MOS Sample & Hold

Ideal Sampling

- Grab exact value of $V_{in}$ when switch opens

Practical Sampling

- $kT/C$ noise
- Limited bandwidth
- $R_{SW} = f(V_{in})$ → distortion
- Switch charge injection
- Clock jitter

Switch Resistance

- Finite switch $R$ → finite bandwidth

Acquisition Bandwidth

- Assuming constant $V_{in}$ and $C$ starts at 0V:

\[ V_{out} (t) = V_{in} (1 - e^{-t/\tau}) \]

- Leads to min. switch size for given bandwidth, resolution
  - Linear settling calc. – remember may only get $T/2$

- (Will $C$ always start at 0V?)

Switch $R_{on}$ Non-Linearity

Sampling Distortion

\[ V_{out} = V_{in} \left( 1 - e^{-t/(I_{SW}T_{SW})} \right) \]
**Constant V_{GS} Sampling**

- Switch overdrive voltage is independent of signal
- Error from finite $R_{ON}$ is linear (to first order)

**Constant V_{GS} Sampling Circuit**

**Complete Circuit**


**Charge Injection**

- “Extra” charge dumped onto holding capacitor
- Channel charge has to go somewhere
- (Also get injection through C\text{in})
- Problems:
  - Offset
  - Distortion (error charge is function of $V_{in}$)

**Worst-Case Error Example**

channel charge: $Q_{CH} = W_{C} (V_{in} - V_{CH})$

max pedestal error: $V_{CE} = V_{CH}$

$\Delta V = \frac{Q_{CH}}{C_{C}} = \frac{W_{C} C_{C}}{C_{C}} (V_{in} - V_{CH} - V_{CE})$

Example: $\Delta V = 10 \times 0.35 \times 5 \times (3.0 - 0.6) = 42$ mV

**Dummy Switch**

- Dummy switch is half width
- Depends on equal split between source and drain
- Is split equal?

Charge Injection Analysis

- Can perform more detailed, distributed analysis
  - Results depend on how fast switch is turned off

- Note that SPICE doesn’t do this (lumped model) – uses “XPART” parameter instead:
  - XPART = 0: Source 60%, Drain 40%
  - XPART = 0.5: equal split
  - XPART = 1: 100% Drain

Rejecting Injection Error

Bottom-Plate Sampling

- Turn off $\Phi_{1a}$ first
  - Injected charge is constant
  - Removed in differential output

- Switch $\Phi_{1b}$ opens later
  - $C_2$ disconnected
  → "zero" charge injected

- Is this useful?
  - $V_2 = 0V$...

Using Bottom-Plate Sampling