Basics of Analog Multiplexers 3

TIPL 2603

TI Precision Labs – Op Amps

Created by Abhijeet Godbole, Art Kay

Presented by Peggy Liska

Analog Multiplexer Parameters Summary

- Part 1: Understanding Performance parameters of Multiplexer

  1) Bandwidth
  - How MUX bandwidth is defined
  - Factors affecting MUX bandwidth

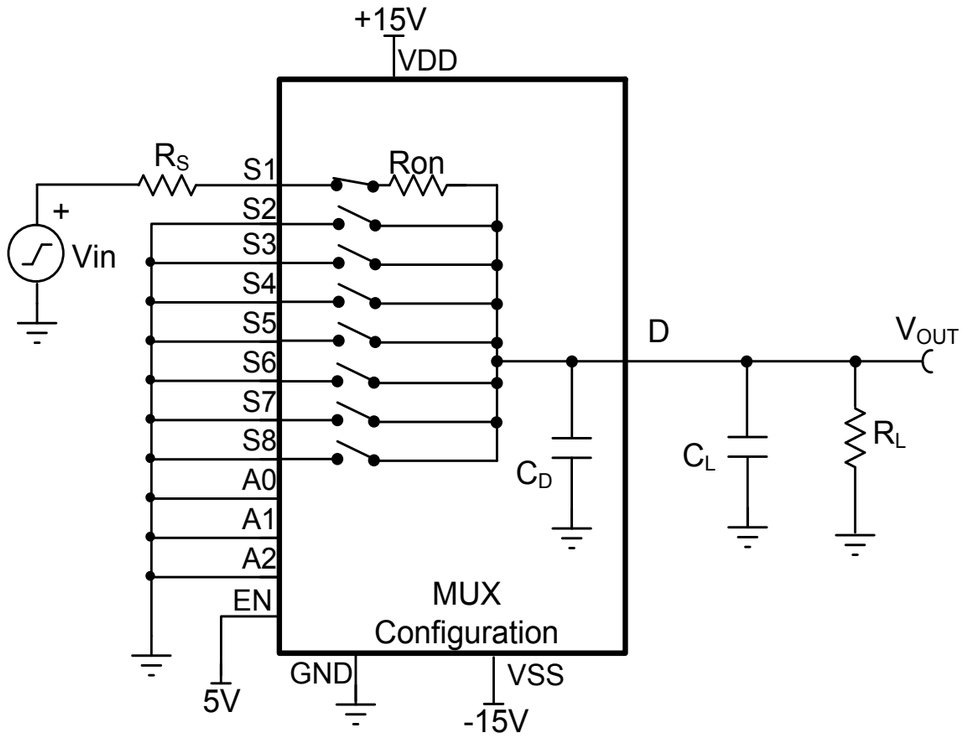
  2) Channel to Channel Crosstalk
  - Understanding Channel to Channel Crosstalk
  - Factors affecting Crosstalk

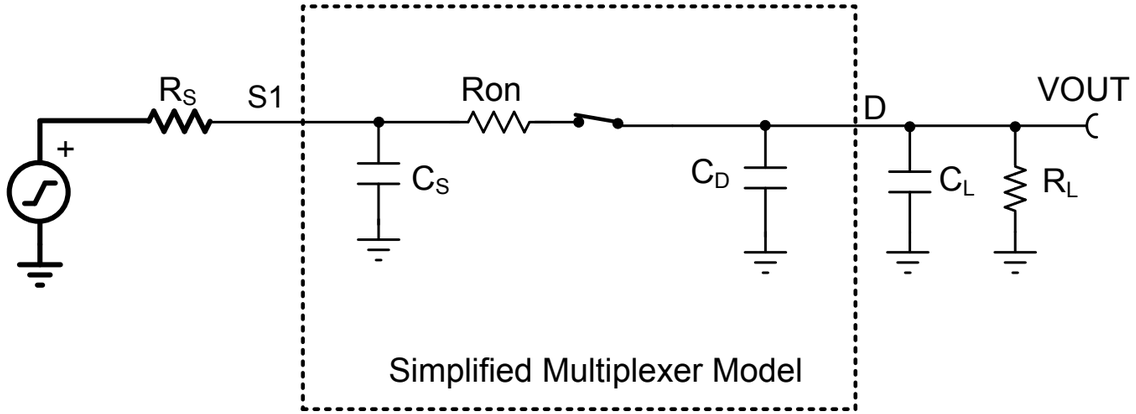
  3) OFF Isolation
  - Understanding OFF Isolation of MUX
  - Factors affecting OFF Isolation

  4) THD+Noise
  - Understanding THD+Noise parameter

- Goals:
  - 1. To understand performance parameters of multiplexers
  - 2. Understand their importance while designing data acquisition system

Bandwidth





Bandwidth : The frequency at which the output is attenuated by 3 dB from the pass band (dc) response.

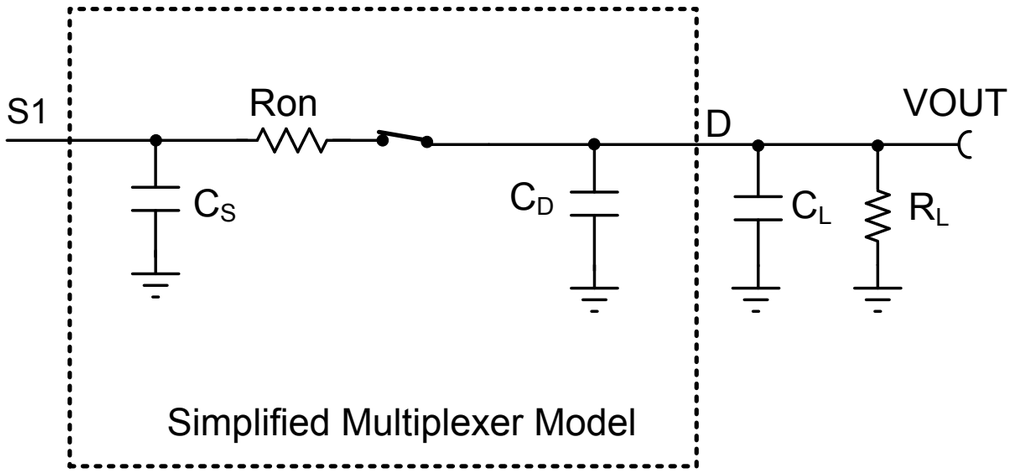
Transfer function

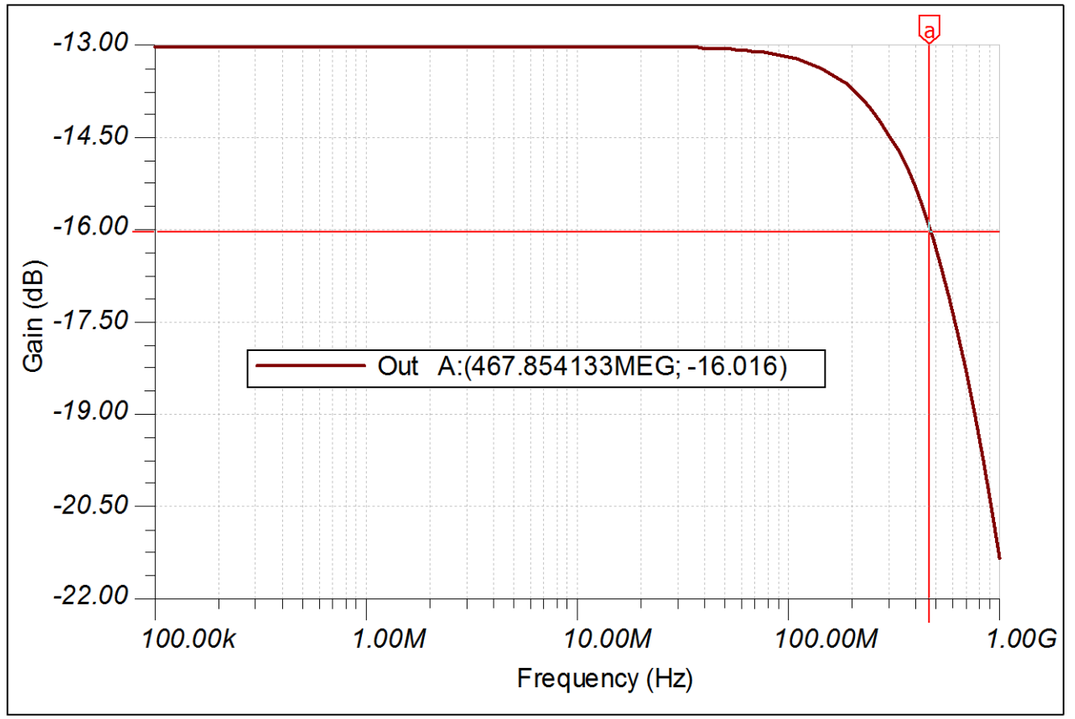
$$\frac{V_{OUT}}{V_{in}} = \left(\frac{R_L}{R_L + R_{on}}\right)\left(\frac{1}{\left(\frac{f}{f_c}\right) + 1}\right)$$

3 dB Cut OFF Frequency:

$$f_c = \frac{(R_L + R_{on})}{2 \cdot \pi \cdot (R_L \cdot R_{on}) \cdot (C_D + C_L)}$$

Bandwidth





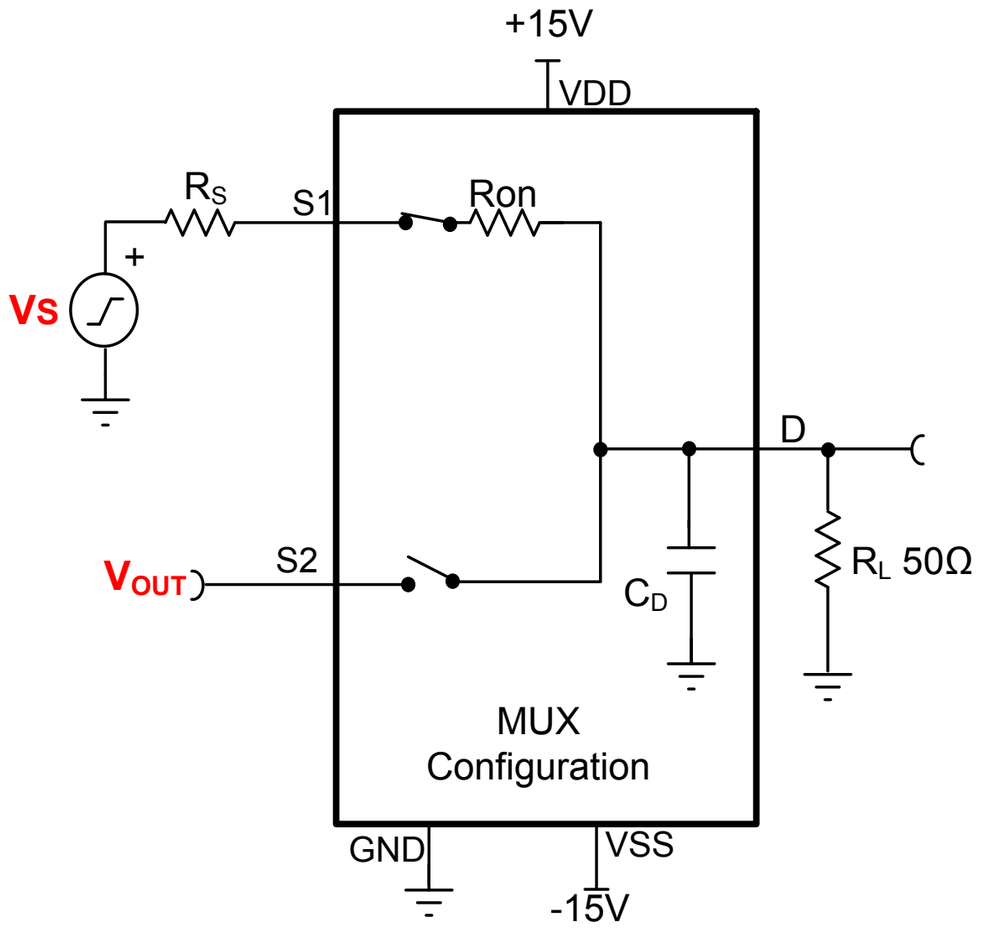
3 dB Cut OFF Frequency:

$$f_c = \frac{(R_L + R_{on})}{2 \cdot \pi \cdot (R_L \cdot R_{on}) \cdot (C_D + C_L)}$$

R_L >> R_{ON} Cutoff Frequency

$$f_c = \frac{1}{2 \cdot \pi \cdot (R_{on}) \cdot (C_D + C_L)}$$

Channel to Channel Crosstalk



Crosstalk: voltage feed through to the source pin of an off-channel from a known signal is applied to the source pin of an on-channel

Channel to Channel Crosstalk (dB)

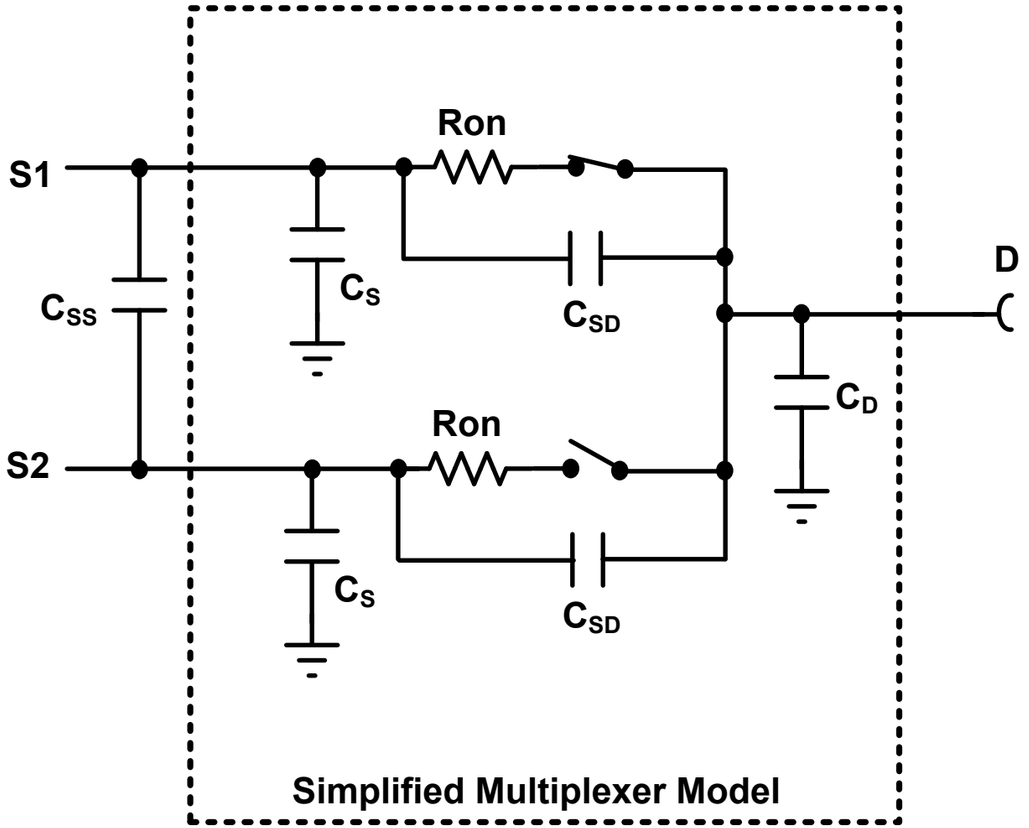
$$= 20 * \log\left(\frac{V_{OUT}}{V_S}\right)$$

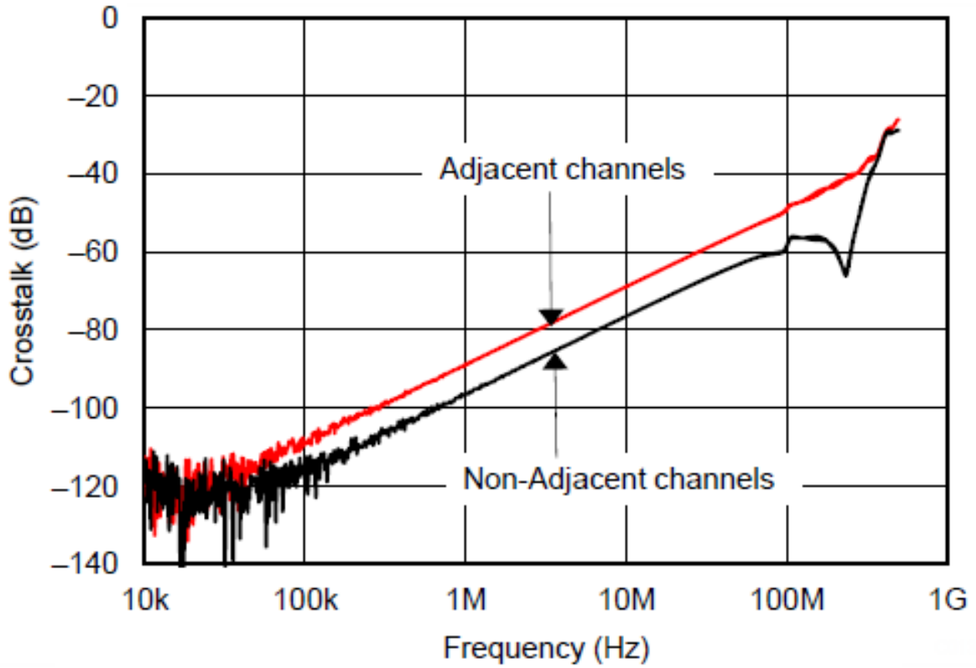
Where

Vs : Voltage applied to source pin of on channel

V_{OUT}: Voltage measured at source pin of off channel

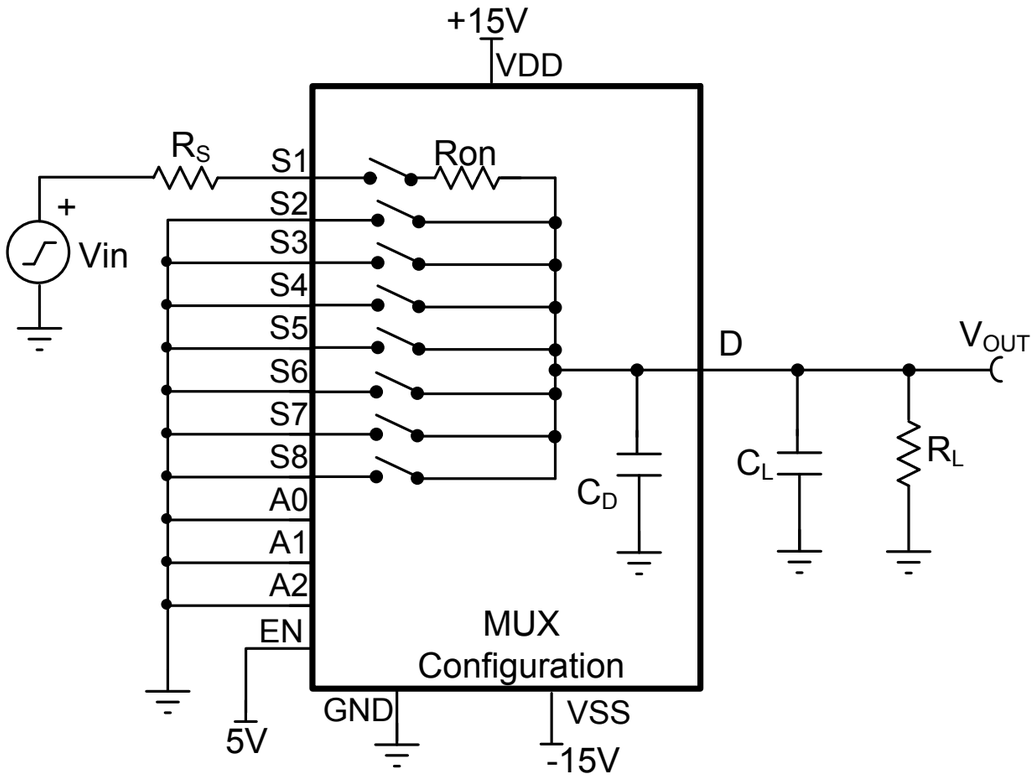
Channel to Channel Crosstalk





MUX36S08 Channel to Channel Crosstalk vs. Frequency

OFF Isolation



OFF Isolation: voltage at output pin of an multiplexer when a known signal is applied at the source pin of an OFF-channel

OFF Isolation (dB)

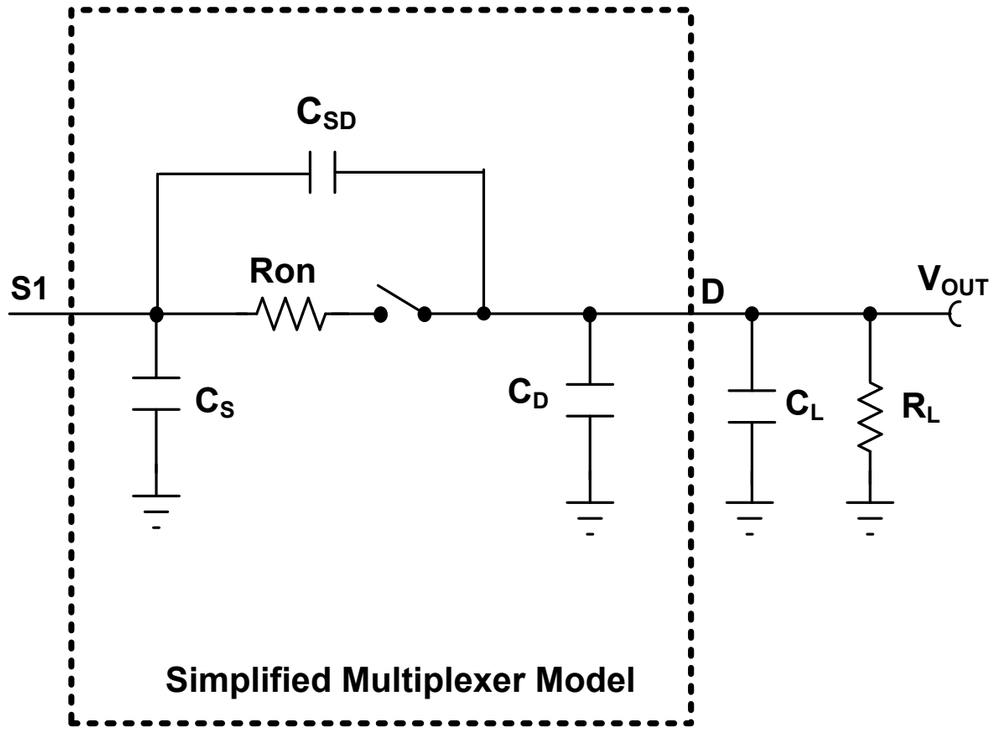
$$= 20 * log\left(\frac{V_{OUT}}{V_{in}}\right)$$

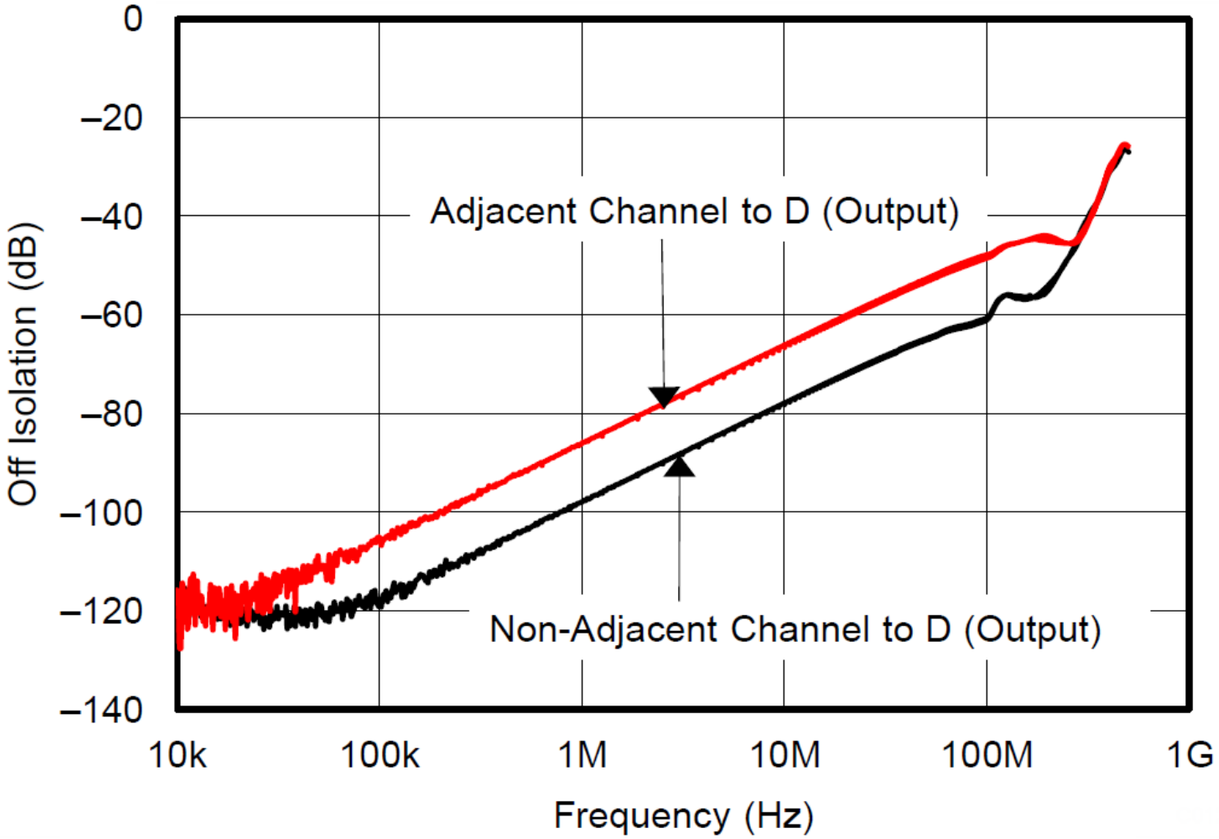
Where

Vin : Voltage applied at source pin of off channel

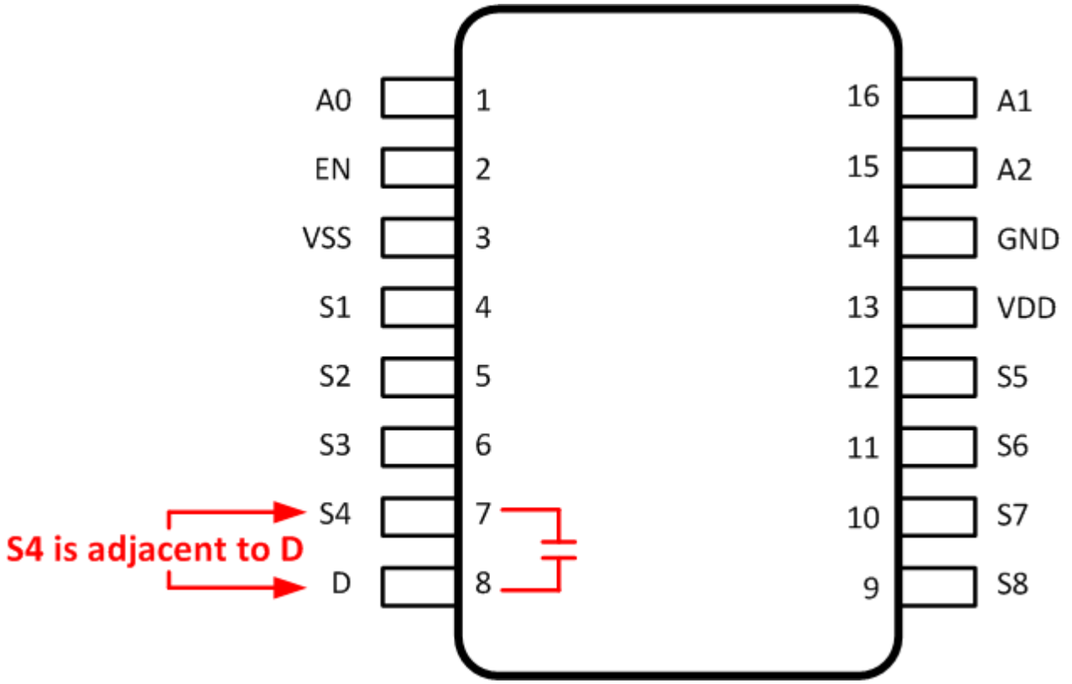
V_{OUT}: Voltage measured at source pin of off channel

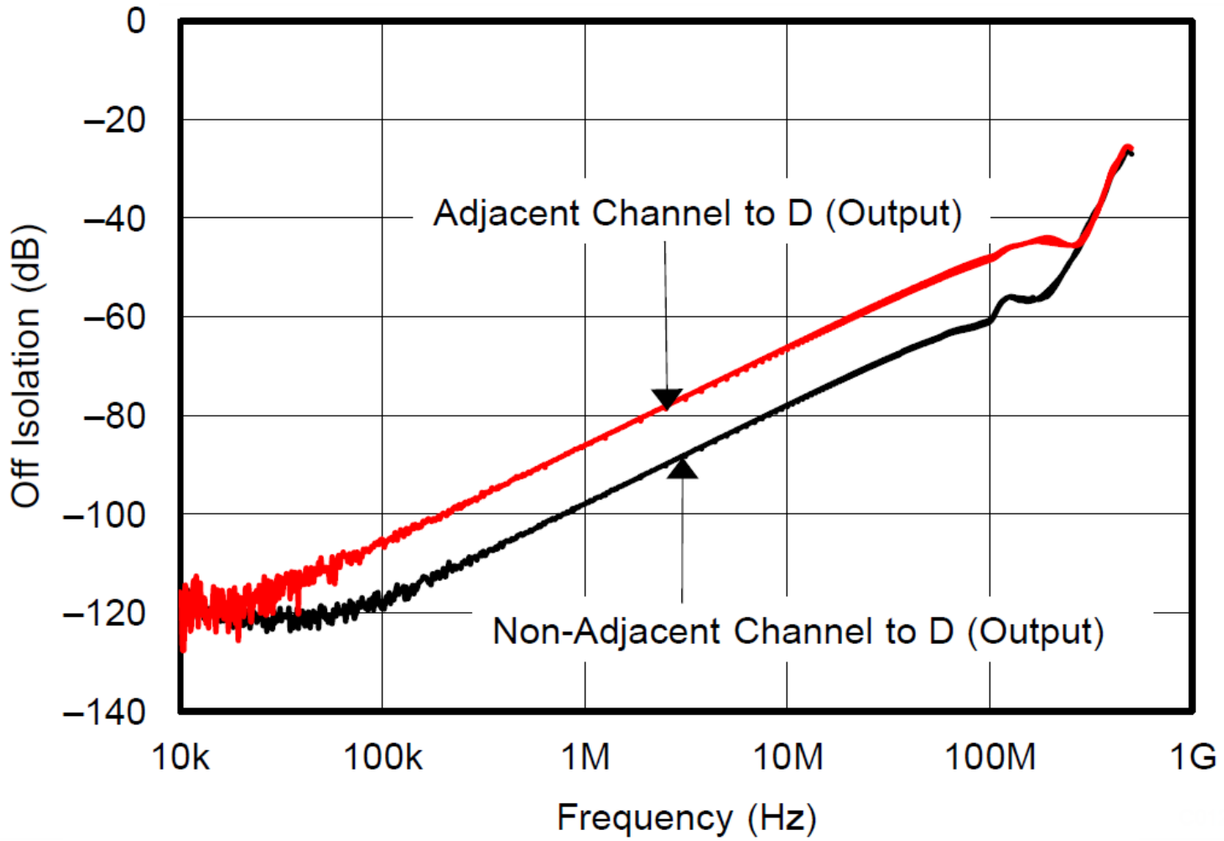
OFF Isolation



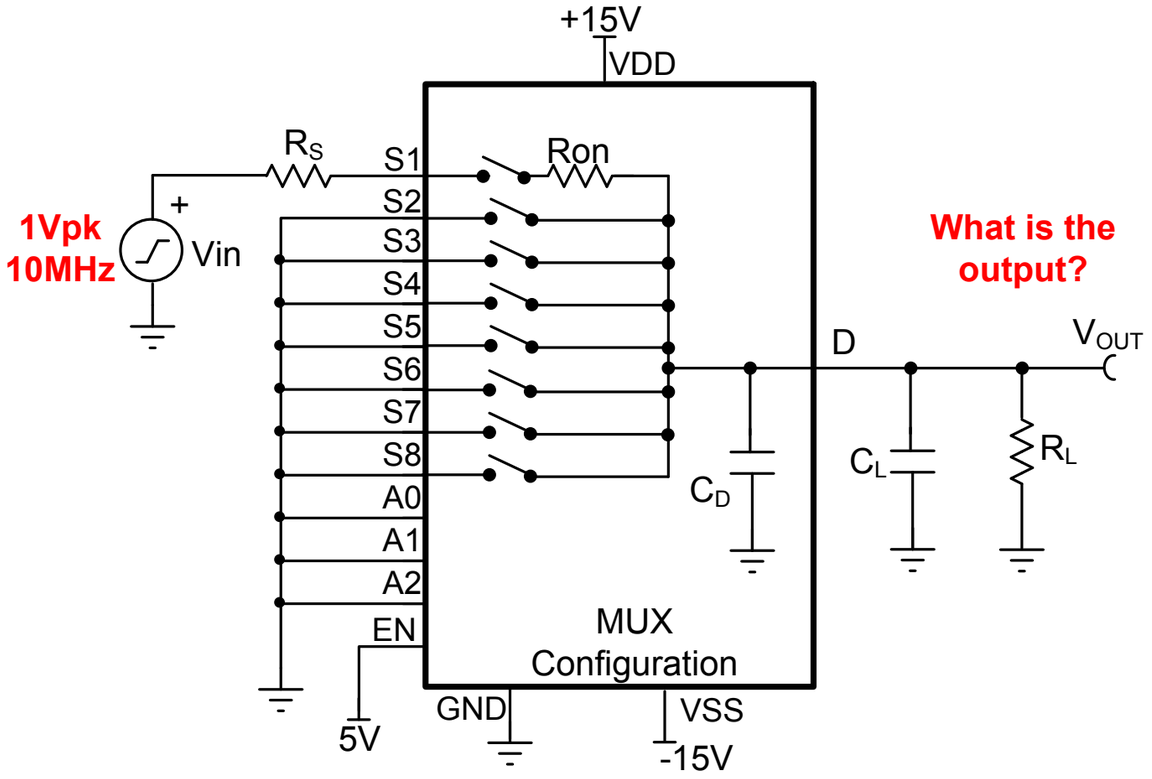


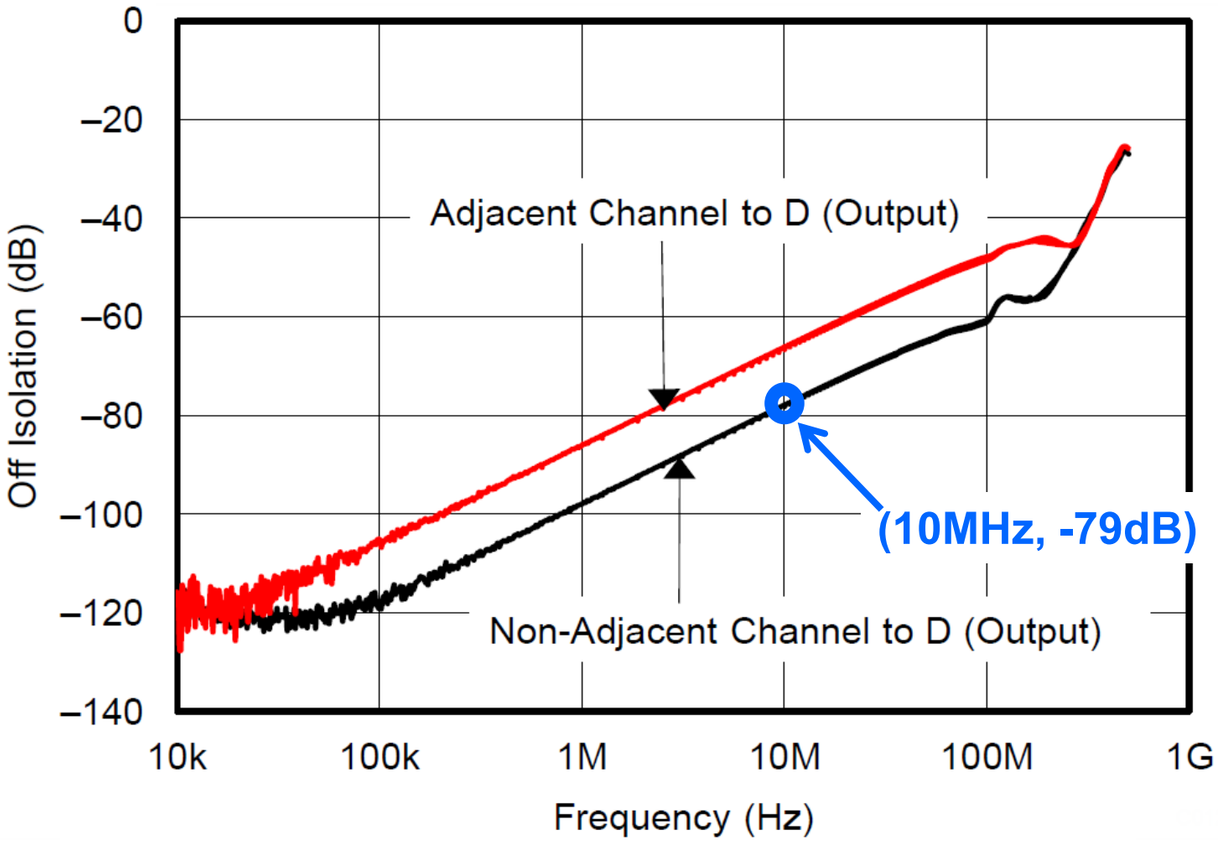
Off Isolation: Adjacent Channels





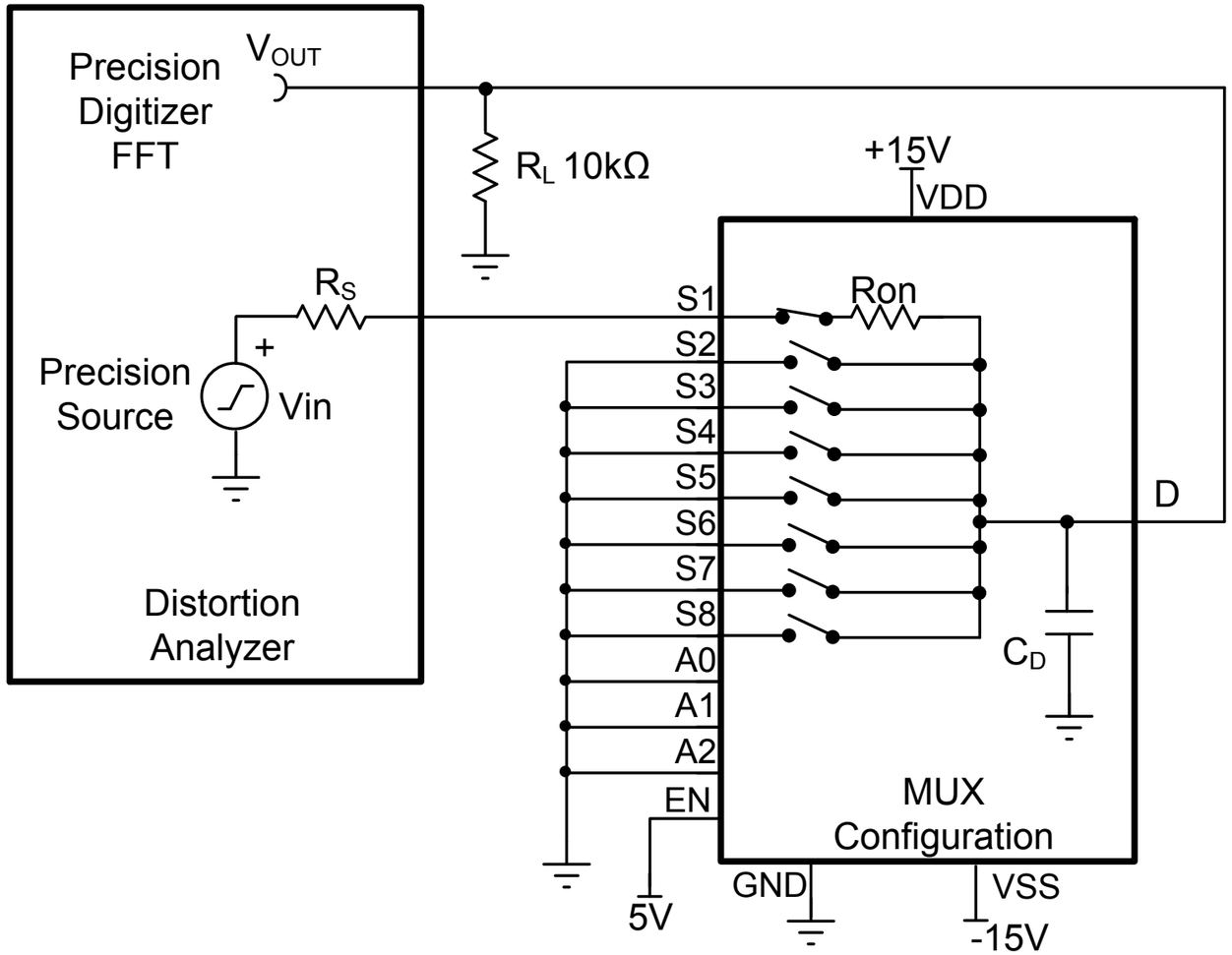
Off Isolation: Example Calculation

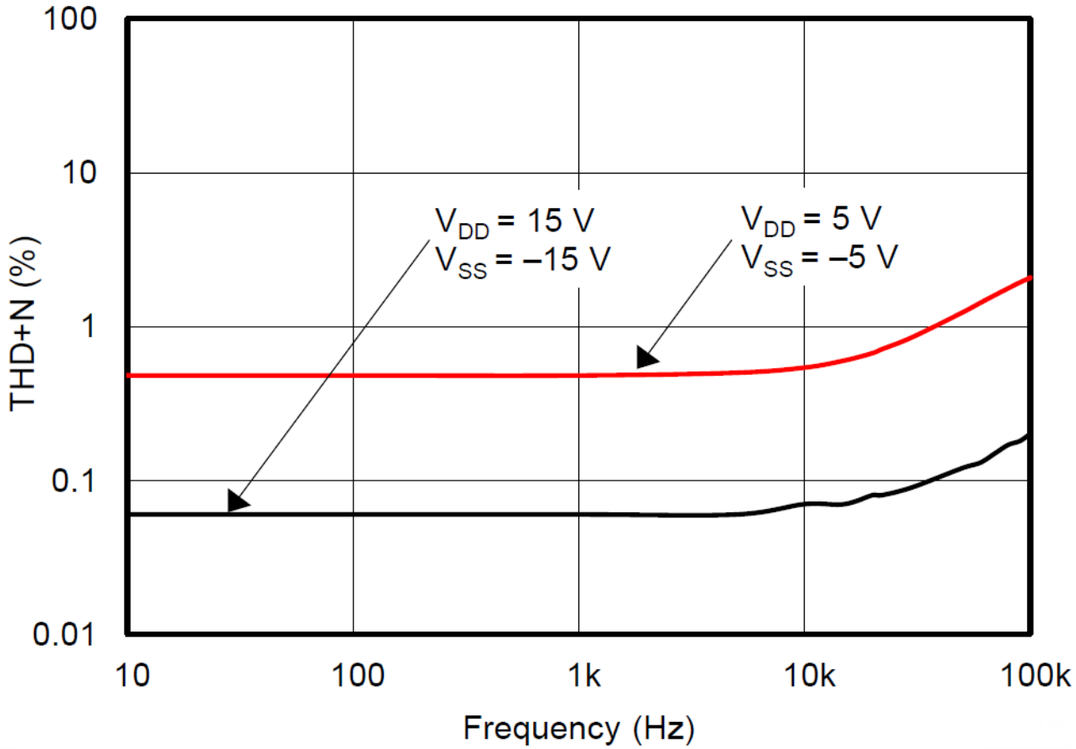




$$V_{OUT} = 1Vpk \cdot 10^{\left(-\frac{79dB}{20}\right)} = 112\mu Vpk$$

Total Harmonic Distortion + Noise: THD+N

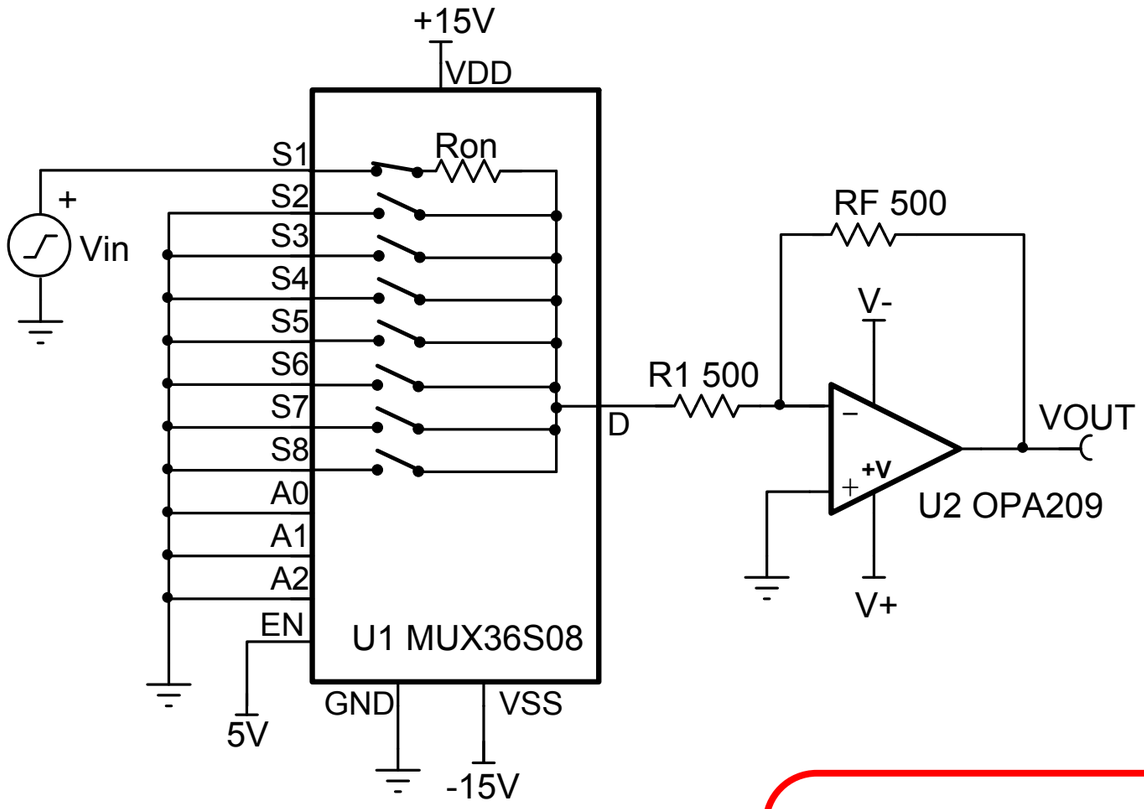


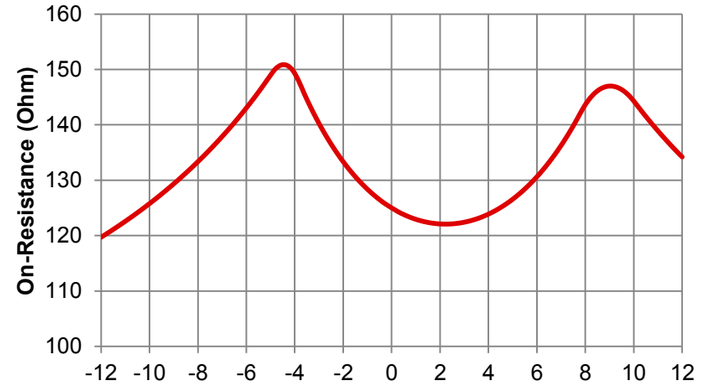


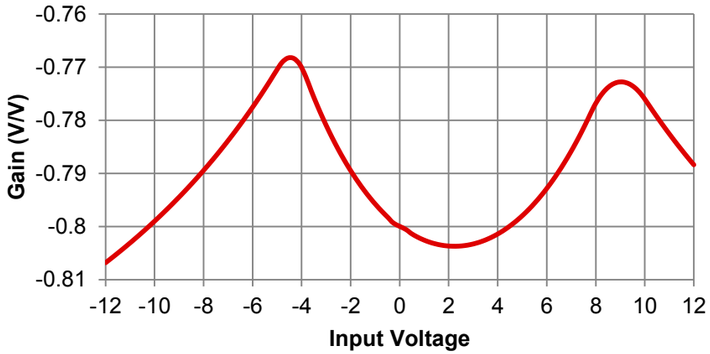
Total Harmonic Distortion + Noise

$$(THD+N)(\%) = 100\left(\sqrt{\frac{\sum_{i=2}^{\infty}\left(V_i^2\right)+V_n^2}{V_f^2}}\right)$$

THD+Noise

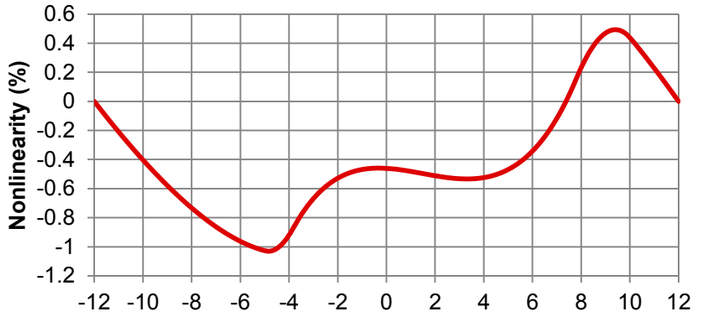






Effective Gain with MUX R_{ON} is:

$$AG = -RF/(R1 + R_{ON})$$



Thanks for your time!
Please try the quiz.

Basics of Analog Multiplexer – 3

Multiple choice quiz
TI Precision Labs – Op Amps

Quiz: Basics of Analog Multiplexer – 3

1. Bandwidth of a multiplexer is defined as
   a. the range of frequencies that are attenuated by > 3 dB when the input is applied to the source pin of an on-channel and the output measured at the drain pin
   b. the range of frequencies that are attenuated by < 3 dB when the input is applied to the source pin of an on-channel and the output measured at the drain pin
   c. the range of frequencies that are attenuated by < 10 dB when the input is applied to the source pin of an on-channel and the output measured at the drain pin
   d. None of the above

2. Multiplexer bandwidth depends on
   a. the on resistance of the multiplexer
   b. the load capacitance at the output of the multiplexer
   c. the multiplexer power supply
   d. Both a and b

Quiz: Basics of Analog Multiplexer – 3

3. Channel to Channel crosstalk is measured in
   a. Decibels (dB)
   b. Hertz (Hz)
   c. Micro-Volts (µV)
   d. None of the above

4. Channel to Channel crosstalk of a multiplexer depends on
   a. the parasitic capacitance of the multiplexer
   b. the board stray capacitance between adjacent multiplexer channels
   c. the on resistance of the multiplexer
   d. all of the above

Quiz: Basics of Analog Multiplexer – 3

5. Off Isolation of a multiplexer
   a. is a frequency-dependent phenomenon
   b. caused mainly by the off parasitic capacitance of the multiplexer
   c. improves with higher load capacitance at the output of multiplexer
   d. all of the above

6. THD+Noise performance of a multiplexer
   a. is a measure of signal distortion at the output of the multiplexer
   b. improves with lower on resistance of the multiplexer
   c. both a and b
   d. none of the above

Solution: Basics of Analog Multiplexer – 3

1. Bandwidth of a multiplexer is defined as
   a. the range of frequencies that are attenuated by > 3 dB when the input is applied to the source pin of an on-channel and the output measured at the drain pin
   b. the range of frequencies that are attenuated by < 3 dB when the input is applied to the source pin of an on-channel and the output measured at the drain pin
   c. the range of frequencies that are attenuated by < 10 dB when the input is applied to the source pin of an on-channel and the output measured at the drain pin
   d. None of the above

2. Multiplexer bandwidth depends on
   a. the on resistance of the multiplexer
   b. the load capacitance at the output of the multiplexer
   c. the multiplexer power supply
   d. Both a and b

Solution: Basics of Analog Multiplexer – 3

3. Channel to Channel crosstalk is measured in
   a. Decibels (dB)
   b. Hertz (Hz)
   c. Micro-Volts (μV)
   d. None of the above

4. Channel to Channel crosstalk of a multiplexer depends on
   a. the parasitic capacitance of the multiplexer
   b. the board stray capacitance between adjacent multiplexer channels
   c. the on resistance of the multiplexer
   d. all of the above

Solution: Basics of Analog Multiplexer – 3

5. Off Isolation of a multiplexer
   a. is a frequency-dependent phenomenon
   b. caused mainly by the off parasitic capacitance of the multiplexer
   c. improves with higher load capacitance at the output of multiplexer
   d. all of the above

6. THD+Noise performance of a multiplexer
   a. is a measure of signal distortion at the output of the multiplexer
   b. improves with lower on resistance of the multiplexer
   c. both a and b
   d. none of the above

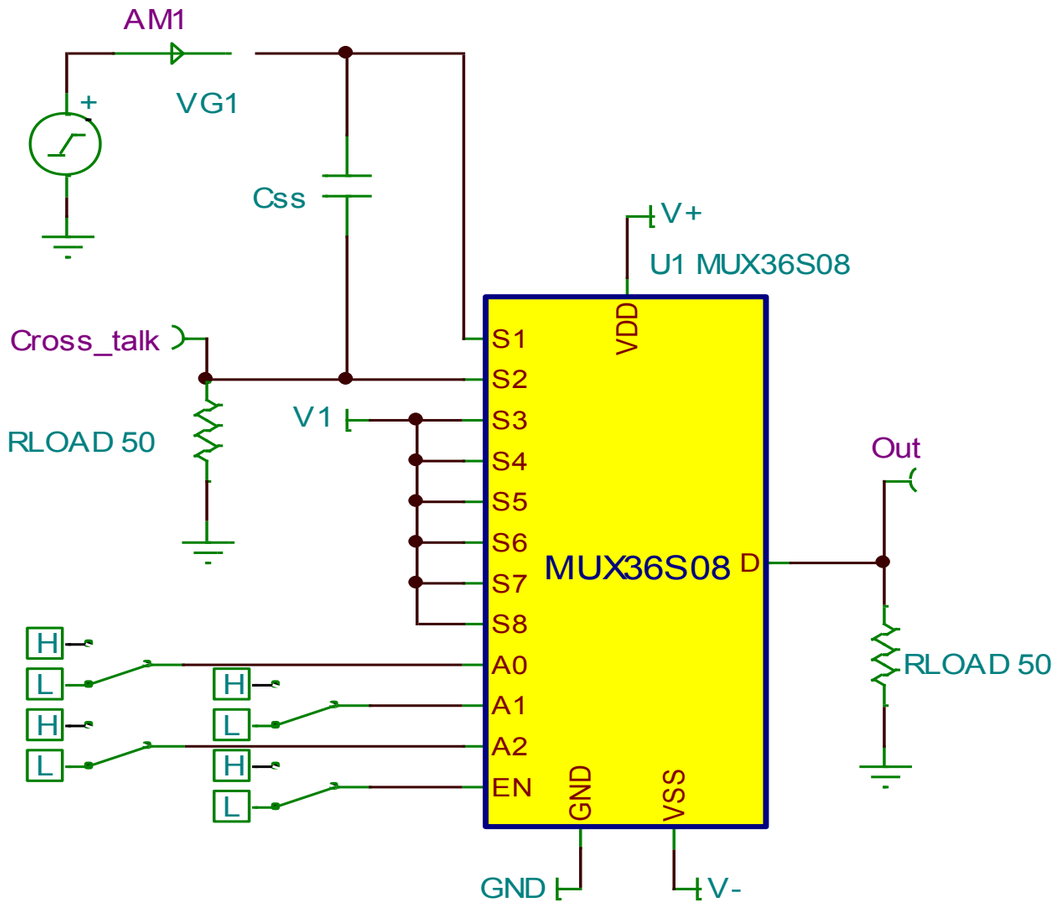
Basics of Analog Multiplexer – 3

Exercises

TI Precision Labs – Op Amps

1. **A data acquisition system is required to capture a sensor signal whose frequency varies from DC to 5MHz. The multiplexer used in this data acquisition system has an on resistance of 100Ω and a total output capacitance of 100pF. Is this multiplexer suitable for this application? (Neglect the effect of load resistance for this calculation.)**

2. **A multiplexer used in a particular application has a channel to channel crosstalk of -89dB at 1MHz. Due to poor board layout techniques, there is parasitic stray capacitance of 1pF between adjacent channels (C_{SS}) as shown below. Simulate and see how this affects the multiplexer crosstalk performance.**



Basics of Analog Multiplexer – 3

Solution

TI Precision Labs – Op Amps

1. **A data acquisition system is required to capture a sensor signal whose frequency varies from DC to 5MHz. The multiplexer used in this data acquisition system has an on resistance of 100Ω and a total output capacitance of 100pF. Is this multiplexer suitable for this application? (Neglect the effect of load resistance for this calculation.)**

Multiplexer bandwidth calculation

3 dB cutoff frequency is given by

$$fc = \frac{(R_L + R_{ON})}{2 * \pi * (R_L * R_{ON}) * (C_D + C_L)}$$

As $R_L >> R_{ON}$, the equation for 3 dB cutoff frequency

$$fc = \frac{1}{2 * \pi * (R_{ON}) * (C_D + C_L)}$$

Where R_{ON}=100 Ohms, $(C_D + C_L) = 100pF$. substituting these values in above equation

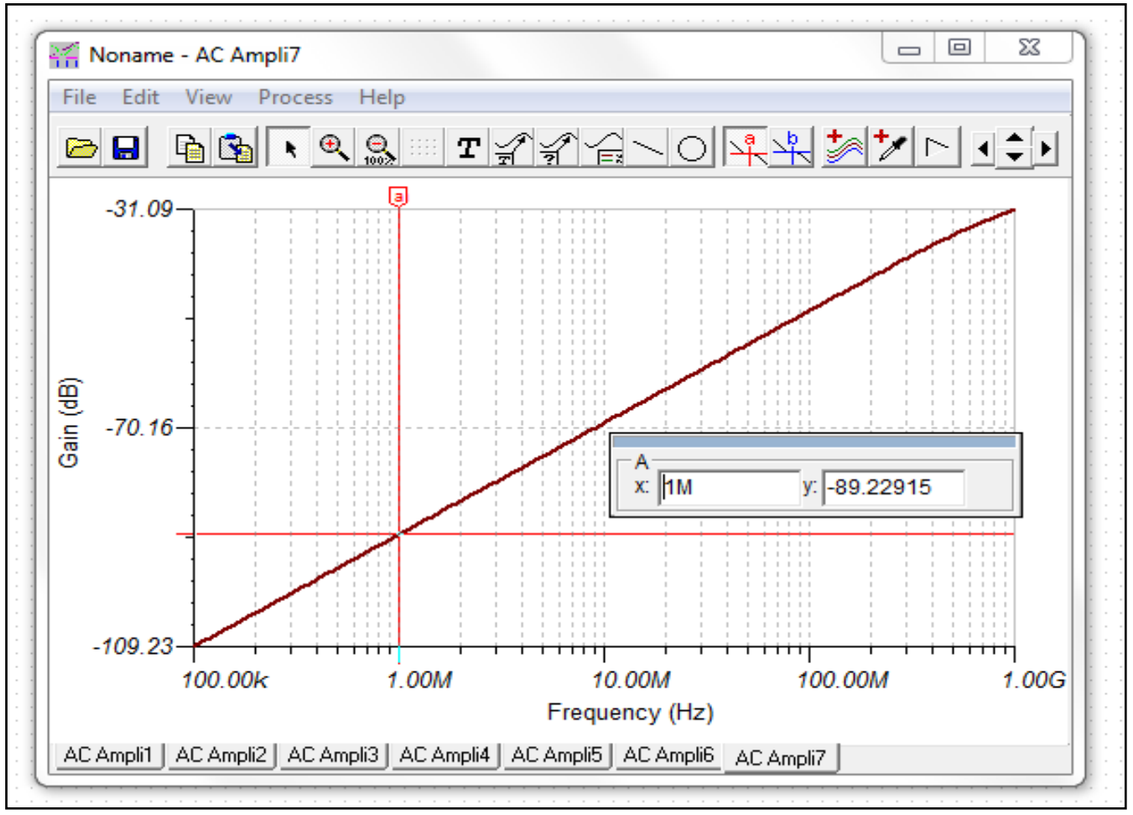
$$fc = \frac{1}{2 * \pi * (100) * (100pF)}$$

$$fc = 15.92MHz$$

Since the multiplexer 3 dB cutoff frequency is well above input signal frequency requirement, this multiplexer is suitable for this application.

2. **A multiplexer used in a particular application has a channel to channel crosstalk of -89dB at 1MHz. Due to poor board layout techniques, there is parasitic stray capacitance of 1pF between adjacent channels (C_{SS}) as shown below. Simulate and see how this affects the multiplexer crosstalk performance.**

1. Open the TINA simulation file.
2. To see actual crosstalk performance of the MUX36S08, delete C_{SS} from the schematic and simulate the TINA file for AC transfer characteristics.
3. You will get crosstalk performance results as shown here.



2. **A multiplexer used in a particular application has a channel to channel crosstalk of -89dB at 1MHz. Due to poor board layout techniques, there is parasitic stray capacitance of 1pF between adjacent channels (C_{SS}) as shown below. Simulate and see how this affects the multiplexer crosstalk performance. (continued)**

1. **Open the TINA simulation file.**

2. **To see effect of stray capacitance on crosstalk performance of MUX36S08, introduce a C_{SS} of 1pF between channel 1 (S1) and channel 2 (S2) and simulate the TINA file for AC transfer characteristics.**

3. **You will get crosstalk performance results as shown here.**

4. **You can see that the device performance degrades from -89dB to -69dB due to the introduction of stray capacitance.**