ANALOG ELECTRONIC CIRCUITS – AV211

Opamp Specifications

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Introduction

This report is on the specifications of two commercially available opamps **ADA4665-2** and **LTC6090**. The datasheets of the two opamps were downloaded from www.analog.com. The datasheets of the two opamps are studied in this report. The two opamps have been compared based on the various specifications of the two opamps. The comparison is also done on the basis of the inferences drawn from the various graphs. Two application circuits using each of the two opamps has been simulated using LTSpice.

Comparison Based on Different Electrical Characteristics

Power Supply:

ADA4665-2:

Single-supply operation: 5 V to 16 V
Dual-supply operation: ±2.5 V to ±8 V

LTC6090:

Supply Range: ±4.75V to ±70V (140V)

Inference:

i. The supply voltage range of LTC6090 is much higher than that of ADA4665-2.
ii. At higher supply voltages, ADA4665-2 might fail whereas LTC6090 would work.
iii. The opamps might work beyond the specified range but the manufacturer does not guarantee it.
iv. If the input voltage signal is more than the supply voltage, then the signal might get clipped.
v. The negative and positive supply voltage provided neet not be equal.

Large-signal Voltage Gain:

ADA4665-2:

Conditions	Min	Typ	Max
R_L = 10 kΩ, V_O = 0.5 V to 15 V	85dB or 1.778×10^4V/V	100dB or 10^5	
−40°C ≤ T_A ≤ +125°C	75dB or 5.623×10^3V/V		

LTC6090:

Conditions	Min	Typ	Max	Unit
R_L = 10 kΩ	1000	>10000		V/mV
V_{OUT} from -60V to 60V	1000			

Inference:

i. The large signal voltage gain of the opamp LTC6090 is around 100 times higher than that of the opamp ADA4665-2.
ii. The closed loop gain of a circuit using LTC6090 will have lesser dependence on the large signal voltage gain as compared to a circuit using ADA4665-2.
iii. The closed loop gain of a circuit using ADA4665-2 will have a higher decrease(error) as compared to the circuit using LTC6090 which will be less affected by the large signal voltage gain.

Input Offset Voltage:

ADA4665-2:

Conditions	Min	Typ	Max	Unit
V_{CM} = 5 V		1	4	mV
V_{CM} = 0 to 5 V		1	6	mV
V_{CM} = 16 V		1	4	mV
V_{CM} = 0 to 16 V		1	6	mV
−40°C ≤ T_A ≤ +125°C			9	mV

LTC6090:

Conditions	Min	Typ	Max	Unit
V+ = 70V, V– = –70V, V_{CM} = V_{OUT} = 0V, V_{OD} = Open		±330	±1000	µV
−40°C ≤ T_A ≤ +125°C		±330	±1250	µV

Inference:

i. The input offset voltage of the opamp, ADA4665-2 is higher than that of LTC6090.
ii. The error in the output voltage of the circuit using the opamp ADA4665-2 will be higher than in the circuit using the opamp LTC6090.

Input Offset Voltage Drift(ΔV_{OS}/ΔT):

ADA4665-2:

Conditions	Min	Typ	Max	Unit
−40°C ≤ T_A ≤ +125°C		3		µV/°C

LTC6090:

Conditions	Min	Typ	Max	Unit
T_A = 25°C, ΔT_J = 70°C	-5	±3	5	µV/°C

Inference:

i. The offset voltage changes with temperature. Therefore both the opamps will work better around room temperature.
ii. As temperature increases, the drift in offset voltage also increases and hence the output voltage will be affected.

Input Bias Current:

ADA4665-2:

Conditions	Min	Typ	Max	Unit
V_{SY} = 16 V, V_{CM} = $V_{SY}/2$, T_A = 25°C		0.1	1	pA
V_{SY} = 16V, −40°C ≤ T_A ≤ +125°C			200	pA
V_{SY} = 5 V, V_{CM} = $V_{SY}/2$, T_A = 25°C		0.1	1	pA
V_{SY} = 5V, −40°C ≤ T_A ≤ +125°C			100	pA

LTC6090:

For C-, I suffixes:

Conditions	Min	Typ	Max	Unit
Supply Voltage = ±70V		3		pA
Supply Voltage = ±15V		0.3		pA
Supply Voltage = ±15V, −40°C ≤ T_A ≤ +125°C			50	pA

For H suffixes:

Conditions	Min	Typ	Max	Unit
Supply Voltage = ±70V		3		pA
Supply Voltage = ±15V		0.3		pA
Supply Voltage = ±15V, −40°C ≤ T_A ≤ +125°C			800	pA

Inference:

i. All the above opamps have low values of I_B at room temperature.
ii. ADA4665-2 has higher value of I_B at higher supply voltage.
iii. The maximum value of input bias current of LTC6090H is higher.
iv. Therefore, it is better to use ADA4665-2 or LTC6090C or LTC6090I if the internal impedence is less.

Input Offset Current:

ADA4665-2:

Conditions	Min	Typ	Max	Unit
V_{SY} = 5 V, V_{CM} = $V_{SY}/2$, T_A = 25°C		0.1	1	pA
V_{SY} = 5 V, −40°C ≤ T_A ≤ +125°C			10	pA
V_{SY} = 16 V, V_{CM} = $V_{SY}/2$, T_A = 25°C		0.1	1	pA
V_{SY} = 16 V, −40°C ≤ T_A ≤ +125°C			40	pA

LTC6090:

For C-, I suffixes:

Conditions	Min	Typ	Max	Unit
Supply Voltage = ±15V		0.5		pA

$-40°C \le T_A \le +125°C$			30	pA

For H suffixes:

Conditions	Min	Typ	Max	Unit
Supply Voltage = ±15V		0.5		pA
$-40°C \le T_A \le +125°C$			120	pA

Inference:

i. All the above opamps have low values of I_{OS} at room temperature.
ii. The maximum value of input offset current of LTC6090H is higher.
iii. Therefore the bias current compensation when used for LTC6090H might have lesser effect as compared to ADA4665-2.

I_P and I_N values:

ADA4665-2:

Conditions	I_P			I_N			Unit
	Min	Typ	Max	Min	Typ	Max	
V_{SY} = 5 V, $V_{CM} = V_{SY}/2$, T_A = 25°C		0.15	1.5		0.05	0.5	pA
V_{SY} = 5 V, ,$-40°C \le T_A \le +125°C$			105			95	pA
V_{SY} = 5 V, $V_{CM} = V_{SY}/2$, T_A = 25°C		0.15	1.5		0.05	0.5	pA
V_{SY} = 16 V, ,$-40°C \le T_A \le +125°C$			220			180	

LTC6090:

- For C-, I suffixes:

Conditions	I_P			I_N			
	Min	Typ	Max	Min	Typ	Max	Unit
Supply Voltage = ±15V		0.55			0.05		pA
$-40°C \le T_A \le +125°C$			65			35	pA

- For H suffixes:

Conditions	I_P			I_N			
	Min	Typ	Max	Min	Typ	Max	Unit
Supply Voltage = ±15V		0.55			0.05		pA
$-40°C \le T_A \le +125°C$			860			740	pA

Inference:

i. The values of I_N and I_P determine the error in the offset voltage due to I_B and I_{OS}.

ii. LTC6090H works under higher temperatures. The maximum values of I_N and I_P are higher for LTC6090H when compared to ADA4665-2. Thus the error in the output voltage due to I_N will be higher in case of LTC6090.

Common-mode Rejection Ratio(CMRR):

ADA4665-2:

Conditions	Min	Typ	Max	Unit
V_{CM} = 0 to 5 V	55	50		dB
−40°C ≤ T_A ≤ +125°C	75			dB

LTC6090:

Conditions	Min	Typ	Max	Unit
V_{CM} = -67V to 67V	130	>140		dB
−40°C ≤ T_A ≤ +125°C	126			dB

Inference:

i. The CMRR should be high, around 100dB for good working of the opamp.
ii. The CMRR of LTC6090 is fairly high. Therefore, it provides good noise rejection.
iii. The CMRR of ADA4665-2 is comparatively low. Therefore, it is not preferable in cases where there is noise.

Power Supply Rejection Ratio(PSRR):

ADA4665-2:

Conditions	Min	Typ	Max	Unit
V_{SY} = 5V to 16 V	70	95		dB
−40°C ≤ T_A ≤ +125°C	65			dB

LTC6090:

Conditions	Min	Typ	Max	Unit
V_S = ±4.75V to ±70V	112	>120		dB
−40°C ≤ T_A ≤ +125°C	126			dB

Inference:

i. PSRR should be a negative value, since it calculates rejection. We need lower PSRR so that the change in offset voltage is lower and hence the change in output voltage
ii. Both the opamps have positive PSRR. LTC6090 has a higher PSRR than ADA4665-2.
iii. Both the opamps would have high fluctuations in power supply. The fluctuation will be higher in case of LTC6090.

Gain Bandwidth Product(GBW):

ADA4665-2:

Conditions	Min	Typ	Max	Unit
R_L = 10kΩ, C_L = 50pF, A_V = 1		1.2		MHz

LTC6090:

For C-, I suffixes:

Conditions	Min	Typ	Max	Unit
f_{TEST} = 20kHz, R_L = 10k, −40°C ≤ T_A ≤ +125°C	5.5	12		MHz

For H suffixes:

Conditions	Min	Typ	Max	Unit
f_{TEST} = 20kHz, R_L = 10k, −40°C ≤ T_A ≤ +125°C	5	12		MHz

Inference:

i. The GBW should be high. Higher GBW ensures that the maximum gain can be extracted from the opamp without much attenuation.
ii. The GBW of LTC6090 is about 10 times higher than that of ADA4665-2.
iii. Therefore, we obtain a better gain for LTC6090 at higher frequencies. At higher frequencies, the gain gets attenuated in the case of ADA4665-2.

Slew Rate:

ADA4665-2:

Conditions	Min	Typ	Max	Unit
R_L = 10kΩ, C_L = 50pF, A_V = 1		1		V/µs

LTC6090:

For C-, I suffixes:

Conditions	Min	Typ	Max	Unit
A_v = -4, R_L = 10k, −40°C ≤ T_A ≤ +125°C	10	21		V/µs

For H suffixes:

Conditions	Min	Typ	Max	Unit
f_{TEST} = 20kHz, R_L = 10k, −40°C ≤ T_A ≤ +125°C	9	21		V/µs

Inference:

i. Slew rate is the rate of change of output. Higher the slew rate, lesser is the distortion produced in the output waveform.

ii. The slew rate of both the opamps is less. Therefore the output waveform can get distorted in case of both the opamps.
iii. The slew rate of ADA4665-2 is lower than that of LTC6090.
iv. Therefore, there is a higher chance that the output waveform of a circuit using ADA4665-2 get distorted. The shape of the output waveform can change.

Settling Time 0.1% (t_s):

ADA4665-2:

Conditions	Min	Typ	Max	Unit
V_{IN} = 1V step, R_L = 2 kΩ, C_L = 50 pF		6.5		µs

LTC6090:

Conditions	Min	Typ	Max	Unit
A_V = 1V/V		2		µs

Inference:

i. The settling time of ADA4665-2 is greater than that of LTC6090.
ii. The settling time should be as small as possible so that there will be lesser distortions in the output waveform.
iii. The output waveform of LTC6090 will have lesser distortions due to settling time.

Output Short-Circuit Current(I_{SC}):

ADA4665-2:

Conditions	Min	Typ	Max	Unit
V_{SY} = 5 V, V_{CM} = V_{SY}/2, T_A = 25°C		±30		mA

LTC6090:

Conditions	Min	Typ	Max	Unit
Supply Voltage = ±70V		90		mA
Supply Voltage = ±15V	50			mA

Inference:

i. I_{SC} is the maximum output current that can be drawn. If the current is to be greater than I_{SC}, we will not get the expected output.
ii. The I_{SC} of LTC6090 is greater than that of ADA4665-2.

Temperature Range:

ADA4665-2:

Operating Temperature Range: −40°C to +125°C

LTC6090:

Operating Junction Temperature Range: −40°C to +125°C

Specified Junction Temperature Range:

- LTC6090C: 0°C to 70°C
- LTC6090I: –40°C to 85°C
- LTC6090H: –40°C to 125°C

Comparison Based on Typical Performance Characteristics

Input Bias Current vs. Input Common-Mode Voltage:

ADA4665-2:

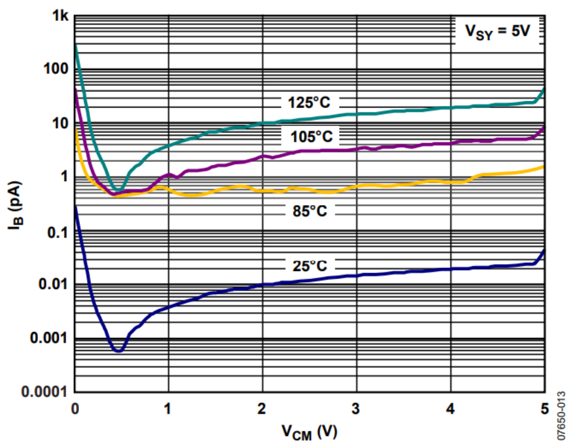


Figure 10. Input Bias Current vs. Input Common-Mode Voltage

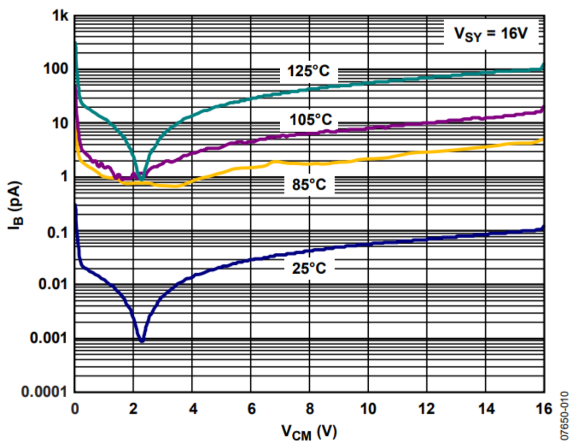
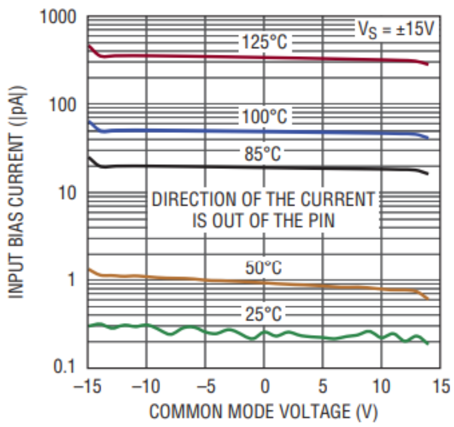


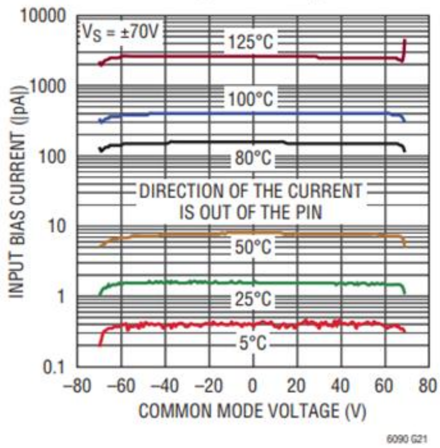
Figure 13. Input Bias Current vs. Input Common-Mode Voltage

LTC6090:

Input Bias Current vs Common Mode Voltage and Temperature



Input Bias Current vs Common Mode Voltage and Temperature



Inference:

i. The input bias current changes with change in V_{CM} in case of ADA4665-2 whereas it remains almost constant with change in V_{CM} in case of LTC6090.

ii. At a particular temperature, I_B of LTC6090 is higher than that of ADA4665-2. Therefore, higher error will be produced due to I_B in case of LTC6090.

iii. In both the graphs of ADA4665-2, we observe that I_B is maximum when V_{CM} = 0, then decreases exponentially, reaches a minimum and again increases exponentially.
iv. For ADA4665-2, I_B reaches a minimum around 0.5V when supply voltage=5V and it reaches a minimum around 2V when supply voltage=16V.
v. At the above voltages, both I_B and V_{CM} are less for ADA4665-2. Hence, the error in output voltage will also be less.
vi. In cases where V_{CM} keeps varying, it is better to use LTC6090.

Open-Loop Gain and Phase vs. Frequency:

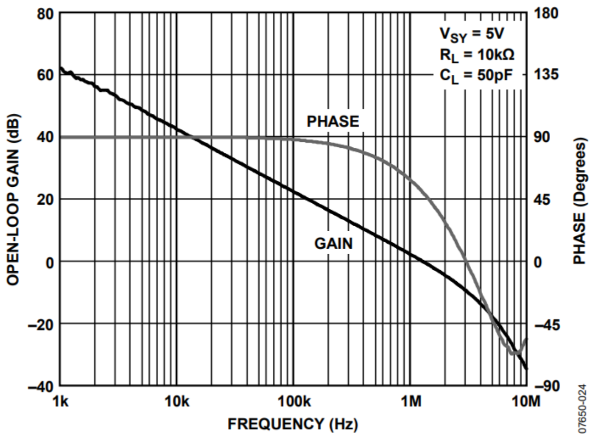


Figure 21. Open-Loop Gain and Phase vs. Frequency

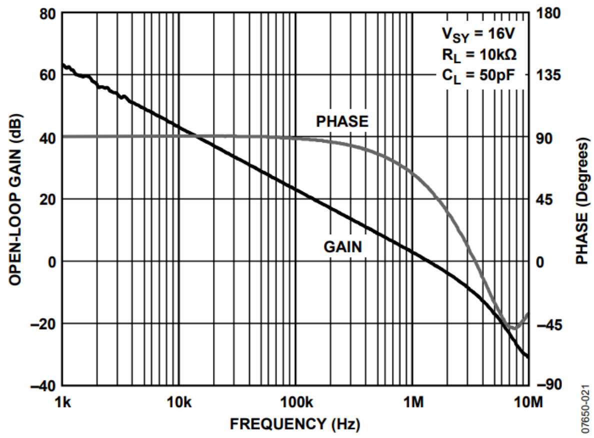
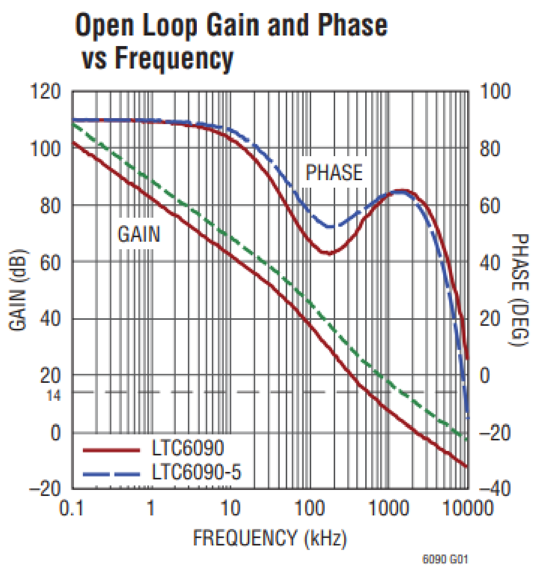


Figure 24. Open-Loop Gain and Phase vs. Frequency

<u>LTC6090:</u>



<u>Inference:</u>

i. The open loop gain decreases with increase in frequency for both the opamps.
ii. We can observe that the slope of the graph is -20dB/decade for both the opamps.

Closed-Loop Gain vs Frequency:

<u>ADA4665-2:</u>

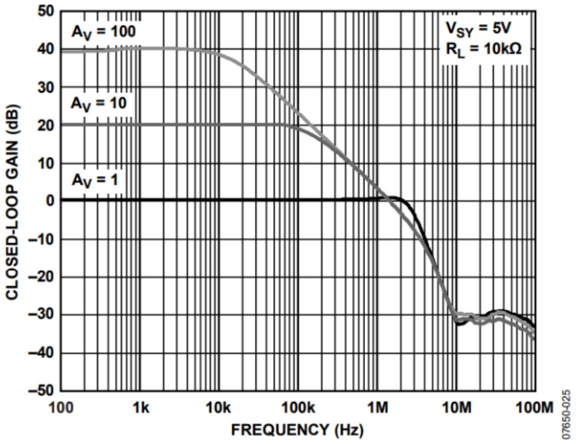


Figure 22. Closed-Loop Gain vs. Frequency

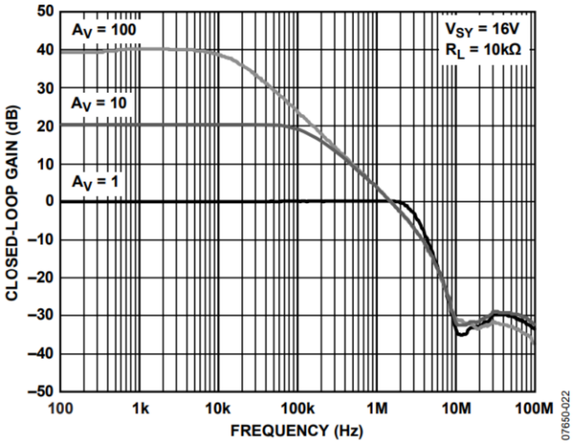
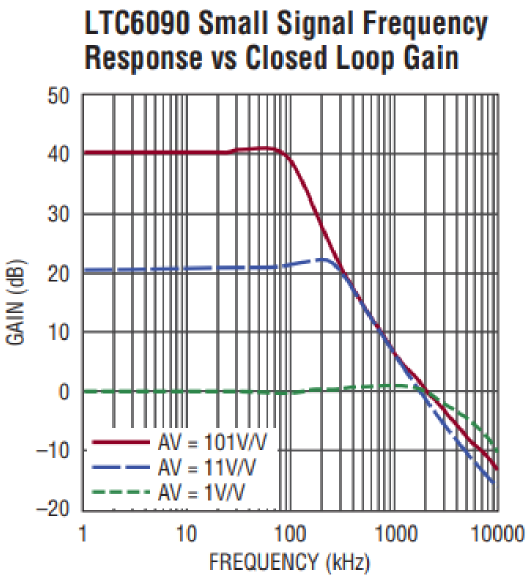


Figure 25. Closed-Loop Gain vs. Frequency

<u>LTC6090:</u>



<u>Inference:</u>

i. The closed-loop bandwidth of LTC6090 is around 10 times that of ADA4665-2.

ii. The gain bandwidth product can be observed from the graph. For ADA4665-2, it is 1.2MHz. For LTC6090, it is 12MHz.

iii. The closed-loop bandwidth decreases with increase in gain for both the opamps.

iv. Therefore, for higher gain, the opamps work well at lower frequencies. At higher frequencies, there will be lesser gain.

Output Impedance vs Frequency:

ADA4665-2:

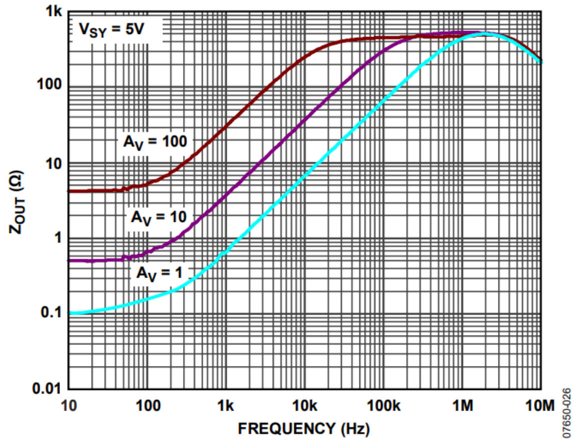


Figure 23. Output Impedance vs. Frequency

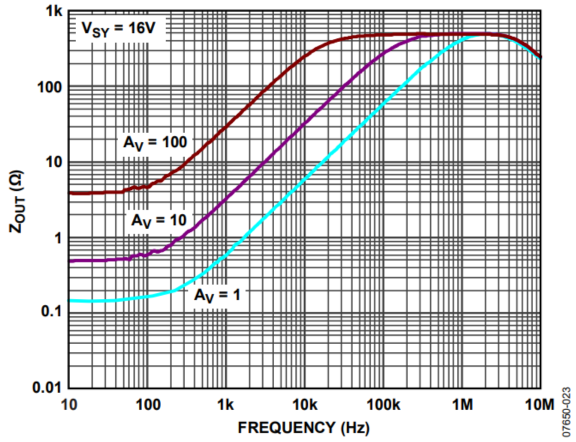
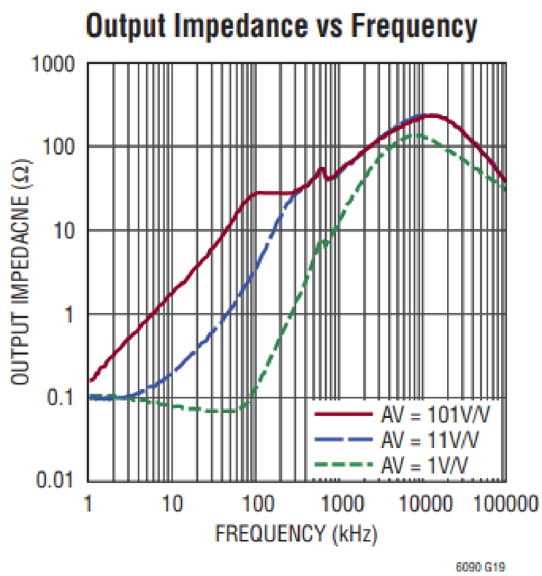


Figure 26. Output Impedance vs. Frequency

LTC6090:



Inference:

i. The output impedance is almost the same for both the opamps ADA4665-2 and LTC6090.

ii. The ideal output impedance of an opamp is zero. If the output impedance is high, there can be a voltage drop across the opamp which can cause power dissipation and hence contribute to temperature rise of the opamp.

iii. Here, the output impedance increases with increase in frequency.

iv. Therefore at high frequencies, there can be a voltage drop across the opamp.

CMRR vs Frequency:

ADA4665-2:

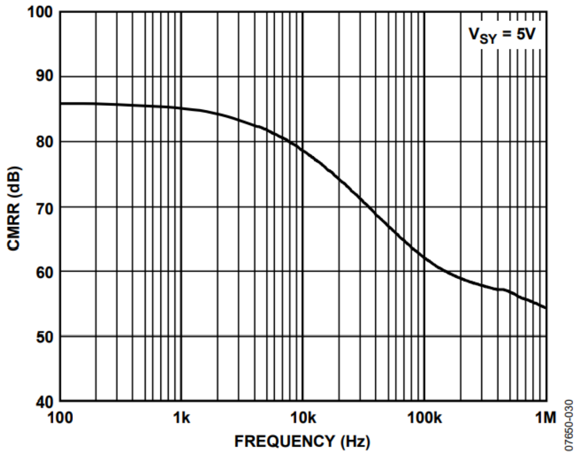


Figure 27. CMRR vs. Frequency

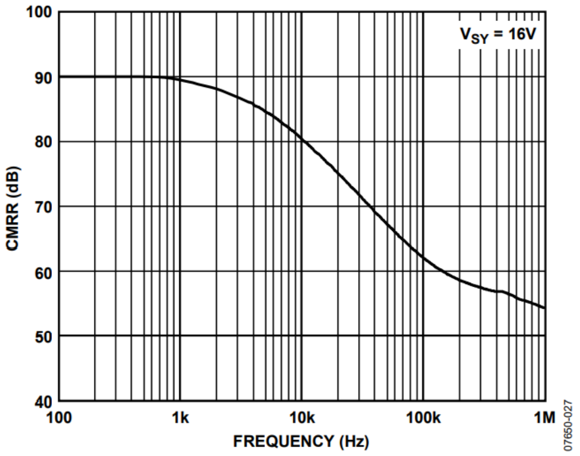
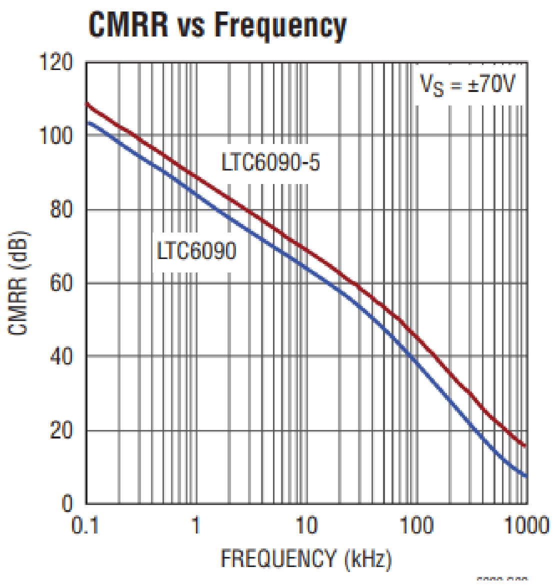


Figure 30. CMRR vs. Frequency

LTC6090:



Inference:

i. LTC6090 has a good CMRR at low frequencies as compared to ADA4665-2.

ii. The CMRR decreases with increases in frequency for both the opamps.

iii. CMRR is lesser at higher frequencies because when the transistors are operated at higher frequencies, the effect due to the stray capacitors increases.

PSRR vs Frequency:

ADA4665-2:

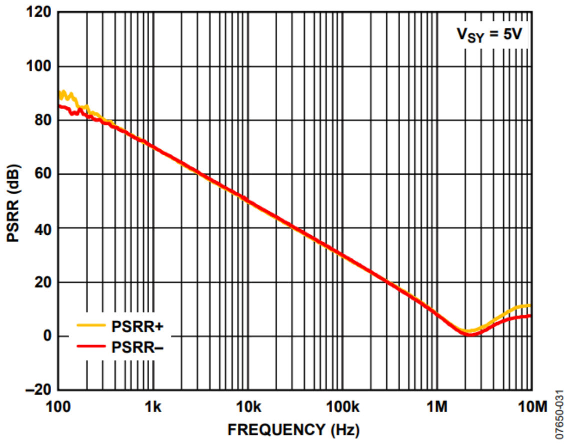


Figure 28. PSRR vs. Frequency

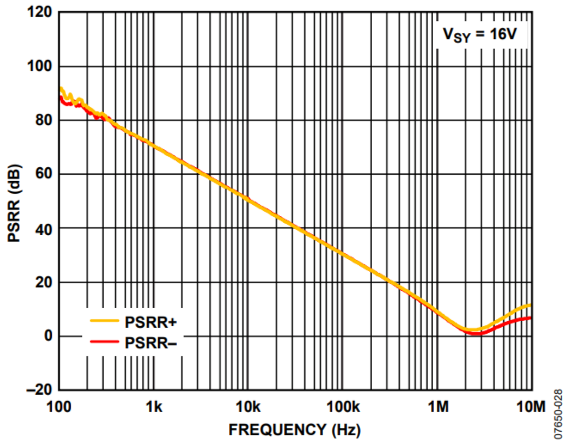
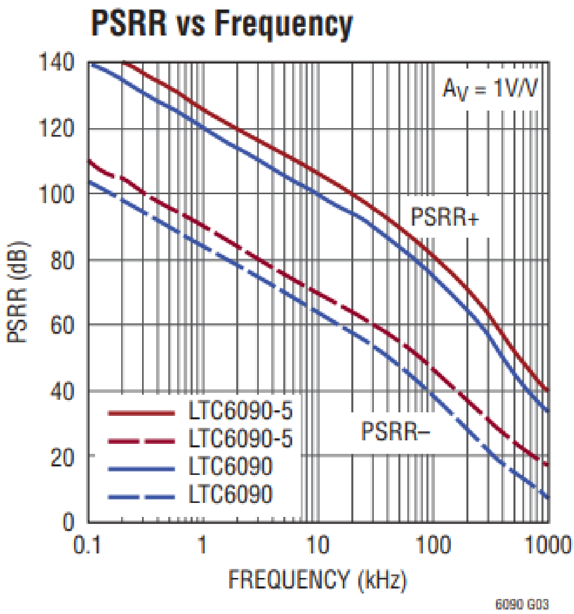


Figure 31. PSRR vs. Frequency

LTC6090:



Inference:

i. For both the opamps, PSRR decreases with increase in frequency.

ii. Lower the PSRR, lesser the fluctuation in offset voltage and hence lesser the fluctuation in output voltage.

iii. Therefore, at higher voltages, the fluctuations in output voltage due to power supply will be less.

Some Typical Performance Characteristics of ADA4665-2

Input Offset Voltage vs Common-Mode Voltage:

ADA4665-2:

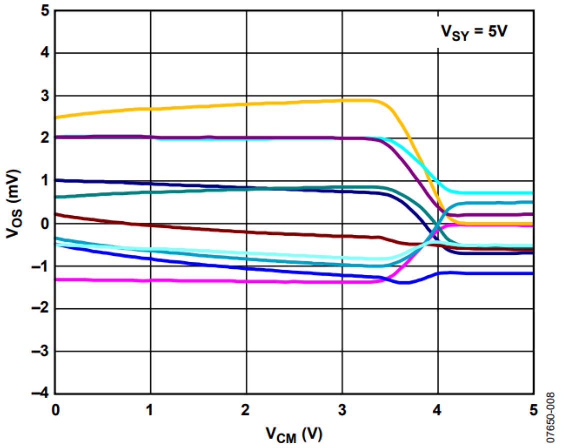


Figure 5. Input Offset Voltage vs. Common-Mode Voltage

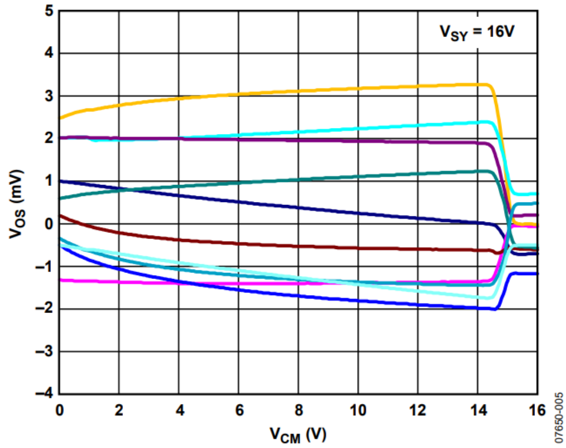


Figure 8. Input Offset Voltage vs. Common-Mode Voltage

Inference:

i. In both the graphs, we observe that the offset voltage decreases as the common-mode voltage approaches the supply voltage.
ii. The offset voltage decreases rapidly for higher common-mode voltage.
iii. Both offset voltage and common-mode voltage contribute to an error in the output voltage. Therefore, we should check which of the two parameters weighs more and set the values as per our requirement.

Input Bias Current vs. Temperature:

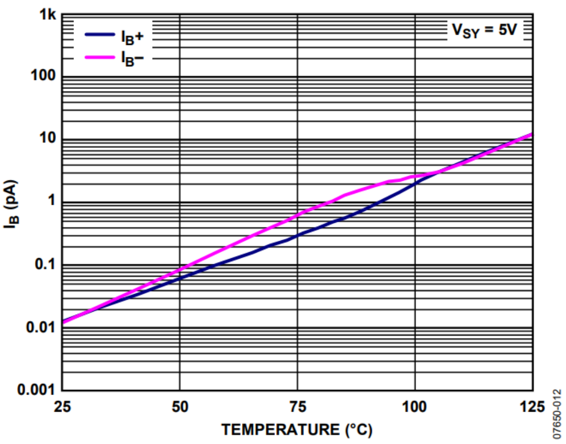


Figure 9. Input Bias Current vs. Temperature

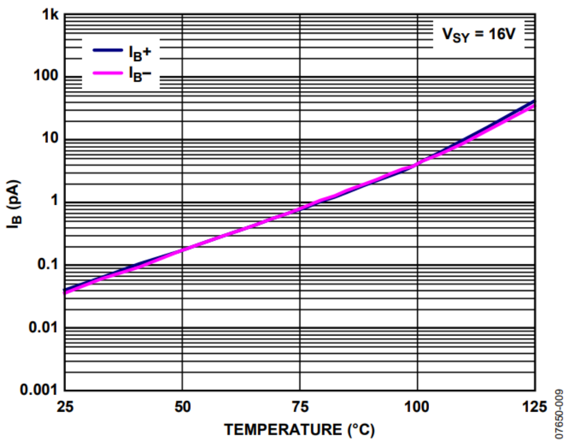


Figure 12. Input Bias Current vs. Temperature

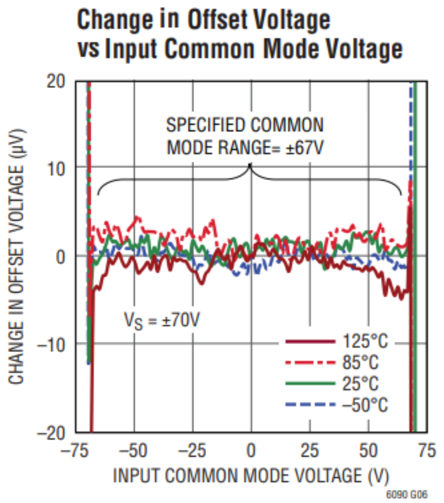
Inference:

i. In both the graphs, we observe that the input bias current increases exponentially with temperature.

ii. The input bias current is higher when the supply voltage is 16V, i.e., the iput bias current is higher at higher supply voltage.
iii. The input bias current is very less at room temperature. As temperature is increased, the input bias current increases and will contribute to higher error in output voltage.

Some Typical Performance Characteristics of LTC6090

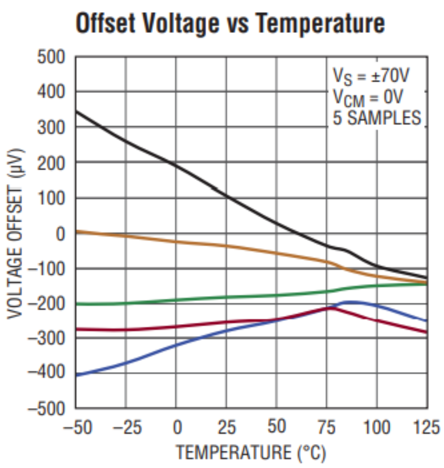
Change in Offset Voltage vs Input Common Mode Voltage:



Inference:

i. The change in offset voltage remains almost the same for all common mode voltages except when the value of the common mode voltage approaches the maximum supply voltage(±70V).
ii. Therefore, the opamp should be operated within the supply voltage range.

Offset Voltage vs Temperature:

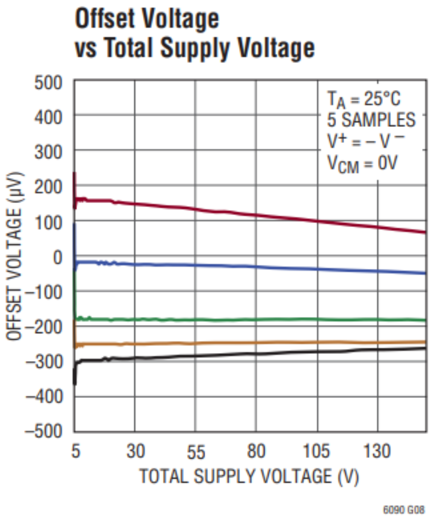


Inference:

i. The magnitude of offset voltage is higher at lower temperatures. The magnitude decreases with increase in temperature.

ii. Therefore, the error in output voltage due to offset voltage will be greater at lower temperatures.

Offset Voltage vs Total Supply Voltage:

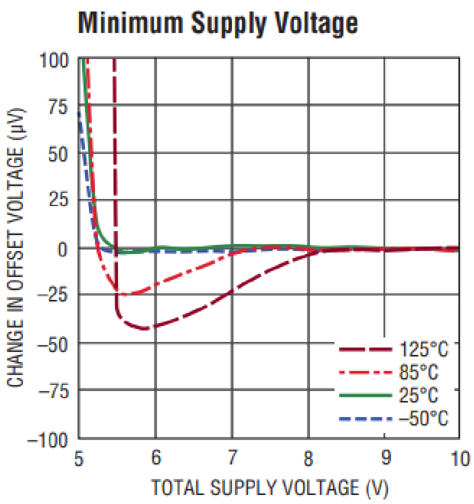


Inference:

i. The offset voltage remains almost constant with the total supply voltage, except when the total supply voltage is very low(=5V).

ii. When the total supply voltage = 5V, the graph is a vertical line which indicates a sudden increase in offset voltage.

Change in Offset Voltage vs Total Supply Voltage:



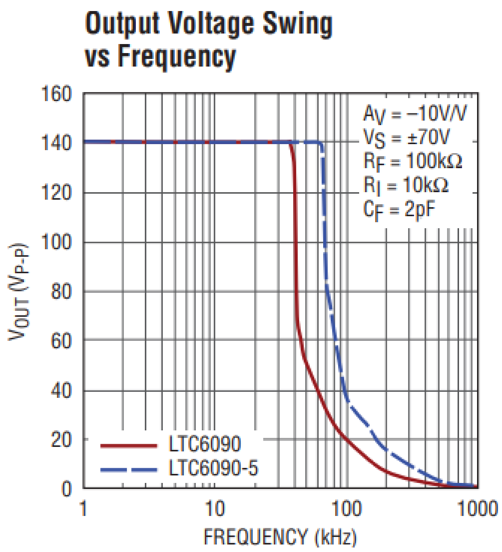
Inference:

i. The change offset voltage is almost zero except at lower total supply voltage.

ii. The graph is almost a straight line at low total supply voltage which indicates a high fluctuation in offset voltage at low total supply voltage.

iii. Therefore, it is better not to use the opamp at a very low supply voltage.

Output Voltage Swing vs Frequency:

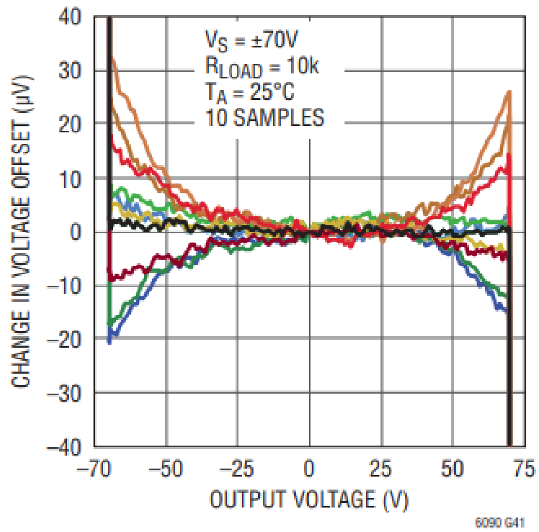


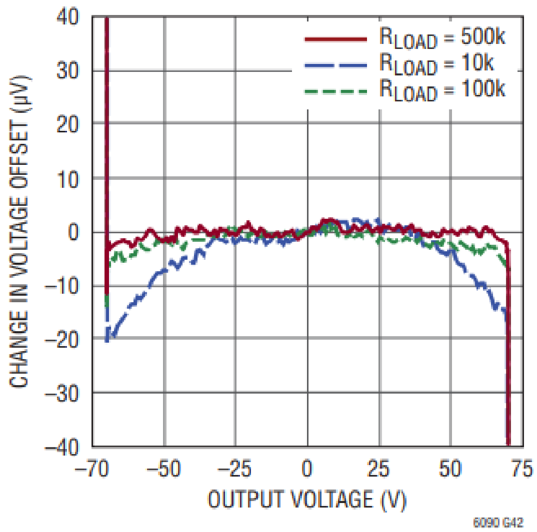
Inference:

i. Here, the total supply voltage provided is 140V. At low frequencies, the output voltage swing remains almost constant at 140V.

ii. At higher frequencies, the output voltage swing decreases and approaches 0 at around 100kHz.

Change in Offset Voltage vs Output Voltage:





Inference:

i. The change in offset voltage is almost zero when the output voltage is between is -25V and 25V.

ii. Beyond this range, the magnitude of the change in offset voltage increases and the graph becomes a vertical line when the output voltage approaches ±70V.

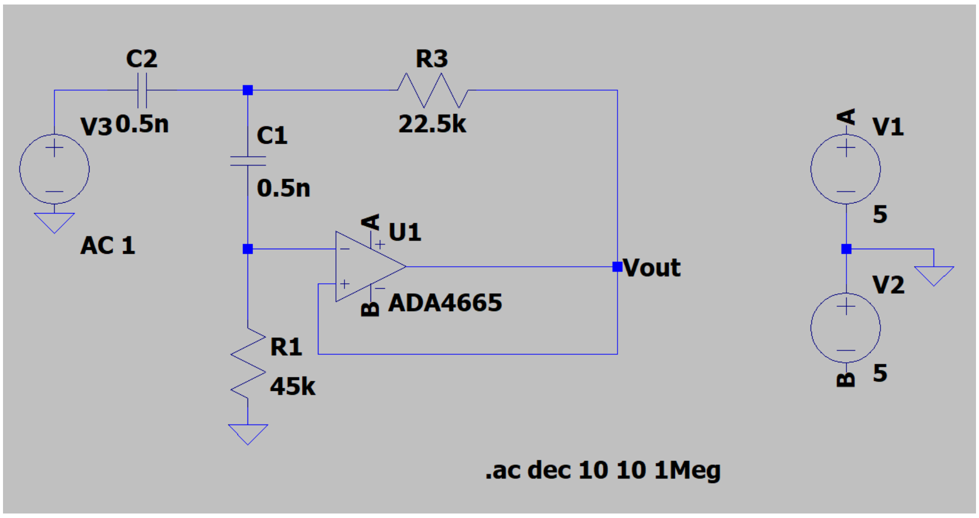
iii. The magnitude of the change in offset voltage increases as the load resistance increases.

Application Circuits

Two-Pole High Pass Filter (using ADA4665-2):

The ADA4665-2 is well suited for active filter designs. An active filter requires an opamp with a unity-gain bandwidth at least 100 times greater than the product of the corner frequency, fc, and the quality factor, Q.The circuit given below is a two-pole high-pass filter, with cut-off frequency at 10 kHz and quality factor, Q of 1/√2.

Circuit Diagram from LTSpice:



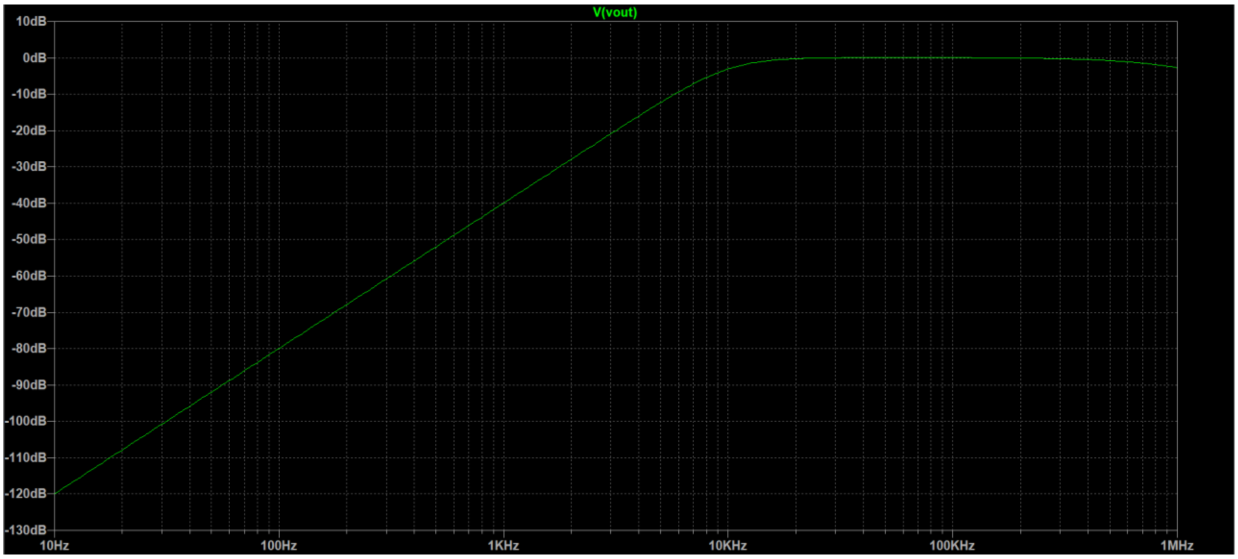
Calculation:

$R_1 = 22.5k\Omega$, $C_1 = C_2 = 0.5nF$. When R2 = 2R1 and C1 = C2, the values of Q and the cut-off frequency are calculated as follows:

$$Q = \frac{\sqrt{R1\,R2\,C1\,C2}}{R1(C1+C2)}$$ Q = 1/√2

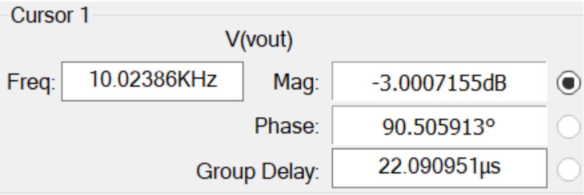
$$f_c = \frac{1}{2\pi\sqrt{R1\,R2\,C1\,C2}}$$ $f_c = 10k\Omega$

Graph obtained by Simulation:



Measuring the Cut-off Frequency:

The cut-off frequency is obtained at -3dB.



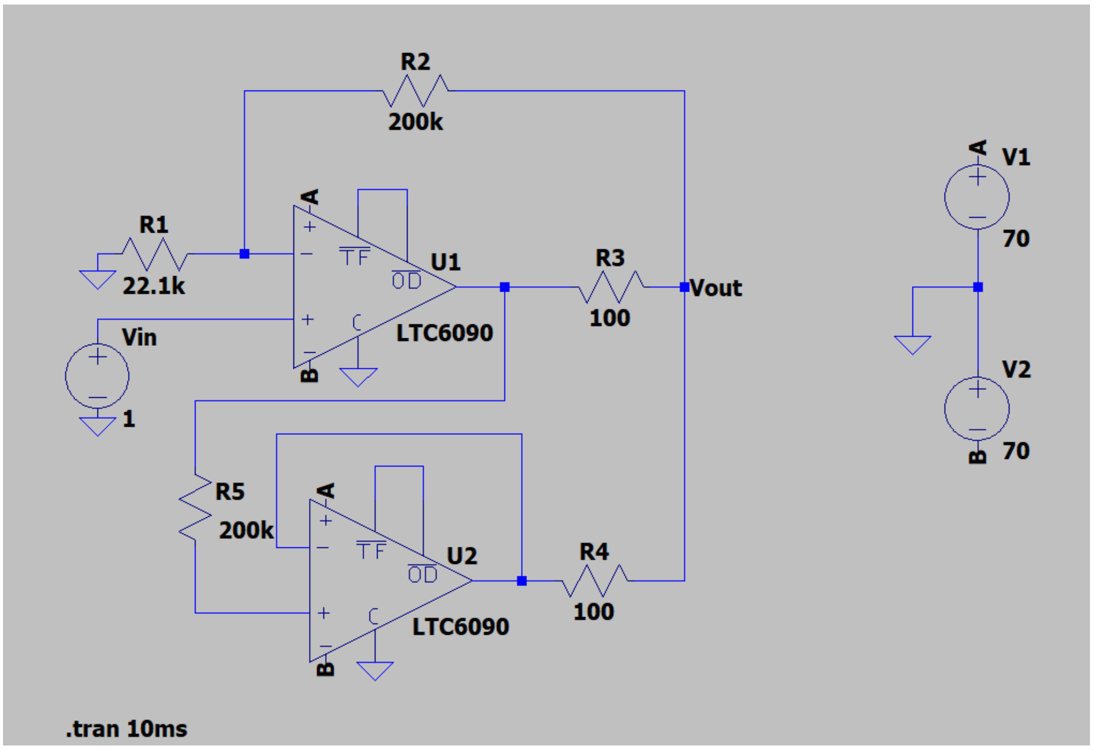
Cut-off frequency from simulation = 10.02386kHz

Inference:

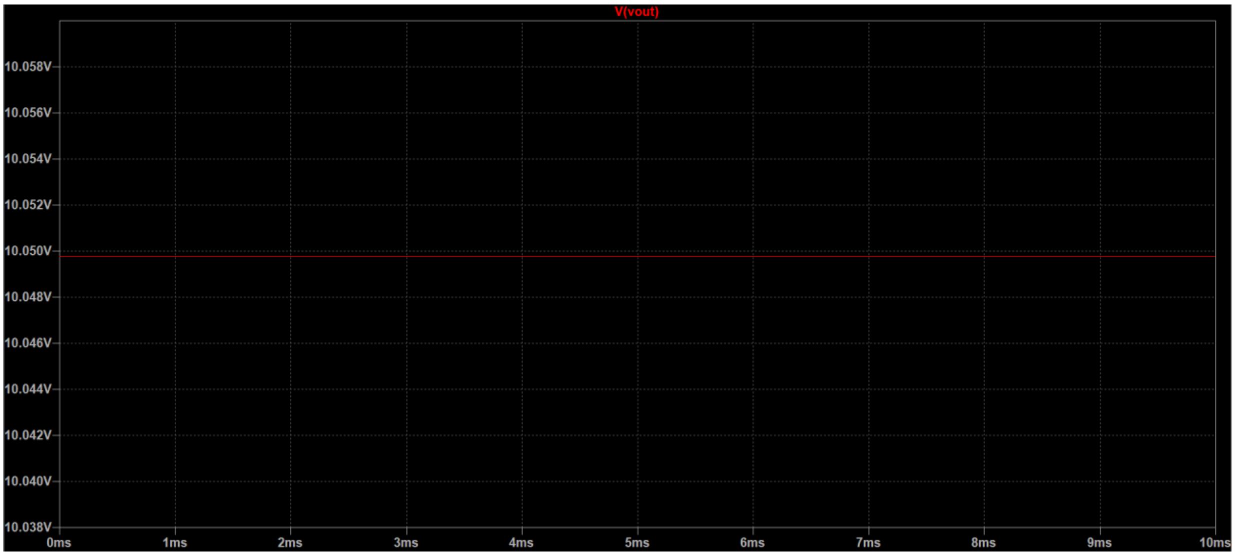
i. The output is similar to that of a high pass filter.
ii. The circuit does not allow the passage of low frequency signals.
iii. The cut-off frequency obtained is close to the calculated cut-off frequency of 10kHz.
iv. The circuit allows the passage of signals with a frequency above the cut-off frequency, i.e., 10kHz.
v. The output obtained by simulation is a bit different from that given in the datasheet. This is because the circuit components used in simulation will be ideal

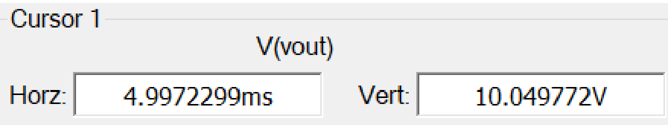
Gain of 10 with Protected Output Current Doubler (using LTC6090):

Circuit Diagram:



<u>Output Voltage Waveform:</u>

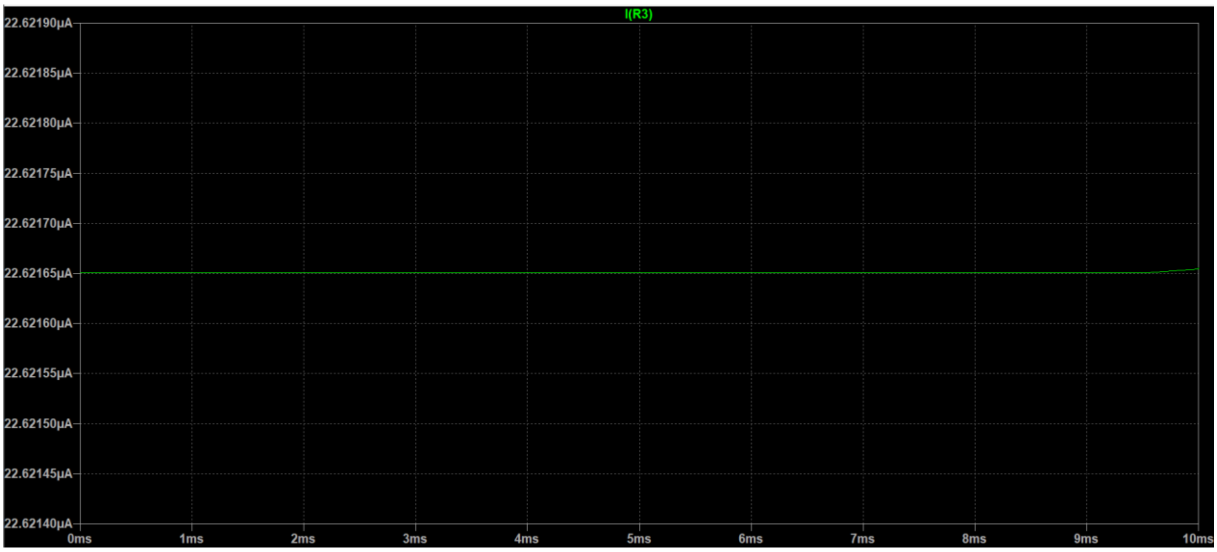


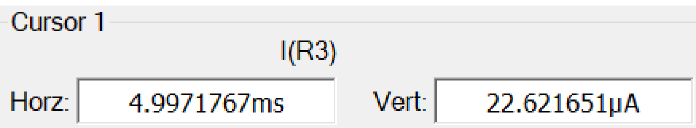


Output Voltage = 10.049772V

Thus, gain obtained = 10.049772V = 10(approx.)

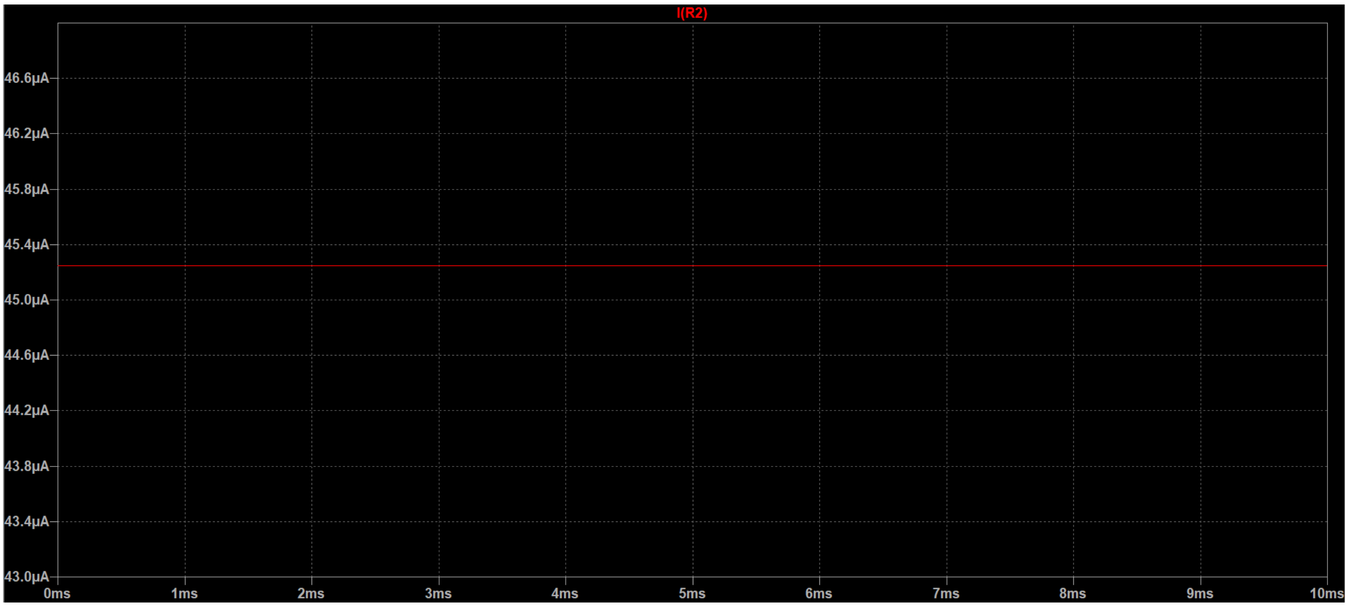
<u>Output Current:</u>

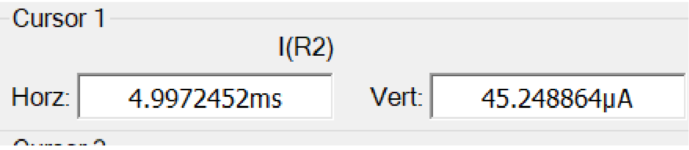




Output Current = 22.62165µA

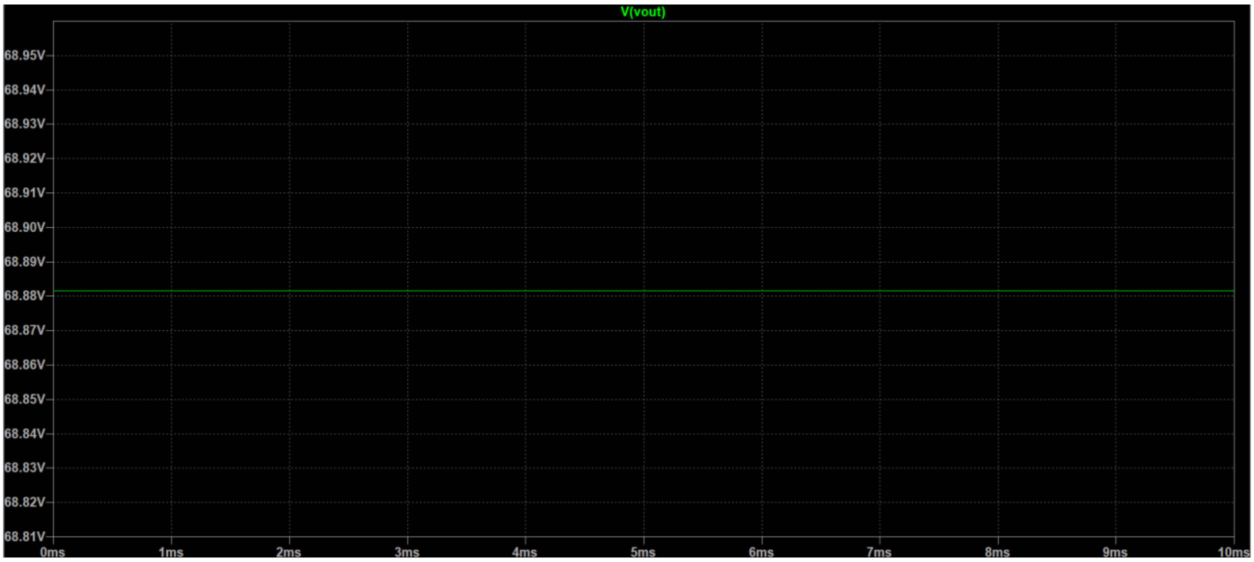
Current through R2:

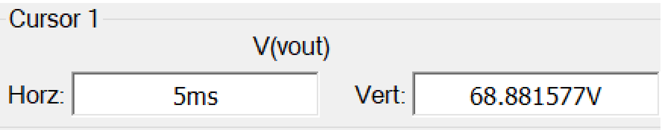




Current = 45.248864µA = 2*output current(approx.)

Output Voltage when input voltage = 10V





Output voltage = 68.881577V

Inference:

i. When an input voltage of 1V is applied, you observe that a gain of around 10 is obtained.
ii. The current through the resistance R2 is almost double the output current. Therefore, the circuit acts as an output current doubler.
iii. When an input voltage of 10V is applied, you observe that instead of obtaining a voltage of 100V (as per the required gain), an output voltage around 70V is obtained. Therefore, the circuit clips the voltage at around ±70V.
iv. Therefore the circuit provides a gain of 10 and functions as a protected output current doubler.

Conclusion

ADA4665-2 has lower power at high voltage: 290 μA per amplifier typical. It offers a low supply current of 400 μA maximum per amplifier at 25°C and 600 μA maximum per amplifier over the extended industrial temperature range. Hence the opamp is suitable for low power applications. It has low input bias current: 1 pA maximum. It also has low offset voltage drift of 3 μV/°C, and hence can be used over a temperature range of a −40°C to +125°C.

LTC6090 features high open loop gain which is suitable for high gain configurations. It has low input offset voltage(1.25mV Maximum) which provides good DC performance. It also has low input bias current(50pA Maximum) It has very high CMRR (130dB Minimum) and hence will provide good noise rejection. It also a high slew rate(21V/μs) which is useful in high frequency applications. It also has a very high supply range.