead>
<tr>
<th>Qty</th>
<th>Jameco SKU</th>
<th>Component Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>690718</td>
<td>Resistor Carbon Film 240 Ohm 1/4 Watt 5% R10 &amp; R12. Part of DUT power supply.</td>
</tr>
<tr>
<td>1</td>
<td>51377</td>
<td>15V 1A 3Pin Standard Regulator U3. Part of Null Amp 15V power supply.</td>
</tr>
<tr>
<td>1</td>
<td>51502</td>
<td>-15 V 2.2 A 3Pin Standard Regulator U4. Part of Null Amp -15V power supply.</td>
</tr>
<tr>
<td>1</td>
<td>23579</td>
<td>1.2V to 37V 1.5 A Standard Regulator U5. Part of DUT VCC power supply.</td>
</tr>
<tr>
<td>1</td>
<td>23819</td>
<td>-1.2V to -37V 1.5A Standard Regulator U6. Part of DUT VEE power supply.</td>
</tr>
<tr>
<td>1</td>
<td>691104</td>
<td>OP Amp Single General Purpose ±18 Volt 8-Pin MDIP Rail U8.1 Buffer &amp; U8.2 Inverting Amplifier. Part of Adjustable Dual-Tracking Reference.</td>
</tr>
<tr>
<td>1</td>
<td>1368771</td>
<td>Voltage Reference Precision 10 Volt 8 mA 8-Pin PDIP U7. Part of Adjustable Dual-Tracking Reference.</td>
</tr>
<tr>
<td>4</td>
<td>691340</td>
<td>Resistor Carbon Film 100k Ohm 1/4 Watt 5% R9 DUT load &amp; R8 isolation resistor. R15 &amp; R16- Part of Adjustable Dual-Tracking Reference. Connect multimeter at test point TP1 during offset voltage, bias current, offset current, open-loop gain, CMRR &amp; PSRR test. DUT load is only connected during output voltage swing &amp; open-loop gain measurement.</td>
</tr>
<tr>
<td>3</td>
<td>691411</td>
<td>Resistor Carbon Film 200k Ohm 1/4 Watt 5% R5, R6 &amp; R7 Short R6 &amp; R7 during VOS test. Short R7 during non-inverting input bias current test. Short R6 during inverting input bias current test.</td>
</tr>
<tr>
<td>14</td>
<td>15270</td>
<td>50 Volt 0.1 μF Ceramic Disk Capacitor C3, C4, C5, C6, C7, C8, C9, C11, C13, C15, C17, C18, C19 &amp; C20.</td>
</tr>
<tr>
<td>4</td>
<td>29891</td>
<td>10 μF 50 Volt Radial Capacitor C10, C12, C14 &amp; C16. Part of DUT &amp; Null Amp power supply.</td>
</tr>
<tr>
<td>1</td>
<td>240427</td>
<td>10 k Potentiometer R14 Trimpot to control DUT output. Part of Adjustable Dual-Tracking Reference.</td>
</tr>
<tr>
<td>2</td>
<td>240777</td>
<td>5K Ohm Potentiometer R11 &amp; R13 Trimpot to set VCC &amp; VEE. Part of DUT power supply.</td>
</tr>
</tbody>
</table>
| 2   | 15413      | 220pf 50 Volt Ceramic Disc Capacitor C1 & C2.
1U2 DUT. Connect multimeter at test point TP2 during output voltage swing (voltmeter) & short-circuit current (ammeter) test. Connect ammeter in series with DUT pin 4 to measure IEE supply current and DUT pin 7 for ICC.

2 R9 DUT load. By connecting 2 1k in parallel R9 = 500 & in series R9 = 2k.
Connect DUT load when testing output voltage swing & open-loop gain.

1 R1 & R2, Noise Gain = 1 + R3 / R2

1DIP Switch On Off Single Pole Single Throw 4 Raised Slide 0.15 Amp 30 Volt PC Pins 2000 Cycle 2.5mm Through Hole

S3 (VEE) & S4 (VCC) DUT power switch. S1 (-15V) & S2 (15V) Null Amp power switch. To turn off/on DUT & Null Amp independent of the laboratory DC power supply.

Step 1 - Servo Loop Test Circuit Schematic

The Servo Loop Test Circuit is composed of the DUT (OP07 or uA741) & LF411 op amp IC.

"MAiSAKit* the Measuring Amplifier in Servo Amplifier Kit
Step 2 - DUT & Null Amp Power Supply Circuit Schematic

The DUT & Null Amp Power Supply Circuit is composed of U3 LM7815, U4 LM7915, U5 LM317 & U6 LM337 voltage regulator ICs.

DUT supply is adjustable (VEE = -25V to -1.25V & VCC = 1.25V to 25V). Null Amplifier is fixed at VEE = -15V & VCC = 15V.

Step 3 - Adjustable Dual-Tracking Reference Circuit Schematic

The Adjustable Dual-Tracking Reference Circuit is composed of U7 REF102 10V voltage reference & U8 LM358 op amp ICs.
**Step 4 - IC placement**

Layout the ICs on the breadboard according to the circuit schematic to ease signal tracing & troubleshooting.

**Step 5 - Passive Component placement**

Place the components on the breadboard according to the schematic. Install 0.1uF bypass capacitor as close as possible to the IC power supply pins.
Step 6 - IC & Passive Component connection

Connect ICs & passive components via AWG 22 solid wire. It is suggested to use multi-colored wire to ease signal tracing & troubleshooting.