Application Report
SNOA662B–August 1980–Revised April 2013

AN-116 Use the LM158/LM258/LM358 Dual, Single Supply Op Amp

ABSTRACT

This application note discusses the use of the LM158/LM258/LM358 dual op amp when operated from a single supply.

Contents

1 Introduction 2
2 Single Supply Operation 2
3 AC Gain 3
4 Inverting DC Gain 4
5 Non-Inverting DC Gain 4
6 Zero T.C. Input Bias Current 4
7 Balanced Supply Operation 5

List of Figures

1 Worst Case Signal Levels with +12V Supply 3
2 Operating with AC Signals 3
3 Typical DC Coupled Inverting Gain 5
4 Typical DC Coupled Non-Inverting Gain 5
5 Split Supply Operation of LM358 6

List of Tables

1 Comparison of Dual Op Amps LM1458 and LM358 2
2 Conventional Op Amp Circuits Suitable for Single Supply Operation 6

1 Introduction

Using the LM158/LM258/LM358 dual op amp with a single supply in place of the LM1458/LM1558 with split supply will reap profits in terms of:

- Input and output voltage range down to the negative (ground) rail
- Single supply operation
- Lower standby power dissipation
- Higher output voltage swing
- Lower input offset current
- Generally similar performance otherwise

The main advantage, of course, is that you can eliminate the negative supply in many applications and still retain equivalent op amp performance. Additionally, and in some cases more importantly, the input and output levels are permitted to swing down to ground (negative rail) potential. Table 1 shows the relative performance of the two in terms of guaranteed and/or typical specifications.

In many applications the LM158/LM258/LM358 can also be used directly in place of LM1558 for split supply operation.

2 Single Supply Operation

The LM1458/LM1558 or similar op amps exhibit several important limitations when operated from a single positive (or negative) supply. Chief among these is that input and output signal swing is severely limited for a given supply as shown in Figure 1. For linear operation, the input voltage must not reach within 3 volts of ground or of the supply, and output range is similarly limited to within 3–5 volts of ground or supply. This means that operation with a +12V supply could be limited as low as 2 Vp-p output swing. The LM358 however, allows a 10.5 Vp-p output swing for the same 12V supply. Admittedly these are worst case specification limits, but they serve to illustrate the problem.

Table 1. Comparison of Dual Op Amps LM1458 and LM358

Characteristic	LM1458	LM358
V_{IO}	6 mV Max	7 mV Max
CM V_I	24 Vp-p[(1)]	0–28.5V[(1)]
I_{IO}	200 nA	50 nA
I_{OB}	500 nA	−500 nA
CMRR	60 dB Min @ 100 Hz 90 dB Typ	85 dB Typ @ DC
$\overline{e}_n$ @ 1 kHz, R_{GEN} 10 kΩ	45 nV/$\sqrt{Hz}$ Typ	40 nV/$\sqrt{Hz}$ Typ[(2)]
Z_{IN}	200 MΩ Typ	Typ 100 MΩ
A_{VOL}	20k Min 100k Typ	100k Typ
f_c	1.1 MHz Typ	1 MHz Typ[(2)]
P_{BW}	14 kHz Typ	11 kHz Typ[(2)]
dV_o/dt	0.8V/µs Typ	0.5V/µs Ty[(2)]
V_o @ R_L = 10k/2k	24/20 Vp-p[(1)]	28.5 Vp-p
I_{SC}	20 mA Typ	Source 20 mA Min (40 Typ) Sink 10 mA Min (20 Typ)
PSRR @ DC	37 dB Min 90 dB Typ	100 dB Typ
I_D ($R_L = \infty$)	8 mA Max	2 mA Max

(1) From laboratory measurement based on V_S = 30V on LM358 only, or V_S = ±15V
(2) From data sheet typical curves

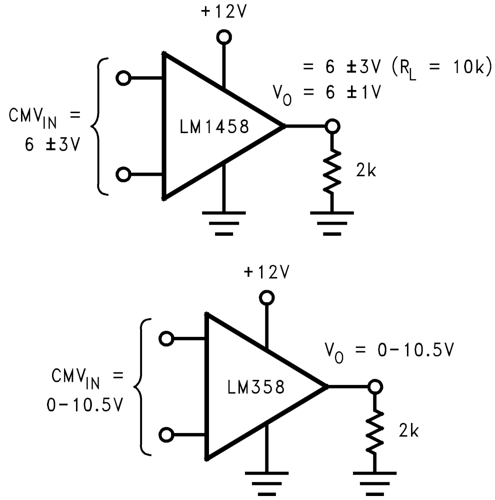


Figure 1. Worst Case Signal Levels with +12V Supply

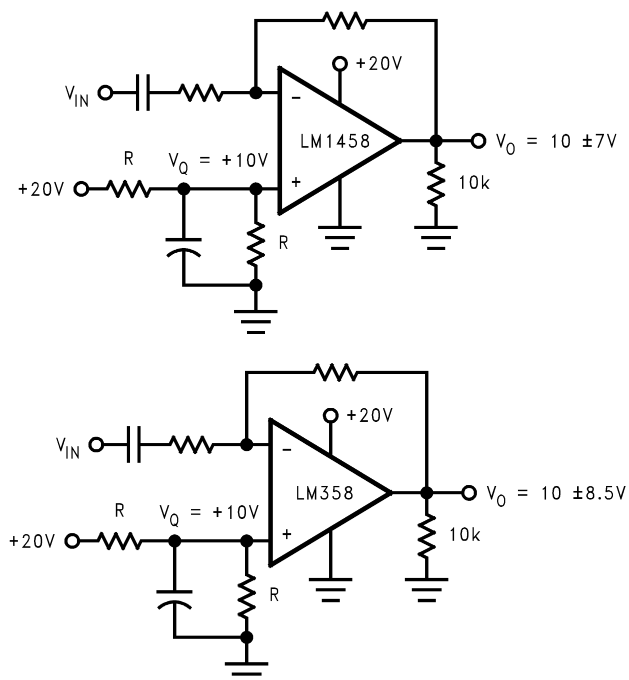


Figure 2. Operating with AC Signals

3 AC Gain

For AC signals the input can be capacitor coupled. The input common mode and quiescent output voltages are fixed at one-half the supply voltage by a resistive divider at the non-inverting input as shown in Figure 2. This quiescent output could be set at a lower voltage to minimize power dissipation in the LM358, if desired, so long as $V_Q \geq V_{IN}$ pk. For the LM1458 the quiescent output must be higher, VQ ≥ 3V + V_{IN} pk thus, for small signals, power dissipation is much greater with the LM1458. Example: Required V_O = V_Q ±1V pk into 2k, V_{SUPPLY} = as required. Find quiescent dissipation in load and amplifier for LM1458 and LM358.

LM358

$$V_Q = +1V$$
$$V_{SUPPLY} = +3.5V$$
$$P_{LOAD} = \frac{E_L^2}{R_L} = \frac{1}{2k} = 0.5\,mW$$
$$P_D = V_S I_S{*} + (V_S - V_Q) I_L$$
$$= 3.5V \times 0.7\,mA + (3.5 - 1)\frac{1V}{2k}$$
$$P_D = 2.45 + 1.25 = 3.7\,mW$$
$$P_{TOTAL} = 3.7 + 0.5 = 4.2\,mW$$

*From typical characteristics (1)

LM1458

$$V_Q = 4V$$
$$V_{SUPPLY} = 8V$$
$$P_{LOAD} = \frac{4^2}{2k} = 8\,mW$$
$$P_D = P_D{*} + (V_S - V_Q) I_L$$
$$= 22\,mW + (8 - 4)\frac{4V}{2k}$$
$$P_D = 22 + 8 = 30\,mW$$
$$P_{TOTAL} = 30 + 8 = 38\,mW$$

*From typical characteristics (2)

The LM1458 requires over twice the supply voltage and nearly 10 times the supply power of the LM358 in this application.

4 Inverting DC Gain

Connections and biasing for DC inverting gain are essentially the same as for the AC coupled case. Note, of course, that the output cannot swing negative when operated from a single positive supply. Figure 3 shows the connections and signal limitations.

5 Non-Inverting DC Gain

The non-inverting gain connection does not require the V_Q biasing as before; the inverting input can be returned to ground in the usual manner for gains greater than unity, (see Figure 4). A tremendous advantage of the LM358 in this connection is that input signals and output may extend all the way to ground; therefore DC signals in the low-millivolt range can be handled. The LM1458 still requires that V_{IN} = 3V–17V. Therefore maximum gain is limited to $A_V = (V_O - 3)/3$, or A_V max = 5.4 for a 20V supply.

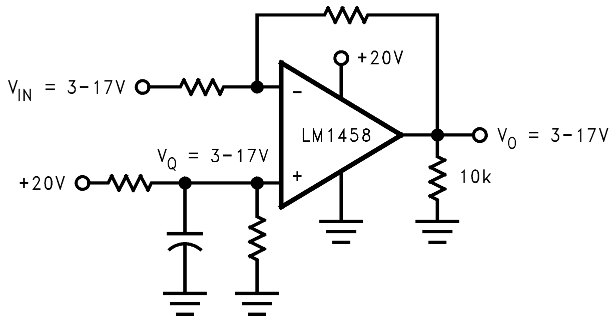
There is no similar limitation for the LM358.

6 Zero T.C. Input Bias Current

An interesting and unusual characteristic is that I_{IN} has a zero temperature coefficient. This means that matched resistance is not required at the input, allowing omission of one resistor per op amp from the circuit in most cases.

7 Balanced Supply Operation

The LM358 will operate satisfactorily in balanced supply operation so long as a load is maintained from output to the negative supply.



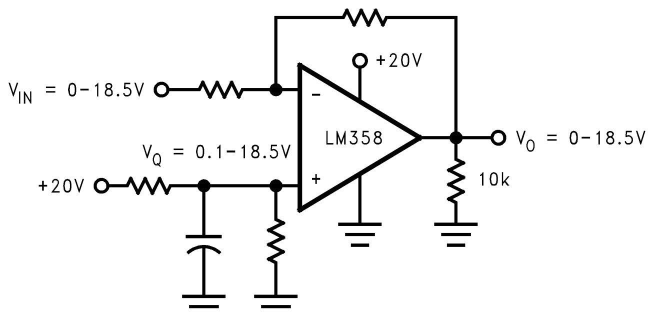
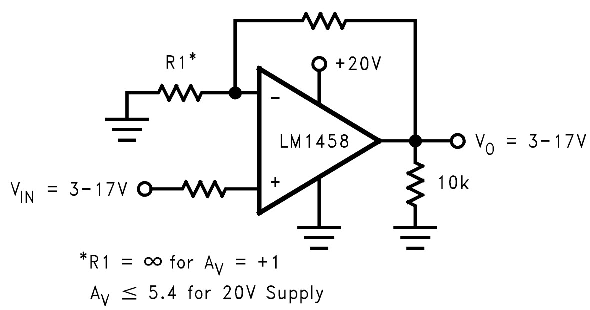


Figure 3. Typical DC Coupled Inverting Gain



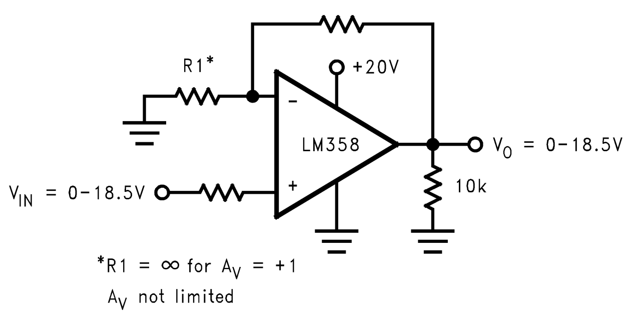


Figure 4. Typical DC Coupled Non-Inverting Gain

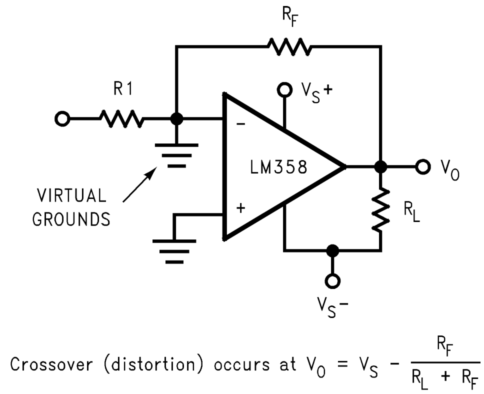


Figure 5. Split Supply Operation of LM358

The output load to negative supply forces the amplifier to source some minimum current at all times, thus eliminating crossover distortion. Crossover distortion without this load would be more severe than that expected with the normal op amp. Since the single supply design took notice of this normal load connection to ground, a class AB output stage was not included. Where ground referenced feedback resistors are used as in Figure 5, the required load to the negative supply depends upon the peak negative output signal level desired without exhibiting crossover distortion. R_L to the negative rail should be chosen small enough that the voltage divider formed by R_F and R_L will permit V_o to swing negative to the desired point according to the equation:

$$R_L = R_F \frac{V_{\bar{S}} - V_o}{V_o} \quad (3)$$

R_L could also be returned to the positive supply with the advantage that V_o max would never exceed (V_{S^+} − 1.5V). Then with ±15V supplies $R_{L\ MIN}$ would be 0.12 R_F. The disadvantage would be that the LM358 can source twice as much current as it can sink, therefore R_L to negative supply can be one-half the value of R_L to positive supply.

The need for single or split supply is based on system requirements which may be other than op amp oriented. However if the only need for balanced supplies is to simplify the biasing of op amps, there are many systems which can find a cost effective benefit in operating LM358's from single supplies rather than standard op amps from balanced supplies. Of the usual op amp circuits, Table 2 shows those few which have limited function with single supply operation. Most are based on the premise that to operate from a single supply, a reference V_Q at about one-half the supply be available for bias or (zero) signal reference. The basic circuits are those listed in AN-20.

Table 2. Conventional Op Amp Circuits Suitable for Single Supply Operation(1)(2)(3)

Application	Limitations
AC Coupled amp	V_Q
Inverting amp	V_Q
Non-inverting amp	OK
Unity gain buffer	OK
Summing amp	V_Q
Difference amp	V_Q
Differentiator	V_Q
Integrator	V_Q
LP Filter	V_Q
I–V Connector	V_Q
PE Cell Amp	OK

(1) See AN-20 for conventional circuits
(2) V_Q denotes need for a reference voltage, usually at about V_S/2.
(3) OK means no reference voltage required

Table 2. Conventional Op Amp Circuits Suitable for Single Supply Operation[1][2][3] (continued)

Application	Limitations
I Source	$I_{O\ MIN} = \frac{1.5}{R1}$
I Sink	OK
Volt Ref	OK
FW Rectifier	V_Q or modified circuit
Sine wave osc	V_Q
Triangular generator	V_Q
Threshold detector	OK
Tracking, regulator PS	Not practical
Programmable PS	OK
Peak Detector	OK to $V_{IN} = 0$

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