Basics of Analog Multiplexers 2

TIPL 2602
TI Precision Labs – Op Amps

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Analog Multiplexer Parameters Summary

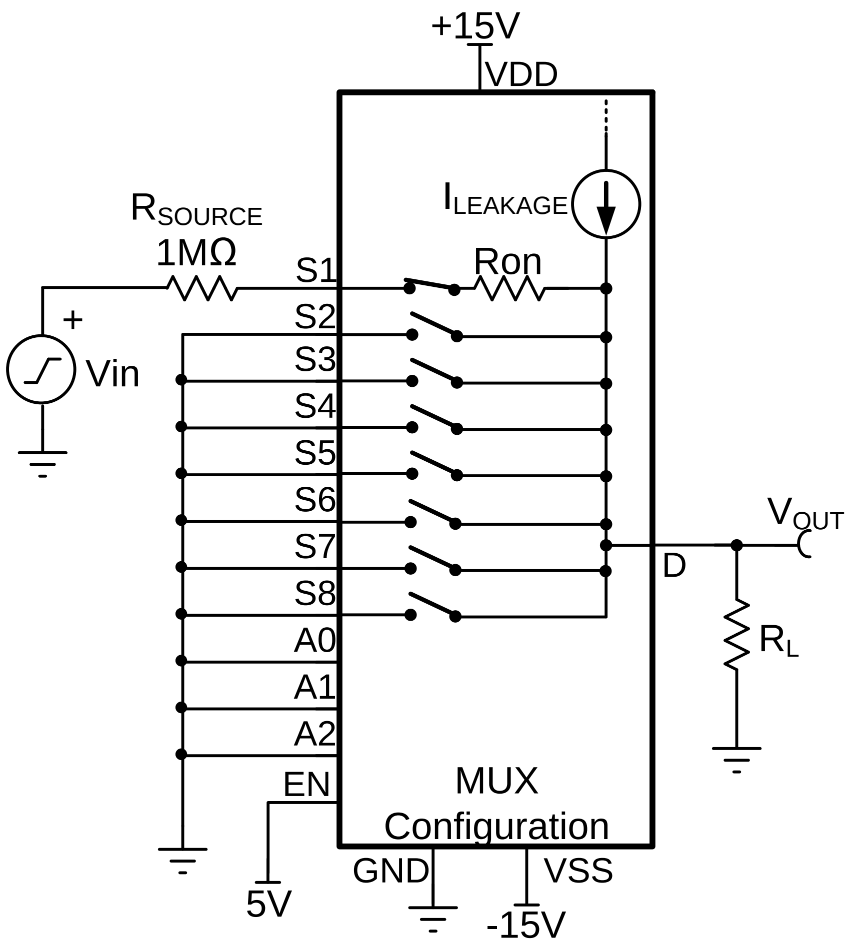
- Part 1: Understanding Performance parameters of Multiplexer

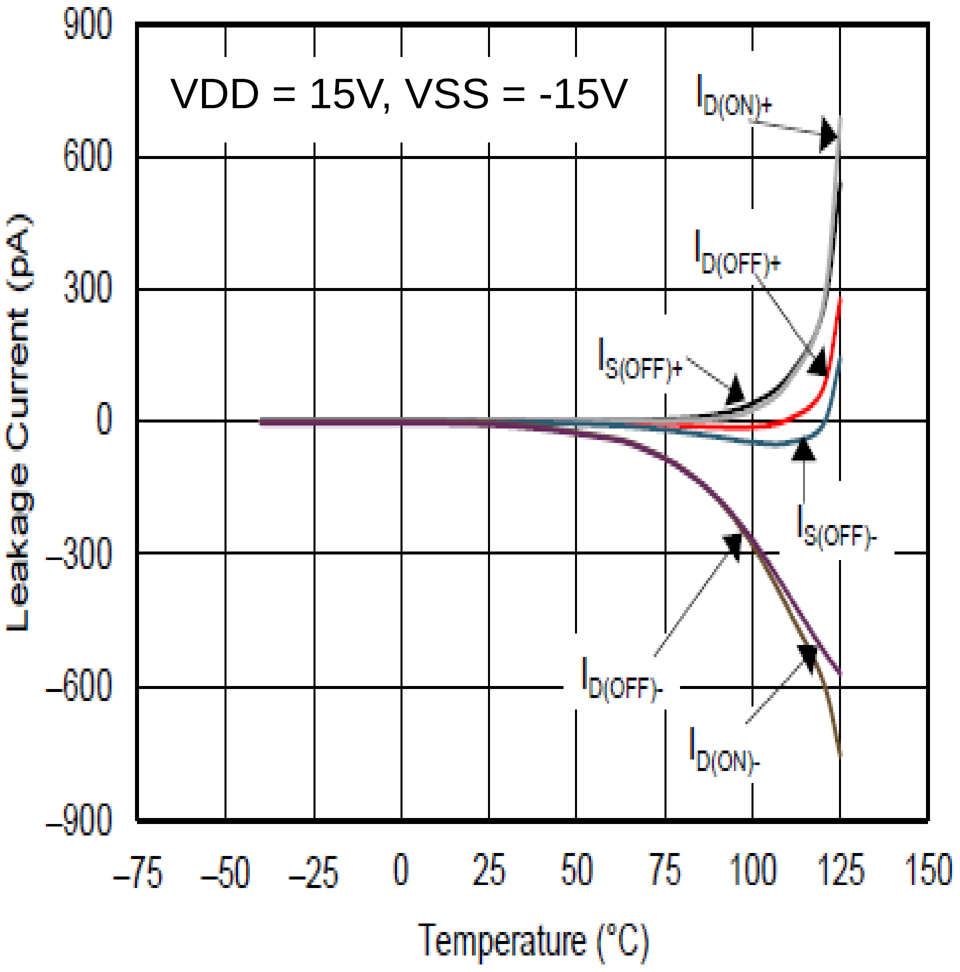
  1) Leakage Current
  - Types of Leakage Current
  - Offset issues Related to Leakage Current

  2) Charge Injection
  - Understanding Charge Injection Phenomenon
  - Effect of Charge Injection on Multiplexer Output Voltage Error

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

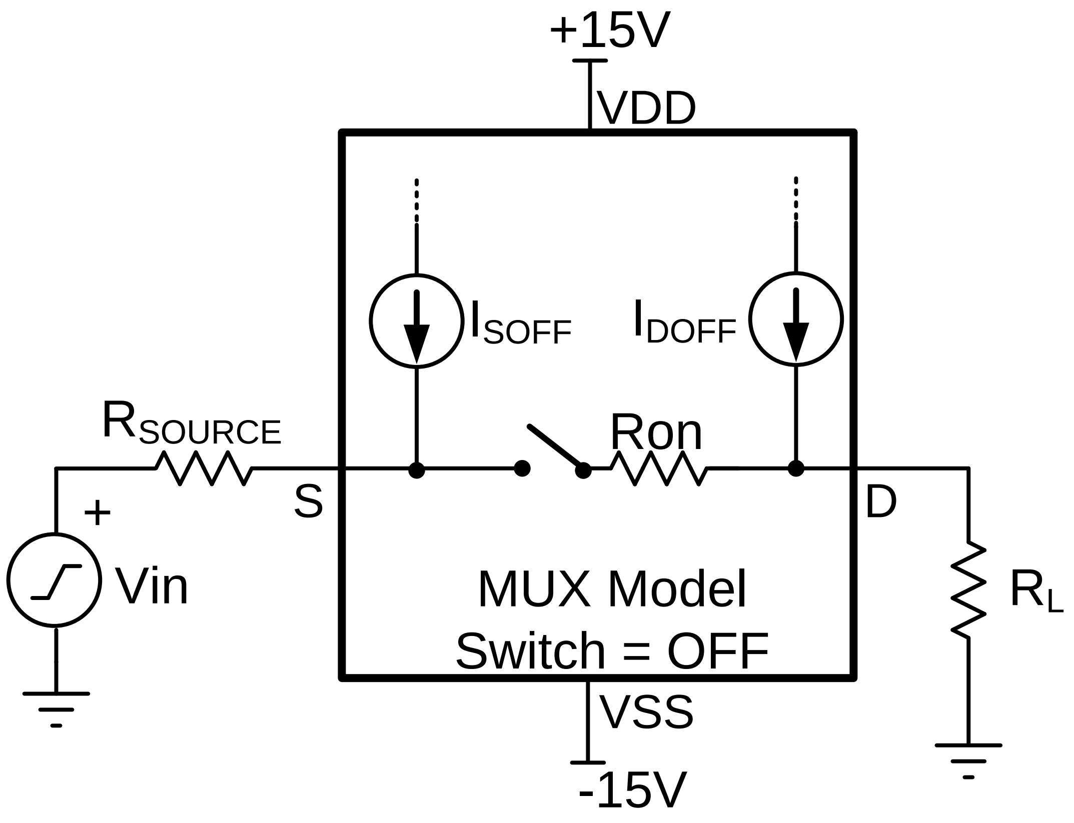
Leakage Current

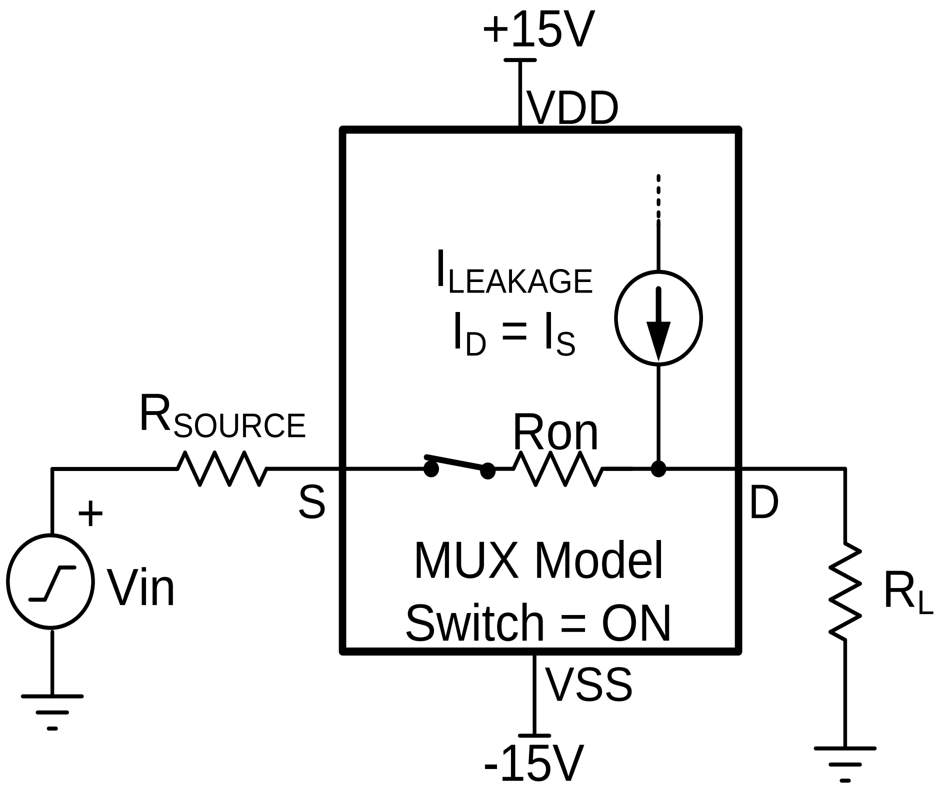




- **Leakage Current**: Current flowing out Source (S) and Drain (D) pins when MUX switch is ON or OFF
- **Switch = OFF**: Leakage current flows out Source pin and Drain pin, $I_{S(OFF)}$ and $I_{D(OFF)}$
- **Switch = ON:** Approximate leakage current out Source and Drain pin is $I_{S(ON)} = I_{D(ON)}$

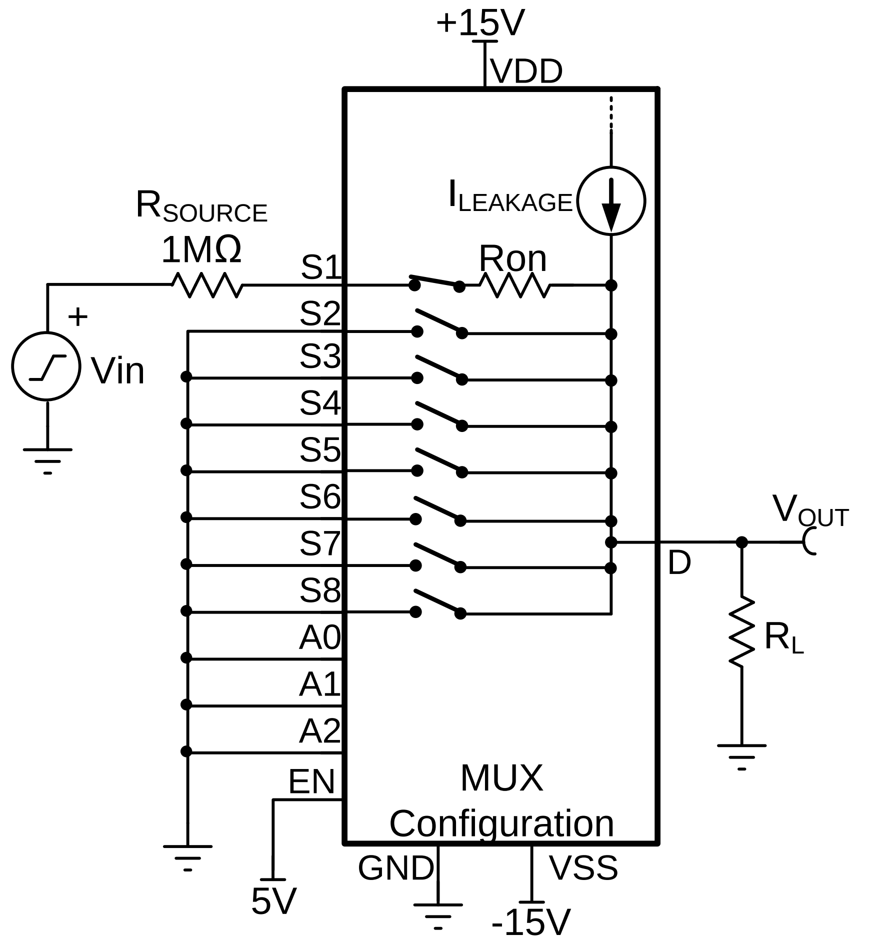
Leakage Current





- **Switch = OFF:** $I_{S(OFF)}$ flows through R_{SOURCE} and $I_{D(OFF)}$ flows through R_L
- **Switch = ON:** Error introduced by leakage current: $V_{ERROR} = (R_{ON} + R_{SOURCE}) \times I_{D(ON)}$

Offset Error Introduced by Leakage Current



18-bit System Example Calculation

$$V_{ref} = 5V$$

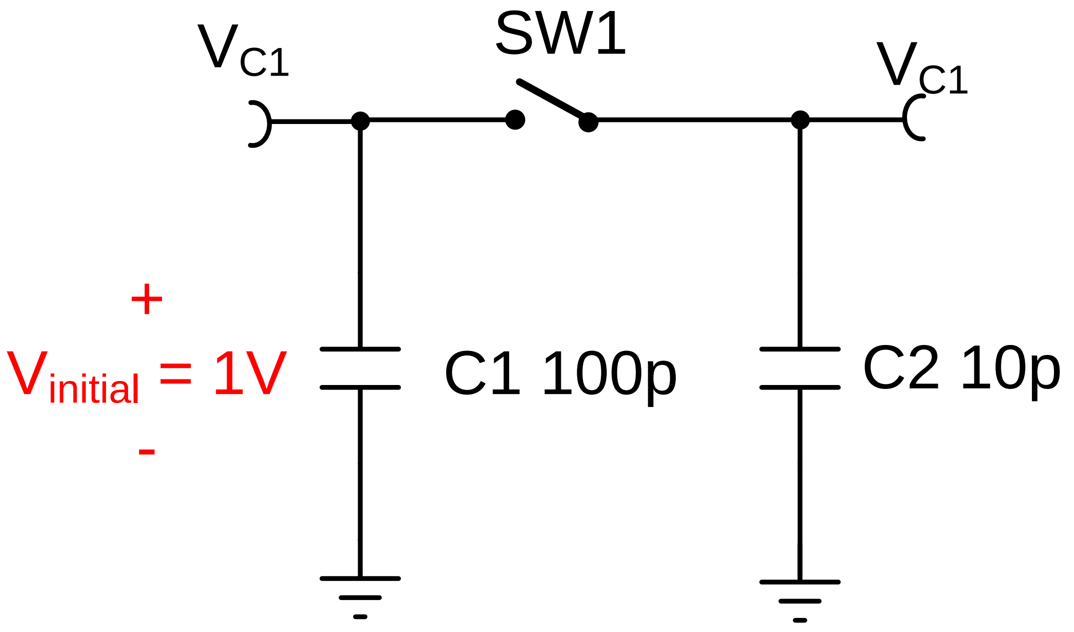
$$V_{LSB} = \frac{5V}{2^{18}} = 19.073\mu V$$

$$OffsetError(V) = I_{LEAKAGE} \cdot R_{SOURCE} = (100pA)(1M\Omega) = 100\mu V$$

$$OffsetError(Bits) = \frac{OffsetError(V)}{V_{LSB}} = \frac{100\mu V}{19.073\mu V} = 5.24\ codes$$

Multiplexer Examples	Multiplexer leakage current (25°C/85°C)	Offset error (25°C/85°C) ($I_{LEAKAGE}$ x R_{Source})	Offset Error 18 bit System (in bits)
MUX1 (Low Leakage)	10pA/50pA	10µV/50µV	0.52 / 2.62
MUX2 (High Leakage)	100pA/500pA	100µV/500µV	5.24 / 26.22

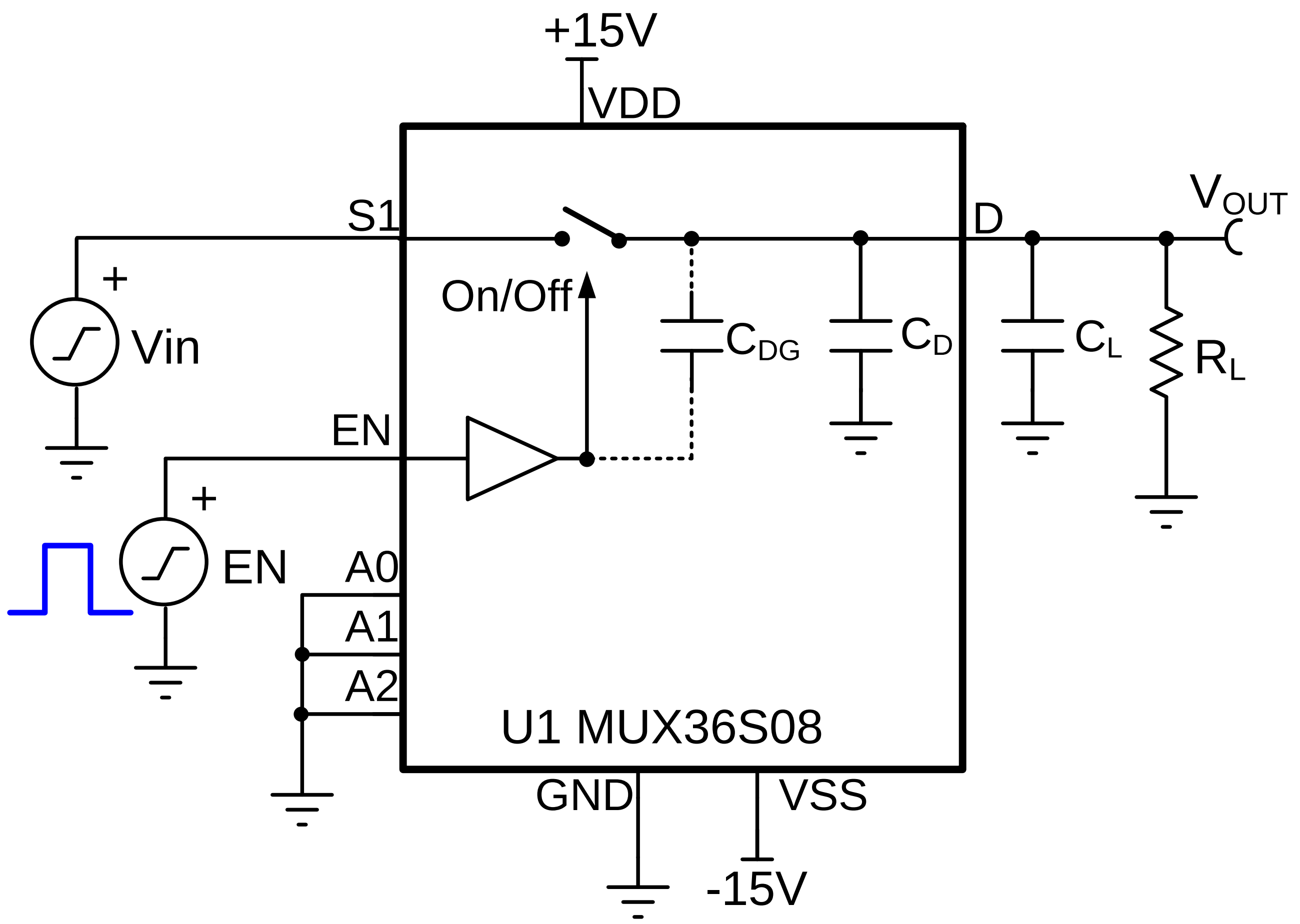
Review: Charge Equation

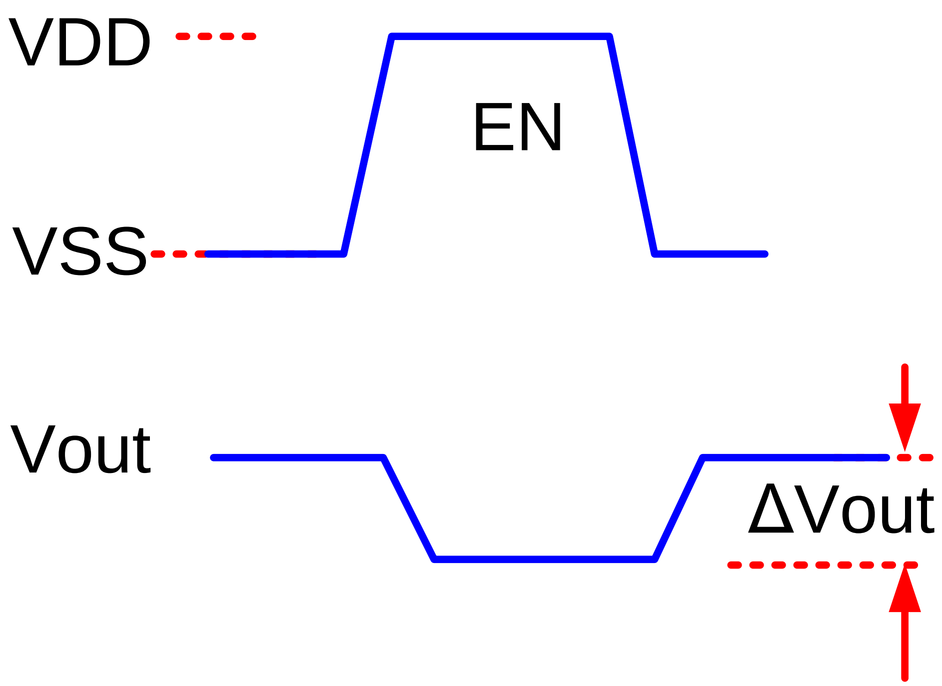


Charge Equation Example

Definition Q = Charge in Coulombs C = Capacitance in Farads V = Voltage in Volts	$\mathrm{Q} = \mathrm{C} \cdot \mathrm{V}$
Charge of C1, Assuming initial 1V	$\mathrm{Q} = C_1 \cdot \mathrm{V}_1 = (100pF) \cdot (1V) = 100pC$
Close switch	$\mathrm{C}_{\mathrm{total}} = C_1 + C_2 = 110pF$
New Voltage after charge redistribution	$\mathrm{V}_{\mathrm{final}} = \frac{Q}{C_{total}} = \frac{100pC}{110pF} = 0.909V$

Charge Injection (Q_{INJ})

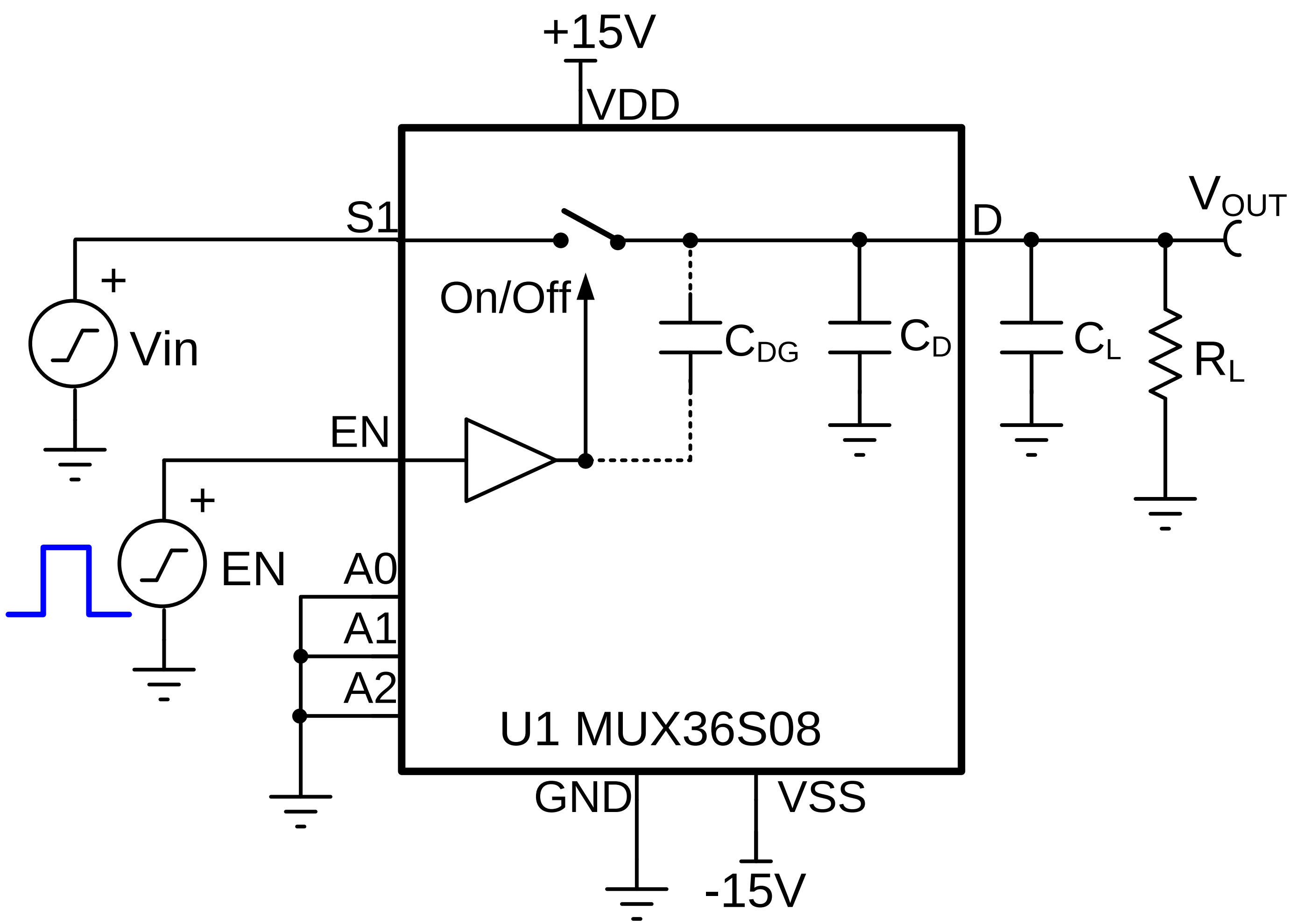


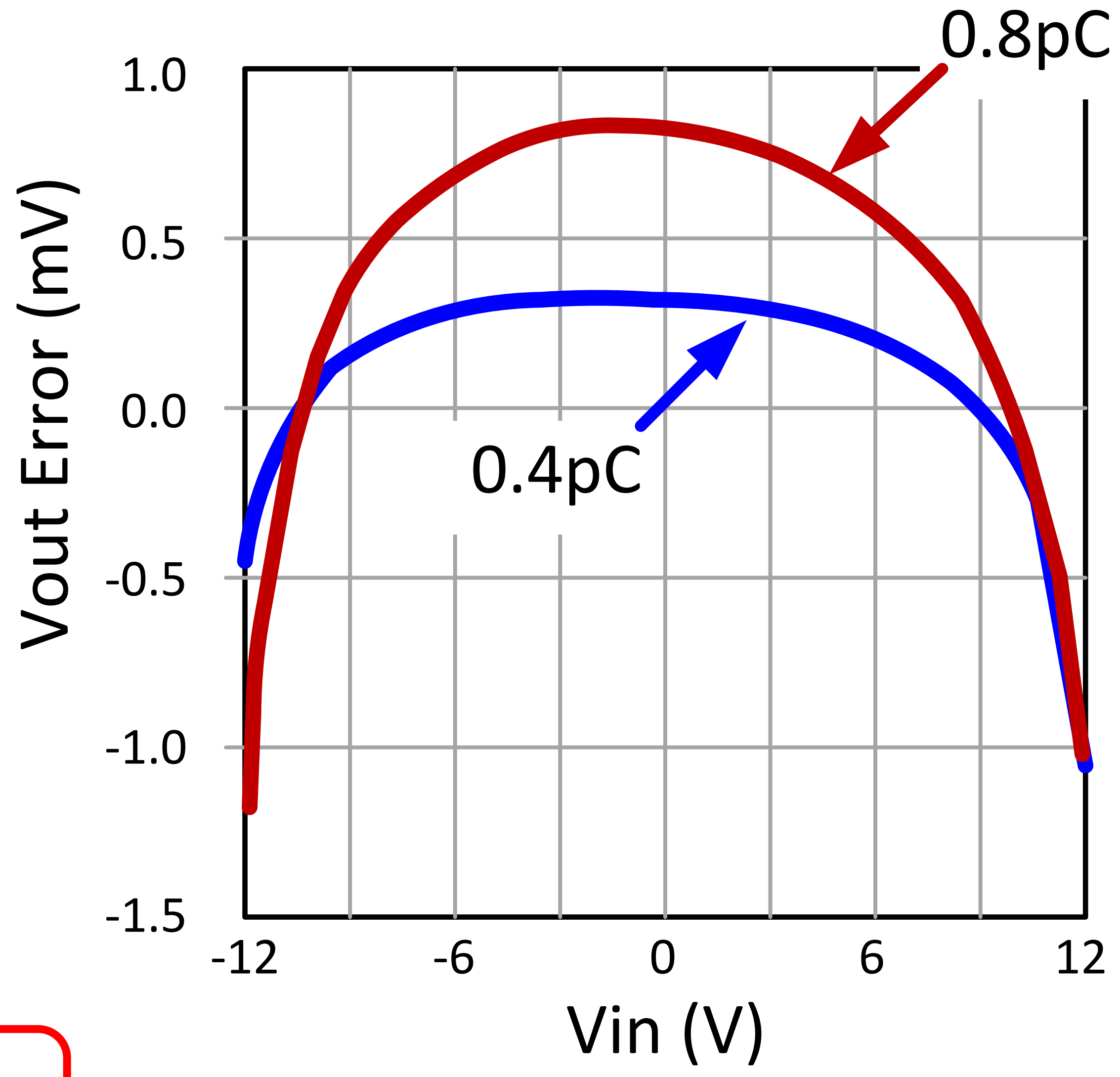


$$Q_{NJ} = (C_D + C_L) \cdot \Delta Vout$$

- **Charge injection Error**: Voltage change introduced at the output of switch when switch is turned ON or OFF
- Larger load capacitance minimizes the effect of charge Injection at the multiplexer output

Charge Injection Error vs. Input Voltage





Error = Q_{INJ} / C_L

Summary: MUX Leakage Current and Charge Injection

Leakage Current

- Introduces DC offset Error
- Varies with temperature and can introduces linearity errors too
- Important parameter for high input impedance data acquisition systems

Charge Injection

- Introduces output voltage error when control logic is switched
- Typically worse on multiplexers with large Con.
- Smaller the load capacitor higher the error introduced due to charge injection
- Important parameter for fast switching systems

Thanks for your time!
Please try the quiz.