Enhancement of Op-Amp Characteristics by Improving Common Mode Rejection Ratio

Himanshu Sirohia, Koushik Chakraborty, Neha Mathur

Abstract - The present invention relates to the "CMRR of Op-Amp" developed for Characteristics Improvement of Operational-Amplifier. CMMR is an acronym for Common Mode Rejection Ratio which is a measure of the capability of an op-amp to reject a signal that is common to both inputs [2,15]. Ideally, CMRR is infinite: if both inputs fluctuate by the same amount, then it will not affect the output. But practically its value depends on the circuit used and the value of its components [1, 11]. Practical value of CMRR is 90db, but this invention will improve its conventional value. In order to improve the performance of an Op-Amp, a method has been proposed, measurement setup has been improved to characterize CMRR more accurately according to its ideal value over wider frequency range. Practically op-amps have high CMRRs, the ubiquitous 741 has approximately 90 dB, and almost 3,000 devices are using this in terms of a ratio [3, 5]. CMRR can be enhanced up to 90 to 100 dB using the proposed method.

Keywords: Op-Amp, CMRR, dB

I. INTRODUCTION

The term op amp, abbreviated as operational amplifier, is special type of amplifier in which proper selection of external components is used to perform various mathematical operations [13, 16]. Op-amp is the backbone of Electronic Instrumentation. Its performance is based on various parameters, such as

- Open-loop gain
- Input impedance
- Input offset voltage
- Output voltage range
- Bandwidth with zero phase shift
- Slew rate.
- Output impedance
- CMRR

The work has been proposed to improve CMRR of operational amplifier [6].

Let $\mathbf{V_1=V_{1d}+V_n}$ (V_1 is the input at inverting terminal) and $\mathbf{V_2=V_{2d}+V_n}$, (V_2 is the input at non inverting terminal) where differential input signal is $\mathbf{V_d = V_{1d}-V_{2d}}$ and $\mathbf{V_n}$ is the common input signal [3, 5]. The output of differential amplifier will be in the form $\mathbf{V_{out} = A_d*(V_d) + A_c*V_n}$, then the Common Mode Rejection Ratio of a differential amplifier is defined as the:

$$\mathbf{CMRR=20*log_{10}\,(A_d/A_c)}$$

Where A_d is differential mode signal gain and Ac is common mode signal gain. Thus by improving the ratio of $\mathbf{(A_d/A_c)}$, CMRR can be enhanced to improve the characteristics of op-amp [1, 4].

Calculating CMRR by changing the values of components used

For the Calculation of CMRR we need both differential mode signal gain (A_d) and common mode signal gain (A_c)[7,12]. Here are the formulas with a brief explanation:

Step-1: The differential gain is:

$$\mathbf{A_d= R_c / (2 * (R_e + r_e))}$$

Where, R_e is the emitter resistors value

r_e is the intrinsic emitter resistance

Step-2: The common mode gain is given by:

$$\mathbf{A_c = -R_c / ((2*R_3) + R_e + r_e)}$$

Where, "- " sign means the output is inverted (180° shift)

R_3 is the "tail" resistor

Step-3: The CMRR can either be calculated using the above results, or can be calculated directly using:

$$\mathbf{CMRR=20*log_{10}\,(A_d/A_c)}$$

II. IMPLEMENTATION

The Common mode rejection ratio (CMRR) is the most important specification and indicates how many of the signals in common mode are present for measurement [8,17]. The value of the CMMR often depends on the frequency of the signal and the function must be specified. The CMMR function is specifically used to reduce noise on transmission lines [9, 11]. For example, when measuring the resistance of a thermocouple in the noisy environment, ambient noise appears as a deviation on both input lines and makes it a common mode voltage signal. The CMRR instrument determines the attenuation applied to noise[10,14].

Task 1: For Rc Variation and Re and re Fixed

Case 1:

Using Rc Variable value = 75 k ohm

Fixed Re value =100 ohm

r_e Intrinsic Emitter Resistance value 250 ohm

a) A_d= 75k/ (2 * (100 + 250)

A_d= 75k/ 700

A_d= 107

b) $A_c = -R_c / ((2*R_3) + R_e + r_e)$

A_c = -75 k / ((2*75k) + 100 + 250)

A_c = 0.5

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c) CMRR=20*log_{10} (A_d/A_c)
CMRR=20*log_{10} (107/0.5) db
CMRR=46 db

Case 2:

Using Rc value = 150 k ohm
Fixed Re value =100 ohm
r_e Intrinsic Emitter Resistance value 250 ohm

a) A_d= 150k/ (2 * (100 + 250)
A_d= 75k/ 700
L]A_d= 214

b) A_c = -R_c / ((2*R_3) + R_e + r_e)
A_c = -150 k / ((2*150k) + 100 + 250)
A_c = 0.5

c) CMRR=20*log_{10} (A_d/A_c)
CMRR=20*log_{10} (214/0.5) db
CMRR=52.62 db

Case 3:

Using Rc value= 450 k ohm
Fixed Re value100 ohm
r_e Intrinsic Emitter Resistance value 250 ohm

a) A_d= 450k/ (2 * (100 + 250)
A_d= 75k/ 700
A_d= 642

b) A_c = -R_c / ((2*R_3) + R_e + r_e)
A_c = -450 k / ((2*450k) + 100 + 250)
A_c = 0.5

c) CMRR=20*log_{10} (A_d/A_c)
CMRR=20*log_{10} (642/0.5) db
CMRR=62.17 db

Case 4:

Using Rc value= 75 M ohm
Fixed Re value100 ohm
r_e Intrinsic Emitter Resistance value 250 ohm

a) A_d = 75M/ (2 * (100 + 250)
A_d = 75M/ 700
A_d = 107142

b) A_c = -R_c / ((2*R_3) + R_e + r_e)
A_c = -75M / ((2*75M) + 100 + 250)
A_c = 0.5

c) CMRR=20*log_{10} (A_d/A_c)
CMRR=20*log_{10} (107142/0.5) db
CMRR=106 db

Task 2: For Re Variation and Rc and re Fixed

Case 1:

For Re value= 100 ohm
Fixed Rc value 75k ohm
re Intrinsic Emitter Resistance value 250 ohm

a) A_d= 75k/ (2 * (100 + 250)
A_d= 75k/ 700
A_d= 107

b) A_c = -R_c / ((2*R_3) + R_e + r_e)
A_c = -75 k / ((2*75k) + 100 + 250)
A_c = 0.5

c) CMRR=20*log_{10} (A_d/A_c)
CMRR=20*log_{10} (107/0.5) db
CMRR=46 db

Case 2:

Using Re value= 50 ohm
Fixed Rc value75k ohm
r_e Intrinsic Emitter Resistance value 250 ohm

a) A_d= 75k/ (2 * (50 + 250)
A_d= 75k/ 600
A_d= 125

b) A_c = -R_c / ((2*R_3) + R_e + r_e)
A_c = -75 k / ((2*75k) + 50 + 250)
A_c = 0.5

c) CMRR=20*log_{10} (A_d/A_c)
CMRR=20*log_{10} (125/0.5) db
CMRR=47.95 db

Case 3:

Using Re value= 10 ohm
Fixed Rc value75k ohm
r_e Intrinsic Emitter Resistance value 250 ohm

a) A_d= 75k/ (2 * (10 + 250)
A_d= 75k/ 520
A_d= 144

b) A_c = -R_c / ((2*R_3) + R_e + r_e)
A_c = -75k / ((2*75k) + 10 + 250)
A_c = 0.5

c) CMRR=20*log_{10} (A_d/A_c)
CMRR=20*log_{10} (144/0.5) db
CMRR=49.18 db

Case 4:

Using Re value= 1 ohm
Fixed Rc value75k ohm
r_e Intrinsic Emitter Resistance value 250 ohm

a) A_d= 75k/ (2 * (1 + 250)
A_d= 75k/ 502
A_d= 149

b) A_c = -R_c / ((2*R_3) + R_e + r_e)
A_c = -75k / ((2*75k) + 1 + 250)
A_c = 0.5

c) CMRR=20*log_{10} (A_d/A_c)
CMRR=20*log_{10} (149/0.5) db
CMRR=49.48 db

III. RESULTS

CMRR on behalf of $\mathbf{A_d}$**, Ac** depends on R_c, R_e and r_e.

Case-I: for Rc Variation

S.No	R_c(Ohm)	A_d	A_c	CMRR(dB)
1	75k	107	0.5	46
2	150k	214	0.5	52.62
3	450k	642	0.5	62.17
4	1M	107142	0.5	106

Case-II: for Re Variation

S. No	Re(Ohm)	Ad	Ac	CMRR(dB)
1	100	107	0.5	46
2	50	125	0.5	47.95
3	10	144	0.5	49.18
4	1	149	0.5	49.48

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Case-III: for r_e Variation

Since re is the intrinsic emitter resistance, which is device (Transistor) dependent value so there is no possibility to change it.

IV. CONCLUSION

CMRR calculation comprises ratio of differential gain (Ad) and common mode gain (Ac).In order to improve CMRR a circuit is designed, using transistor, resistors and required input voltage. Designed circuit is providing 46db CMRR. Rc(collector resistors value) is one of the parameter to change the value of CMRR. Calculation of differential gain (Ad) depends on Rc (collector resistors value) and variation of Rc is providing improved value of (Ad). Calculation of common mode signal gain (Ac) depends on Rc (collector resistors value) but variation of Rc is providing constant value of Ac. The result is clearly shows the direct dependency of Ad over CMRR. Re(emitter resistors value) is second parameter to change the value of CMRR. Calculation of differential gain (Ad) also depends on Re (the emitter resistors value) and variation of Re is providing slightly improved value of (Ad).Calculation of common mode signal gain (Ac) also depends on Re (the emitter resistors value) but variation of Re is providing constant value of (Ac).The result is clearly shows the direct dependency of Ad over CMRR calculation. re(intrinsic emitter resistance) is third parameter to change the value of CMRR but it is device (Transistor) dependent value so there is no possibility to change it. Simulation result proves that Rc (collector resistors value) is perfect parameter for the improvement of CMRR.CMRR is increased from 46 db to 106 db by varying the corresponding component value.

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